

Reducing harm to patients from health care associated infection: the role of surveillance

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Australian Commission on Safety and Quality in Health Care

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Abbreviations and acronyms

ACHS	Australian Council on Healthcare Standards
ACSQHC	Australian Commission on Safety and Quality in Health Care
AGAR	Australian Group on Antimicrobial Resistance
AICA	Australian Infection Control Association
AICA-NAB	Australian Infection Control Association National Advisory Board
AIDS	acquired immune deficiency syndrome
AIHW	Australian Institute of Health and Welfare
ANZCOSS	Australia New Zealand Co-operative on Outcomes in Staphylococcal Sepsis
ANZNN	Australian and New Zealand Neonatal Network
ARPAC	Antibiotic Resistance; Prevention and Control
ASA	American Society of Anesthesiologists
ASCTS	Australasian Society of Cardiac and Thoracic Surgeons
ASID	Australasian Society for Infectious Diseases
ATC	anatomical therapeutic chemical
BEACH	Bettering the Evaluation and Care of Health project
BMI	body mass index
BSI	bloodstream infection
CABG	coronary artery bypass graft
CA-MRSA	community-acquired MRSA
CAPTION	Community-Acquired Pneumonia: Towards Improving Outcomes Nationally
CARE-ICU	Controlling Antibiotic Resistance in Intensive Care Units
CCU	critical care unit
CDAD	<i>Clostridium difficile</i> associated disease
CDC	Centers for Disease Control and Prevention (United States)
CFU	colony forming units
CHRISP	Centre for Healthcare Related Infection Surveillance and Prevention (Queensland)
CI	confidence interval
CLAB	central line associated bacteraemia
CNISP	Canadian Nosocomial Infection Surveillance Program
CNS	coagulase-negative staphylococcus
CRAB	carbapenem-resistant <i>Acinetobacter baumannii</i>
CR-BSI	catheter related bloodstream infection

CSF	cerebrospinal fluid
CUSUM	cumulative sum
CVC	central venous catheter
DANMAP	Danish Integrated Antimicrobial Resistance Monitoring and Research Program
DDD	defined daily dose
DRG	diagnosis related group
DUE	drug usage evaluation
EAGAR	Expert Advisory Group on Antimicrobial Resistance
EARSS	European Antimicrobial Resistance Surveillance System
eICAT	electronic Infection Control Assessment Technology (software)
EMRSA	endemic methicillin-resistant <i>Staphylococcus aureus</i>
EOS	early onset sepsis
EPINet	Exposure Prevention Information Network
ESAC	European Surveillance of Antimicrobial Consumption
ESBL	extended spectrum beta-lactamase
ESCMID	European Society of Clinical Microbiology and Infectious Disease
ESGAP	ESCMID Study Group for Antibiotic Policies
FTE	full-time equivalent
GBS	group B streptococci
GPBTU	Gram Positive Bacteria Typing Unit (Western Australia)
HAI	health care associated infection
HBV	hepatitis B virus
HCA	health-care associated
HCV	hepatitis C virus
HCW	health-care worker
HDU	high-dependency unit
HISS	Hospital Infection Standardised Surveillance (New South Wales)
HISWA	Healthcare Associated Infection Surveillance Western Australia
HIV	human immunodeficiency virus
HSV	herpes simplex virus
ICARE	Intensive Care Antimicrobial Resistance Epidemiology
ICD	International Classification of Diseases
ICP	infection control professional
ICU	intensive care unit
IHI	Institute for Healthcare Improvement (United States)
IMPro	Infection Monitor Pro (software)

INICC	International Infection Control Consortium
IP	inpatient episode
IPSE	Improving Patient Safety in Europe
IV	intravenous
IVDRB	intravascular device-related bacteraemia
JETACAR	Joint Expert Technical Advisory Committee on Antibiotic Resistance
KISS	Krankenhaus Infektions Surveillance System (Nosocomial Infection Surveillance System — Germany)
LCBSI	laboratory confirmed bloodstream infection
LIS	laboratory information system
LRTI	lower respiratory tract infection
MBL	metallo-beta-lactamase
MDR-AB	multidrug-resistant <i>Acinetobacter baumannii</i>
MRAB	multiresistant <i>Acinetobacter baumannii</i>
MRGN	multiresistant gram negative bacteria
MRO	multiresistant organism
MRPA	multidrug-resistant <i>Pseudomonas aeruginosa</i>
MRSA	methicillin-resistant <i>Staphylococcus aureus</i>
MSSA	methicillin-sensitive <i>Staphylococcus aureus</i>
MYSTIC	Meropenem Yearly Susceptibility Test Information Collection
NARMS	National Antimicrobial Resistance Monitoring System
NaSH	National Surveillance System for Health Care Workers
NAUSP	National Antimicrobial Utilisation Program
NethMap	surveillance program for antimicrobial resistance in the Netherlands
NHMRC	National Health and Medical Research Council
NHS	National Health Service (United Kingdom)
NHSN	National Healthcare Safety Network (United States)
NICHD	National Institute of Child Health and Human Development
NIP	non-inpatient episode
NNIS	National Nosocomial Infections Surveillance System (United States)
NPS	National Prescribing Service
NPV	negative predictive value
OBD	occupied bed day
OPHE	outpatient haemodialysis event
OR	odds ratio
PBAC	Pharmaceutical Benefit Advisory Committee

PBS	Pharmaceutical Benefits Scheme
PCR	polymerase chain reaction
PDA	portable digital assistant
PFGE	pulsed-field gel electrophoresis
PICC	peripherally inserted central catheters
PICU	paediatric intensive care unit
PMC	pseudomembranous colitis
PPV	positive predictive value
PREZIES	Prevention of Nosocomial Infections through Surveillance (Netherlands)
PVL	Panton-Valentine leukocidin
QALY	quality adjusted life year
QHPSS	Queensland Health Pathology and Scientific Services
RPBS	Repatriation Pharmaceutical Benefits Scheme
RR	relative risk
RSV	respiratory syncytial virus
SARI	Surveillance of Antimicrobial Use and Antimicrobial Resistance in Intensive Care Units
SARS	severe acute respiratory syndrome
SD	standard deviation
SENIC	Study on the Efficacy of Nosocomial Infection Control
SHINE	Safer Hospitals Integrated Information Network (software)
SICU	surgical intensive care unit
SIR	standardised infection ratio
SSI	surgical site infection
STRAMA	Swedish Strategic Program for Rational Use of Antibiotics
SWEDRES	Swedish Antibiotic Utilisation and Resistance in Human Medicine report
TB	tuberculosis
TSN	The Surveillance Network (United States)
UTI	urinary tract infection
VAP	ventilator-associated pneumonia
VDHS	Victorian Department of Human Services
VHPSS	Victorian Hospital Pathogen Surveillance System
ViBES	Victorian Blood Exposures Group
VICNISS	Victorian Hospital-Acquired Infection Surveillance
VISA	vancomycin-intermediate <i>Staphylococcus aureus</i>
VRE	vancomycin-resistant enterococcus

VRSA vancomycin-resistant *Staphylococcus aureus*
WHO World Health Organization

Preface

Australians rightly expect to receive safe, high quality health care. The healthcare system generally fulfils this expectation and provides excellent care. However, some patients acquire infections during their health care and such infections are a leading cause of preventable, and sometimes serious, harm. Healthcare associated infections also have significant resource costs, as they prolong hospital stays and create more work for health care staff.

The Australian Commission on Safety and Quality on Health Care has recognised that a coordinated approach to the prevention and control of healthcare associated infection is essential to improving patient safety. It has a program in place aimed at reducing healthcare association infection, involving systematic, national responses to infection control, hand hygiene and antibiotic stewardship

Preventing healthcare association infections depends on good decision-making – decision-making that is guided by reliable information of the incidence and costs of infections and on the effectiveness of prevention strategies. Surveillance systems play an essential role in providing this information.

This document contains an overview of current healthcare associated infection issues and surveillance initiatives in Australia and reviews of international and Australian surveillance literature. The 51 authors are to be commended for providing such authoritative and compelling analyses. On behalf of the Commission, I extend my thanks to them for their willingness to contribute their expertise and for the substantial efforts required to produce such a comprehensive document.

Preventing health care associated infection is the responsibility of all who care for patients or make decisions about healthcare systems. Many of these people will not read all 18 chapters of this document, but, even so, the overall message is relevant to all of them. That message is that a crucial means to reduce the harm caused by healthcare associated infections is to measure improvement through national and local surveillance systems.



Bill Beerworth
Chair
Australian Commission on Safety and Quality in Health Care

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In particular, the Australian Commission on Safety and Quality in Health Care would like to thank the contributing authors for their generosity in giving their time and expertise on top of already busy workloads. The commitment of the authors to decreasing infections is evident in the content of this document and in the discussions that ensued as part of the collaborative process of producing it. The group not only provided the rigorous scientific content but also participated in the Delphi survey to identify priority recommendations that will be used to inform ongoing work in the prevention of HAIs.

Special acknowledgement is given to members of the Healthcare Associated Infection Surveillance Expert Working Group who coordinated several chapters each, as well as contributing to their own area of expertise. The expert working group, ably led by Professor Michael Whitby, included Professor Peter Collignon, Dr John Ferguson, Associate Professor Michael Richards, Ms Rachel Thomson and Ms Irene Wilkinson.

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Executive summary

Health care associated infections (HAIs) cause patients pain and suffering, and use up valuable health-care resources. These infections prolong hospital admissions, create more work for clinicians and can cause significant harm to patients, some of whom die as a result. Many of these infections are preventable.

Each year in Australia there are about 200,000 HAIs. Spending on HAI surveillance can be a ‘win–win’ situation, because patient outcomes improve and health-care resources are made available for other uses.

The purpose of collecting and analysing reliable surveillance data is to improve quality and patient safety within a service or facility. Effective surveillance systems provide the impetus for change and make it possible to evaluate the effectiveness of interventions. An effective surveillance system is one that provides timely information to hospital managers and clinicians to promote action for health. The value of surveillance as part of a hospital infection control program is supported by high-grade international and national evidence. Currently, there is no systematic Australia-wide approach to the measurement of patient harm caused by or associated with HAI.

Prevention of HAI is the responsibility of all who care for patients, and can cost less than treating such infections. Infection has moved from being considered an unpredictable ‘complication’ to being considered a potentially preventable ‘adverse event’.

This report summarises the state of HAI in Australia and makes recommendations for reducing HAI through surveillance and prevention.

Issues with health care associated infection in Australia

Australian efforts in HAI surveillance and prevention are mostly coordinated at a state or regional level. As a result, Australia does not have a systematic approach to HAI issues (such as infection control, hand hygiene and the management of antimicrobials) or to data gathering and analysis. The resources invested in HAI and the scope of surveillance (which infections are monitored and how) also differ across Australia.

The fragmented state of HAI surveillance in Australia means that information is scarce, unreliable and difficult to generalise from. For example, growing antimicrobial resistance contributes to poor patient outcomes and threatens to undermine the great advances in treatment of infectious diseases, but there is no national program to draw together data on the incidence and prevalence of multiresistant organisms in Australia.

Effect of the quality and safety movement

The quality and safety movement provided new and important impetus for action by framing infection control as a problem for patient safety. In 1991, The Harvard Medical Practice study demonstrated the large volume of potentially preventable harm occurring in hospitals. The report was followed by similar findings worldwide, which led to calls for action to make health care safe. In Australia, one of the major policy responses to this situation was the formation of the Australian Council on Safety and Quality in Health Care — the predecessor to the Australian Commission on Safety and Quality in Health Care (ACSQHC).

HAI is the most common complication affecting patients in hospital. Many such infections can be prevented using approaches based on quality and safety theory, such as:

- quality improvement methodologies
- safety culture (ie a system in which individuals feel responsible for helping to increase safety and quality)
- application of systems thinking (ie understanding the ‘system factors’ that allow individuals to make errors or prevent them from doing so).

Developing a national approach

The ACSQHC focuses on areas of the health system that could benefit from urgent national consideration and action. HAI is one of the commission’s priority areas. The commission’s HAI program focuses on identifying and addressing systemic problems and gaps, so that nationally coordinated action can be taken on this issue. Growing public awareness of the specific risks and significance of HAI makes the need for action more urgent.

This report includes recommendations, but these do not presume a solution; indeed, there is no single solution to the problem of HAI in Australia. Some recommendations are simple to implement, while others would require further action. No single body has responsibility for HAI, and this may have been a barrier to comprehensive improvement in the past. However, there are groups immediately able to act on some of these recommendations. The case this report makes for new action is compelling.

Issues covered in the report

This document first looks at surveillance as a whole, then at specific sites of infection or populations, specific organisms or types of organism, specific locations in the hospital or community, preventive strategies, and human and economic costs. Each of the chapters includes key points and recommendations, which are also given at the end of this executive summary.

The most important sites of infection are the bloodstream and surgical sites. Infections in such sites, particularly those due to methicillin-resistant *Staphylococcus aureus* (MRSA), cause complications, and one in three patients who develop such infections die. MRSA is now endemic in most Australian hospitals.

The most important preventive strategies to reduce and prevent HAI include hand hygiene, the appropriate use of antibiotics and immunisation of health-care workers (HCWs). Monitoring of process (eg hand washing compliance) and outcome (eg bloodstream infections (BSIs)) can improve hand-hygiene practices. Antibiotic stewardship programs have been shown to reduce resistance rates, morbidity, mortality and cost, but Australia needs better national data on use of antimicrobials. HCWs who are not immunised place patients at risk of acquiring vaccine preventable diseases, and more complete data are needed to help staff and employers to reduce this risk.

Specific populations at risk of HAI include neonates and HCWs. Surveillance results can be used to inform birthing practices and so reduce the risk of some neonatal infections. A national perspective is needed on HCW exposure to infectious agents; for example, through injuries from sharps.

Specific organisms, especially those that are multiresistant, increase the morbidity and mortality associated with HAI. They also increase costs; for example, because patients stay longer in hospital if they acquire an HAI. The multiresistant organism *Clostridium difficile* is a major

problem overseas but not yet in Australia. The analysis and recommendations contained in this document provide an opportunity to put into place early warning and response capabilities that incorporate guidelines for the prevention, control and outbreak management of *C. difficile*. Respiratory syncytial virus and rotavirus are two microorganisms that can spread rapidly within hospitalised paediatric patients, increasing length of stay and sometimes causing serious morbidity and mortality, especially in immunocompromised children and premature babies.

Some hospital environments, such as intensive care units (ICUs), provide an ideal setting for the development and spread of antimicrobial-resistant pathogens. Infection in ICUs can be greatly reduced by strategies monitored by effective surveillance. These strategies include the use of ‘bundled’ sets of practices (a number of evidence-based strategies used together) that improve outcomes when performed consistently. Neonatal ICUs have special surveillance needs. Two particular locations that require alternative surveillance approaches are smaller hospitals and residential-care facilities (which have particular infection issues and need to focus on simple surveillance and preventive strategies).

A patient with an HAI will probably stay longer in hospital, and will also be diagnosed and treated during this time, using up valuable health-care resources. Such patients will also lose some quality of life and be at greater risk of dying from infection. High-quality models are needed to determine the cost-effectiveness of programs that mitigate the risk of HAI.

Key points and recommendations

Chapter 1 Surveillance and quality improvement

Key points

- Reliable surveillance data underpin all quality-improvement processes.
- Collection, analysis and reporting of surveillance data on HAIs is associated with a reduction in infection rates, morbidity and mortality.
- Process measurements are usually easier to measure, less ambiguous and more widely applicable than outcome indicators.
- Some outcome measurements are not appropriate for all agencies, due to the effect of confounders that are not associated with or controlled by patient safety activities, and the inability to risk adjust for these effects.
- Other outcome measures — for example, the incidence of health care associated MRSA bacteraemia — appear to be reliable and have driven practice change, leading to significant improvements in patient safety.
- Effective methods of feedback are needed.
- There is insufficient evidence to determine the value of public reporting of HAI in assisting in a reduction in HAI in health-care facilities.

Recommendation on surveillance and quality improvement

1. All health facilities require HAI surveillance systems because these are proven to reduce infection rates when local data collection results in timely feedback.

Chapter 2 Bloodstream infection

Key points

- BSIs are common, and cause significant illness and death; more than half of these infections are associated with health-care procedures.
- Each year in Australia, there are likely to be more than 12,000 BSIs associated with health care.
- Studies in Australia document that 17–29% of patients with hospital-acquired BSIs die while still in hospital. Patients who develop BSIs are also more likely to suffer complications during their hospital stay that result in a longer hospital stay and an increased cost of hospitalisation.
- *Staphylococcus aureus* is the most common cause of health care associated BSIs. In Australia, there are about 7000 *S. aureus* BSI episodes per year, most of which are associated with health-care procedures and are thus potentially preventable.
- The use of intravascular catheters is the most common medical procedure associated with health care associated BSIs. These catheters are associated with more than 3500 BSIs per year in Australia.
- People who are immunocompromised, on haemodialysis or in ICUs are more likely to develop health care associated BSIs and require special preventive measures to be taken.
- Quality-improvement programs in Australia and overseas that have involved surveillance and then implementation of improved policies and procedures have resulted in sustained falls in the incidence of health care associated BSIs. For example, over three years the incidence of MRSA in the United Kingdom and of intravenous (IV) sepsis at the Canberra Hospital has fallen by 50%.

Recommendations on bloodstream infection

1. A mandatory continuous national surveillance system is required to collect and report an agreed minimum dataset for:
 - *S. aureus* bacteraemia, including MRSA
 - central line associated BSI in all ICUs
 - haemodialysis access associated BSI.
2. Australian expert consensus is required to agree on national definitions for IV device-associated BSIs and methods for calculation of infection rates.
3. All health-care settings should take action to monitor and reduce the incidence of IV device-associated BSIs.

Chapter 3 Surgical site infection

Key points

- Surgical site infections (SSIs) are associated with substantial morbidity, mortality and costs.
- Surveillance of SSIs, coupled with prompt feedback of data from the infection prevention team to treating clinicians, can achieve major reductions in SSI rates.
- Reporting of risk-adjusted, procedure-specific SSI rates is a measure of quality of surgical care.
- Surveillance methods based on the United States National Healthcare Safety Network (NHSN) (formerly the National Nosocomial Infections Surveillance System (NNIS)) have

been widely used internationally. Australian state surveillance programs use the NHSN/NNIS definitions.

- Australian states and territories differ in the extent of SSI surveillance, the resources available, and the approaches to mandatory reporting of data and to risk adjustment of infection rates.
- An Australian national surveillance database of SSI rates would primarily be of value if it was timely and allowed valid comparisons of infection rates between hospitals. An agreed national approach to risk adjustment is required before a useful national database can be established. Ongoing local support is needed to promote data quality and ensure that programs are responsive to local needs.
- Benefits of such a database would be:
 - a greater understanding of the nature and extent of SSIs after many types of surgery
 - efficiencies and economies in educational activities and support
 - development of improved surveillance methods.
- Validation studies are essential to develop confidence in data, but have only recently been undertaken for SSI surveillance data.
- There is no widely accepted method of post-discharge surveillance.
- Surveillance of surgical antibiotic prophylaxis and feedback of hospital performance with respect to national guidelines has led to some improvements in clinical practice.

Recommendations on surgical site infection

1. Local surveillance of SSI and infecting pathogens should be undertaken.
 - Surveillance should include all coronary artery bypass graft surgery, major joint prosthesis insertion, and other important surgeries (in terms of surgical frequency, or SSI morbidity; for example, lower segment caesarean section) and procedures locally noted to have higher than expected SSI rates.
 - Standard NHSN/NNIS surveillance methodology (ie definitions of infection and detection methodologies) should be used.
 - Staff need to be trained in data collection, audit and surveillance.
 - Post-discharge surveillance data requires the development of a validated, cost-effective method.
2. Risk-adjustment methodologies for SSI surveillance to facilitate national benchmarking are required.
3. Surgical antibiotic prophylaxis should be used as a key national hospital quality-of-care measure.

Chapter 4 Neonatal infection — early onset

Key points

- Sepsis occurring in the first week of life (early onset sepsis (EOS)) can be a devastating problem; it has an incidence of about 1–2 per 1000 live births and case mortality rates of 8–10%.
- Group B streptococci and Enterobacteriaceae (eg coliform bacteria such as *Escherichia coli*) are the main causes of EOS in more developed countries.
- Intrapartum antimicrobial prophylaxis has lowered the incidence of early onset group B streptococci sepsis by 50–80%.

- Surveillance of EOS is important to demonstrate the effectiveness of preventive efforts and to detect significant changes in incidence or emergence of antibiotic resistance.

Recommendation on neonatal infection — early onset

1. All birthing services should measure and report the incidence of and mortality from early onset bacterial sepsis (including meningitis).

Chapter 5 Health-care worker bloodborne virus exposure

Key points

- There is international agreement that occupational exposure causes a substantial burden and cost to both health-care systems and individuals.
- International experience shows that occupational exposure surveillance can:
 - demonstrate trends in injury and exposure
 - enable early recognition of specific problems
 - be used to direct prevention efforts and risk management
 - permit ready assessment of the impact of prevention efforts.
- Australian health care and HCWs will benefit from the establishment of an ongoing, standardised, aggregated national system for occupational exposure data.

Recommendation on health-care worker bloodborne virus exposure

1. A national surveillance system for monitoring trends in occupational exposure to bloodborne pathogens should be developed.

Chapter 6 Multiresistant organisms

Key points

- Antimicrobial resistance contributes to poor patient outcomes and threatens to undermine the great advances in treatment of infectious diseases that have occurred over the past 40 years.
- The relationship between antibiotics and antibiotic resistance is complex, and encompasses selection and dissemination of resistance determinants between human and bacterial hosts. Antibiotic resistance in the community is emerging as a significant problem worldwide, but Australia has few ways of measuring this nationally at present.
- Surveillance systems for multiresistant organisms have traditionally been laboratory based, with percentage resistance among laboratory isolates being the most frequently used summary measure. However, laboratory surveillance alone does not give a measure of the burden of disease caused by multiresistant organisms. Active prospective surveillance is required to:
 - measure the incidence of new antibiotic resistance in microorganisms
 - detect emerging resistance and outbreaks of cross-infection within an institution
 - monitor the success or otherwise of interventions designed to reduce the acquisition of multiresistant organisms.
- Standardised protocols for screening multiresistant organisms and definitions for surveillance indicators have been developed for Australia, and many hospitals have adopted these. Some states have established centres for data aggregation for at least some organisms, such as

MRSA and vancomycin-resistant enterococci (VRE), but only one state has expanded this to include other types of multiresistant organisms. MRSA is the most commonly reported multiresistant organism and is responsible for the greatest burden of disease.

- Antibiotic usage monitoring and analysis is necessary to improve antibiotic-prescribing patterns and reduce the main driver of resistance. This is particularly important in Australia, where the overall usage in tertiary referral hospitals is high compared to international benchmarks, such as the Scandinavian countries or the Netherlands.

Recommendations on multiresistant organisms

1. A feasibility study on reporting all health care associated MRSA infections, using the established Australian Infection Control Association (AICA) definitions for multiresistant organism indicators, should be undertaken.
2. A comprehensive laboratory-based surveillance program for antibiotic resistance as recommended by the National Health and Medical Research Council (NHMRC) is required.
3. A national surveillance program in high-risk patient groups (eg ICU) for infections caused by gram-negative bacilli harbouring key resistances, including extended spectrum beta-lactamases, plasmid-mediated AmpC and metallo-beta-lactamases, is required.
4. Training programs for Australian laboratories to promulgate best practice methodologies for detecting and reporting resistance in organisms responsible for HAIs — MRSA, vancomycin-intermediate or vancomycin-resistant strains of *S. aureus*, VRE and multiresistant gram negative bacteria — are required.

Chapter 7 Clostridium difficile associated disease

Key points

- *C. difficile* is a common HAI that causes significant patient morbidity and mortality, as well as adds to health-care costs. Almost all cases follow the use of antibiotics, and the major reservoir of infection is infected patients in hospitals or long-term care facilities.
- The emergence of a novel strain of *C. difficile* (NAP1/027(B1/NAP1)) in North America and Europe has been associated with increased frequency, severity and relapse of *C. difficile* disease.
- Principles of *C. difficile* prevention include antibiotic stewardship, monitoring of incidence and outbreaks, appropriate use of contact precautions, accurate identification of infected patients, consistent hand hygiene and improved environmental cleaning.
- A variety of surveillance systems and definitions have been used to monitor infection rates. Recently published international recommendations and definitions support implementation of an appropriate surveillance program in Australia.

Recommendations on *Clostridium difficile* associated disease

1. Early warning and response capabilities for *C. difficile* associated disease (CDAD) should be developed to include:

- reporting of severe cases to jurisdictions and nationally
- ensuring culture for *C. difficile* occurs across a wider spectrum of laboratories.

2. Strain typing and surveillance for *C. difficile* is required nationally, including testing for the presence of the emerging, highly virulent NAP1/027 strain.

3. *C. difficile* surveillance results should be linked with antibiotic use data from each facility to highlight specific drivers of local *C. difficile* incidence.

4. National guidelines for prevention, control and outbreak management of CDAD (including isolation) should be accessible and current.

Chapter 8 Respiratory syncytial virus infection

Key points

- Respiratory syncytial virus (RSV) is the leading cause of paediatric lower respiratory tract infections and related hospitalisations and of HAIs in infants and young children.
- The burden of severe RSV disease falls particularly on premature infants, immunosuppressed patients, and children and adults with chronic respiratory and cardiac disease.
- Mortality rates are low in developed countries but infections have a significant impact on the health-care system.
- Targeted infection control programs that control the spread of RSV within paediatric hospitals are highly cost-effective.
- Effective surveillance systems are required to detect the onset of the annual community-acquired RSV season and to measure the effectiveness of facility infection control programs for health-care acquired cases.

Recommendation on respiratory syncytial virus infection

1. Monitoring and prevention of hospital-acquired paediatric cases of RSV should be based on laboratory-confirmed RSV results.

Chapter 9 Rotavirus infection

Key points

- Rotavirus is the major agent of paediatric hospital-acquired diarrhoea across the world; it particularly affects younger infants, including neonates.
- Mortality rates are low in developed countries; however, the impact on the health-care system is significant.
- Controlling the spread of rotavirus within paediatric hospitals through targeted infection control programs is cost-effective.
- Effective surveillance systems are required for community-acquired cases (to identify the onset of the annual rotavirus season) and for hospital-acquired cases (to measure the effectiveness of facility infection control).
- The recent availability of a rotavirus vaccination makes more effective prevention a prospect.

Recommendation on rotavirus infection

1. Monitoring and prevention of hospital-acquired paediatric cases of rotavirus should be based on laboratory-confirmed rotavirus results.

Chapter 10 Adult intensive care unit acquired infection**Key points**

- Patients in ICUs are at high risk of HAIs that often have severe adverse outcomes.
- The most important HAI types are central line associated BSIs and ventilator-associated pneumonia.
- Many international ICU-acquired HAI surveillance programs base their methods on the United States NHSN/NNIS program.
- Several Australian states undertake ICU surveillance — particularly of BSIs — using either NHSN/NNIS definitions or those of AICA.
- The NHSN/NNIS definitions for BSIs have recently changed, and this should prompt a review of the Australian definitions.
- In the United States, recent comprehensive prevention programs that ‘bundle’ a group of three to five evidence-based HAI strategies have significantly reduced ICU-acquired infections.
- ICUs provide an ideal environment for the development and spread of antimicrobial-resistant pathogens and are the setting for considerable broad-spectrum antimicrobial use. Antimicrobial resistance is expected to increase.
- Optimal antibiotic use, guided by a local knowledge of likely pathogens and their antibiotic resistance, is a key factor in controlling the development of antibiotic resistance.
- No integrated national surveillance system exists to monitor ICU infections, antimicrobial resistance or antibiotic use. Standardised monitoring of antibiotic use has recently been established in some Australian ICUs.

Recommendations on adult intensive care unit acquired infection

1. A mandatory continuous national surveillance system to collect and report on an agreed minimum dataset for central line associated BSIs in all ICUs is required.
2. Australian expert consensus is required to agree on national definitions for central line associated BSIs and ventilator-associated pneumonia, and methods for calculation of infection rates.
3. Evidence-based strategies for HAIs should be used to target central line associated BSIs and ventilator-associated pneumonia. These will include standardised application and auditing of compliance.
4. Monitoring of national antibiotic usage and resistance surveillance data, resistance management, and intervention strategies requires a comprehensive integrated surveillance program.
5. Expansion of the national antibiotic utilisation data obtained from hospital pharmacies to include data from all ICUs.

Chapter 11 Neonatal intensive care unit acquired infection

Key points

- Late onset (intensive care associated) sepsis is a major cause of mortality and morbidity in neonates who require intensive care management. Infection is associated with adverse neurodevelopmental outcomes.
- Best practice is likely to protect most neonates from developing intensive care associated infections.
- Systematic surveillance of infection and antibiotic resistance is required to improve quality and provide meaningful benchmarks.

Recommendations on neonatal intensive care unit acquired infection

1. The late onset neonatal sepsis indicators (BSI and meningitis) developed by the Australian Council on Healthcare Standards (ACHS) and the Australian and New Zealand Neonatal Network (ANZNN) in 2003 require revision.
2. Standardised indications and methods for collection of blood and cerebrospinal fluid cultures from neonates are required.
3. Benchmarking of neonatal intensive care surveillance data is required. Neonatal ICUs should measure and report antibiotic resistance and usage. The development and updating of prescribing guidelines and other aspects of antibiotic stewardship should be based on analysis of antibiotic resistance and usage.

Chapter 12 Smaller hospitals

Key points

- There is limited published literature on HAIs and surveillance programs in smaller hospitals (<100 acute-care beds) because most frequently referenced studies have taken place in larger hospitals.

Recommendations on smaller hospitals

1. A surveillance program for smaller hospitals (<100 acute-care beds) based on the signal event surveillance program and relevant process indicator measures is required.
2. Smaller hospitals require mechanisms to support staff involved in infection prevention and control; for example, through external support networks and alignment of services with infection prevention and control teams from larger hospitals, or with regional, state and territory groups.

Chapter 13 Residential aged-care facilities

Key points

- As Australia's population ages, the number of elderly people living in residential aged-care facilities is expected to increase substantially.
- Residents of residential aged-care facilities are at high risk from community infections and HAIs. They live in a home-like environment, have close contact with potentially infected or colonised residents and staff, have increased antibiotic exposure and exposure to hospital stays, and are often immunocompromised.
- Residents of residential aged-care facilities may become colonised with multiresistant organisms, which are transmitted to other patients when residents are hospitalised.

- Infection surveillance systems in residential aged-care facilities are needed to detect disease outbreaks. Routine detection of sporadic infections is error prone, given the variability in current infection definitions and surveillance methods, and the lack of trained staff.
- Optimal infectious disease control in residential aged-care facilities focuses on preventive strategies (eg immunisation of staff and residents) and compliance with process measures (eg hand hygiene and other standard infection control requirements).

Recommendations on residential aged-care facilities

1. Long-term facilities require a standardised system of local surveillance focusing on processes such as standard infection control precautions, including hand-hygiene compliance and device-related care.
2. Immunisation status among residents and staff should be monitored, with particular reference to influenza, hepatitis B and hepatitis A.
3. The development of validated Australian definitions for infection surveillance in residential aged-care facilities is required.
4. The development of strategies to evaluate and improve antibiotic prescribing in residential aged-care facilities is required.

Chapter 14 Hand hygiene

Key points

- Transfer of microbial pathogens on the hands of HCWs is a key driver of HAI.
- Alcohol-based hand-hygiene programs have been shown to improve hand-hygiene compliance and reduce HAIs in observational studies in Geneva and Melbourne.
- In the United States, the Centers for Disease Control and Prevention (CDC) now recommends that health-care facilities introduce and maintain alcohol-based hand-hygiene programs for HCWs.
- The World Health Organization (WHO) similarly recommends the worldwide introduction of alcohol-based HCW hand-hygiene programs based on their ‘five moments for hand hygiene’ initiative.

Recommendations on hand hygiene

1. Repeated monitoring of hand-hygiene programs through process measures (eg monitoring compliance with WHO’s ‘five moments for hand hygiene’) and outcome measures (eg rates of nosocomial sepsis, using an indicator organism such as MRSA) should be conducted in all health-care facilities.
2. Alcohol-based products used for hand hygiene must conform with international testing standard EN 1500.
3. All hand-hygiene clinical competency assessments should be assessed against WHO’s ‘five moments for hand hygiene’ guidelines.

Chapter 15 Antimicrobial usage: monitoring and analysis

Key points

- Monitoring and analysis of antimicrobial usage is critical to understanding antibiotic resistance and to monitoring effects of containment strategies.
- Methods of antimicrobial data collection differ, but most institutions provide population surveillance data obtained from computerised pharmacy records.

- Surveillance data can be used to identify changes in usage that may be linked to development of resistance and to measure the impact of antimicrobial stewardship programs.
- Antimicrobial stewardship programs have been shown to reduce resistance rates, morbidity, mortality and cost.
- Comprehensive, integrated surveillance programs operate in the United States and Europe, where programs include the European Surveillance of Antimicrobial Consumption, the Danish Integrated Antimicrobial Resistance Monitoring and Research Program, a surveillance program for antimicrobial consumption and resistance in the Netherlands, and the Swedish *Antimicrobial Utilisation and Resistance in Human Medicine* report. In Europe, reports on antimicrobial consumption and resistance are published annually.
- In Australia, the National Antimicrobial Usage Surveillance Program provides monthly reports on hospital inpatient antibiotic usage to contributing hospitals and bi-monthly reports to the Australian Department of Health and Ageing. Data are contributed by 50% of principal referral hospitals from six states.
- Comparison with international data shows that Australian usage rates in hospitals are high for some antimicrobial classes. The total use of antibiotics in the Australian community falls in the middle of the range recorded in European countries.
- The Drug Usage Subcommittee of the Pharmaceutical Benefits Advisory Committee reports on antibiotic use in the community sector to the Expert Advisory Group on Antimicrobial Resistance, the Australian Institute of Health and Welfare and the WHO International Committee on Drug Statistics Methodology. Antibiotic usage data are also published in The Australian Statistics on Medicines. The data are used by the National Prescribing Service to inform program planning.
- Australian antimicrobial usage data are incomplete and not linked with resistance surveillance data, which limits their potential use.

Recommendations on antimicrobial usage: monitoring and analysis

1. Monitoring of national antibiotic usage and resistance surveillance data, resistance management, and intervention strategies requires a comprehensive integrated surveillance program.
2. National antibiotic stewardship guidelines are required for all health-care settings; surveillance data should guide the development and updating of prescribing guidelines, decision support systems (including computerised approval systems), clinical guidelines and education.
3. Antibiotic resistance and usage data should be made available at clinical service, hospital and national levels.

Chapter 16 Health-care worker immunisation

Key points

- Immunising HCWs can prevent infection associated with health care.
- HCW immunisation currently occurs at the level of individual health-care units for the protection of individual HCWs. State and territory governments have begun to consider or initiate systematic programs aimed at disease prevention for the whole health-care population, but Victoria is the only jurisdiction to have established a limited surveillance program. The international situation seems similar.
- In Australia, national recommendations for HCW immunisation were republished in 2003. A national program is warranted, given the existence of the national recommendations, the

mobility of the Australian health-care workforce, inconsistencies between states and territories, and duplications of effort.

- HCW immunisation should be an integral part of national disease control programs. An effective national program would need to be underpinned by national surveillance, with standards comparable to those already in place for the National Immunisation Program.

Recommendations on health-care worker immunisation

1. All Australian HCWs should be immunised in accord with the NHMRC *Australian Immunisation Handbook* to protect HCWs and patients from vaccine-preventable diseases, including influenza.
2. National surveillance of vaccine-preventable infections should include data on employment status as an HCW (ie when a person is vaccinated, information should be collected as to whether the person is an HCW).
3. Standardised recording of HCW immunity and immunisation status is required.

Chapter 17 Costs of health care associated infection

Key points

- The costs of HAIs are difficult to measure and value.
- The costs are an important consideration for any decision to increase investment in infection control programs.
- The greatest cost is the bed days lost to infection within the hospital sector.
- The value of these bed days depends on the need of the general population to access hospital services and the willingness of decision makers to pay for these services.
- Based on the available data and a number of assumptions, it is estimated that almost two million bed days are lost to infection per year in Australia.
- The data must be interpreted carefully because not all infections can be prevented.
- There are also many private and difficult-to-value costs associated with infection: these include pain and suffering for patients and their families.

Recommendation on costs of health care associated infection

1. The process of attributing cost to HAI should be expressed in terms of the number of bed days that are released by effective infection control programs as well as any savings in variable costs.

Part A — Overview

Introduction

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Prevention and control of health care associated infection (HAI) is an essential element of patient safety, and is the responsibility of all who care for patients. Infection has moved from being considered an unpredictable ‘complication’ to being considered a potentially preventable ‘adverse event’.

Although not all HAIs are preventable, it is possible for an institution to significantly reduce the rate of these adverse events. Prevention of HAI has many advantages. It saves valuable resources — for example, by freeing up bed days (the estimated 200,000 cases of HAI in Australia each year are thought to use two million bed days). It also prevents pain and suffering for patients and their families.

This report provides a comprehensive picture of the surveillance of HAI in Australia, demonstrates the costs that these infections impose upon individual Australians and the health system, and lists recommendations as to how this situation can be improved.

Current issues with health care associated infection in Australia

Australia currently does not have a holistic and systemic national approach to the issues of infection control, hand hygiene, HAI, antimicrobial resistance and antimicrobial prescribing. There is no systematic national approach to surveillance for HAI or for routine collection and analysis of national data. Also, the country lacks a national program for drawing together data on incidence and prevalence of multiresistant organisms in hospital and community settings. In addition, there is considerable variation in resources and in the scope of surveillance undertaken in different parts of Australia, with work in this area being undertaken by many disparate specialist groups.

This situation persists despite widespread activity in most jurisdictions, many individual initiatives and the publication of a number of national reports, including some endorsed by the Australian Health Ministers Committee. The history of Australia’s national initiatives on antimicrobial resistance and HAIs is summarised in the box below.

History of Australia’s national initiatives related to the surveillance of health care associated infection

National Health and Medical Research Council working party

In the early 1980s, the National Health and Medical Research Council (NHMRC) established a working party of human and veterinary microbiologists to study antibiotic use. New attention was focused on the issue when an association was discovered between a stockfeed antimicrobial (avoparcin) and vancomycin-resistant enterococci in humans. In response to this finding, a committee of medical, scientific, veterinary and regulatory experts (the Joint Expert Technical Advisory Committee on Antibiotic Resistance (JETACAR)) was established.

Joint Expert Technical Advisory Committee on Antibiotic Resistance report released

The JETACAR report, released in 1999, was entitled *The Use of Antibiotics in Food-producing Animals: Antibiotic-resistant Bacteria in Animals and Humans*. The report made 22 recommendations in the areas of regulation and control of supply of antibiotics, monitoring and surveillance, prescribing of antimicrobials, research, community education, and implementation management.

History of Australia's national initiatives related to the surveillance of health care associated infection (continued)

Government response to Joint Expert Technical Advisory Committee on Antibiotic Resistance

The government response included establishment of an Expert Advisory Group on Antimicrobial Resistance (EAGAR), to provide continuing advice on antibiotic resistance and related matters, and establishment of a Commonwealth Interdepartmental JETACAR Implementation Group.

The Australian Health Ministers Council JETACAR Taskforce released its final report in November 2000. In summary, it recommended that:

- EAGAR continue to provide scientific and policy advice on antimicrobial resistance issues
- an antimicrobial resistance surveillance network implement a national surveillance strategy.

Although EAGAR continued in its role, no national strategy was developed; instead, the Commonwealth continues to support a number of small antimicrobial resistance monitoring programs

Draft expert report

In 2000, the Australian Government Department of Health and Aged Care contracted an expert working group of the Australian Infection Control Association (AICA) to undertake a study of current surveillance activities, policies and programs relating to nosocomial (hospital acquired) infections in Australia. This study recommended the development of a national surveillance and monitoring system for antibiotic resistance across the animal and human health sectors. The report was published as a draft in 2001, but was not finalised.^[1]

Publication of *National Strategy to Address Health Care Associated Infections*

The Australian Council for Safety and Quality in Health Care (the precursor of the Australian Commission on Safety and Quality in Health Care) convened a workshop of stakeholders in 2002. The workshop identified health care associated infection (HAI) to be one of five national priorities in health care. Consultation across the health-care system then resulted in a strategy that contained nine recommendations emphasising the need to improve patient safety and reduce HAI through a nationally coordinated approach. The recommendations centred on national leadership, national infection control guidelines, surveillance definitions and minimum dataset, local governance, education, and consumer involvement. The recommendations were endorsed by all health ministers in July 2003.

Health Care Associated Infections Advisory Committee

The Australian Council for Safety and Quality in Health Care then established a Health Care Associated Infections Advisory Committee. The aim was to progress the recommendations in the *National Strategy to Address Health Care Associated Infections* and to provide national leadership to reduce infections. The committee (via a National Surveillance Working party) reached in-principle agreement in 2004 to a standard set of definitions that facilities could apply to local monitoring of specific HAIs. The committee was signed off in 2005 as no longer required, despite the lack of further implementation of the national strategy.

Further recommendations

In 2006, EAGAR echoed recommendations made by JETACAR in a paper titled *Comprehensive Integrated Surveillance Program to Improve Australia's Response to Antimicrobial Resistance 2006* (this document is not currently available in the public domain).

Influence of the quality and safety movement on thinking about health care associated infection

New impetus for action was provided by the quality and safety movement, when infection control began to be seen as 'a problem for patient safety'.^[2] The origins of this movement can be traced

to the 1991 Harvard Medical Practice study that demonstrated the large volume of potentially preventable harm occurring in hospitals.^[3] This study also drew particular attention to surgical wound infection as a frequent adverse event. The findings were replicated worldwide.^[4, 5, 6, 7, 8]

In response to these studies, many different sources called for action to make health care safe. Particularly influential^[9] were the reports published by the United States Institute of Medicine, especially the report *To Err is Human*.^[10] One of the major policy responses in Australia was the formation of the Australian Commission on Safety and Quality in Health Care (ACSQHC).

Over the past decade it has become clear that not only are HAIs the most common complication affecting patients in hospital, but also that safety and quality theory needs to be applied in designing successful approaches to reduce this harm. HAIs have also been shown to be preventable. Some of the important areas of safety and quality theory for reducing HAIs are:

- quality improvement methodologies — HAI is special in terms of quality improvement because robust measurement is possible, particularly with the use of denominators and risk adjustment (discussed in Chapter 2)
- safety culture — that is, a system in which individuals feel responsible for making efforts to increase safety and quality
- the application of systems thinking — that is, an understanding of the ‘system factors’ that allow individuals to make errors or prevent them from doing so — to infection control.

Developing a national approach to reducing health care associated infection in Australia

In 2005, a review of national safety and quality in Australia recommended that a new national safety and quality body replace the Australian Council for Safety and Quality in Health Care. The new body was to provide a quality improvement focus across the continuum of health care.^[11] A new body was formed, and is known as the Australian Commission on Safety and Quality in Health Care.

One focus of the commission is on areas of the health system that could benefit from urgent national consideration and action because of current and complex problems or community concerns. HAI was nominated as one of the commission’s priority areas for 2007–10.

The purpose of the commission’s HAI program is to develop a national approach to reducing HAI. This includes developing strategies to ensure that improvements are sustained. The program focuses on identifying and addressing systemic problems and gaps to ensure that comprehensive actions are undertaken in a nationally coordinated way by leaders and decision makers in both public and private health.

There is an increasing expectation on the part of the Australian public of both accountability and transparency, and a growing public awareness of the specific risks and significance of HAI, making the need for action more urgent. As the first of several HAI initiatives, the commission invited a core expert group to coordinate the updating of the *National Surveillance of Healthcare Associated Infection in Australia, 2001*.

The group first met in July 2007 and 51 coauthors eventually assisted in the construction of this report. The document aims to provide an overview of current HAI issues and surveillance initiatives in Australia, based on evidence from international and Australian literature on surveillance. The result is an authoritative analysis that builds on the evidence available.

The report includes recommendations, but these do not presume a solution as there is no single solution to the problem of HAI in Australia. Some recommendations would be difficult to implement, others much simpler. No single body has responsibility for HAI, and this may have been a barrier to comprehensive improvement in the past. There are, however, groups immediately able to act on some of these recommendations. The case this report makes for new action is compelling.

Some specific infective areas are not covered in detail in this document — in particular, the complex relationship between patterns of community resistance, prescribing practices in the community and hospital, and the risks and types of HAI.

Structure of document

This document contains 17 chapters that synthesise current evidence about HAI and its surveillance. The document is divided into parts, with chapters varying in structure, depending on whether they deal with:

- surveillance as a whole (Part A)
- specific sites of infection or populations (Part B)
- specific organisms or types of organism (Part C)
- specific locations in a hospital or community (Part D)
- preventive measures (Part E)
- human and economic costs (Part F).

Each chapter stands alone, meaning that there is some overlap in content. Key points and recommendations are given at the start of each chapter and are summarised in the Executive summary.

The key points and recommendations provide detail about both the risks of HAI and the nature of surveillance that can reduce the harm to patients from HAI. In some cases, there is overlap between the recommendations in different chapters — this is significant, because it means that the recommendations apply to several infection issues and are thus particularly important.

Overview

Chapter 1 provides an overview of the value of surveillance and its contribution to quality improvement.

Specific sites of infection and populations

Chapters 2 and 3 cover specific sites of infection — bloodstream infections (BSIs) and surgical site infections (SSIs), respectively. BSIs, especially those due to methicillin-resistant *Staphylococcus aureus* (MRSA), cause complications, and one in three patients who develop such infections die. Many BSIs are preventable, particularly those associated with intravenous lines and devices. Prevention requires quality improvement informed by surveillance. Laboratory results of bloodstream cultures can be used to provide accurate and continuous surveillance.

SSIs have particular importance to patients, and have the greatest impact on costs and length of hospital stay. They are difficult to monitor because rates vary depending on the procedure performed, the surveillance methods applied, and the patient's underlying risk factors. Many infections are diagnosed after discharge; and, if re-admission is required, this may not be in the facility where the original operation was performed. Correct antibiotic prophylaxis is crucial to reducing the rate of such infections, but this also needs to be subject to surveillance.

Chapters 4 and 5 cover specific populations at risk of HAI — neonates and health-care workers (HCWs), respectively. The risk of maternally acquired neonatal infection (via the genital tract) is influenced by the practices of birthing services. The affected infants may be admitted to neonatal intensive care units (ICUs) (discussed below), but surveillance analysis must reach the birthing services.

HCWs are constantly at risk of acquiring disease from their patients. However, we know little about the rates of sharps injury and other forms of occupational exposure nor the rates of occupational acquisition of bloodborne disease

Specific organisms

The complex relationship between antibiotic usage and resistant organisms is covered in Chapter 6. This chapter also outlines the incidence of new disease caused by multiresistant organisms (MROs), which increases the morbidity and mortality associated with infections, and contributes to increased costs of care due to prolonged hospital stay and other factors, including the need for more expensive drugs. *S. aureus* is responsible for the largest proportion of health care associated bacterial infection, with the methicillin-resistant form (MRSA) now endemic in most Australian hospitals.

Chapter 7 deals with virulent *Clostridium difficile*, which is an infection problem that is not yet prominent in Australia. The organism usually causes diarrhoea and significantly lengthens hospital stay. However, the new virulent strain emerging in North America and Europe also causes epidemics and extensive mortality. Management of an outbreak requires early detection and specific precautions, and Australia is not yet well prepared for an outbreak of *C. difficile*.

Chapters 8 and 9 cover two microorganisms that have community prevalence but can spread rapidly within hospitalised paediatric patients — respiratory syncytial virus (RSV) infection and rotavirus infection, respectively. The result of such infections in the absence of surveillance and containment is increased length of stay, and sometimes serious morbidity and mortality, especially in the immunocompromised child and premature babies.

Specific locations in health-care facilities and the community

Chapter 10 deals with ICUs, which unfortunately provide an ideal environment for the development and spread of antimicrobial resistant pathogens. Effective surveillance and the use of ‘bundled’ sets of three to five practices that have been shown to improve outcomes when performed consistently can profoundly reduce infections in ICUs.

A neonate admitted to intensive care (covered in Chapter 11) is also at risk of acquiring preventable infections that cause mortality and severe morbidity, especially if the infant is premature. Surveillance of these events, and appropriate linkage to antibiotic practice, can be challenging for individual neonatal ICUs — benchmarking with other units is essential.

Chapter 12 looks at smaller hospitals (less than 100 acute-care beds), which are mainly located in rural regions and usually co-located with aged-care beds on the same site. Surveillance systems in smaller hospitals need to take into account the limitations of analysing small sample sizes.

Chapter 13 covers residential aged-care facilities. These facilities have special issues around infection; they need simple surveillance and a focus on preventive strategies, such as staff immunisation.

Preventive measures

Chapters 14, 15 and 16 discuss the crucial preventive strategies of hand hygiene, appropriate use of antibiotics and immunisation of HCWs, respectively. To maintain and improve hand hygiene practices, monitoring of both process and outcome are required. Antibiotic stewardship programs can reduce resistance rates, morbidity, mortality and cost.

Currently, Australia has incomplete antimicrobial usage data, and the data that are available are of limited usefulness because they are not linked with resistance surveillance data.

Where HCWs are not immunised, they place patients at risk of acquiring vaccine preventable diseases such as measles, mumps, rubella, hepatitis and influenza. It is unclear what level of aggregation of surveillance is required, but the current piecemeal records make it difficult for well-intentioned staff or employers to be sure they have done all they can to reduce this risk.

Human and economic costs

The cost of HAI is discussed in Chapter 17. A patient with an HAI will probably stay longer in hospital, and will also be diagnosed and treated during this time, using up valuable health-care resources. Patients will also lose some quality of life and be at greater risk of dying from infection. The chapter is a reasoned call for the need for high-quality models to determine the cost-effectiveness of programs that mitigate the risk of HAI.

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1 Surveillance and quality improvement

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Key points

- Reliable surveillance data underpin all quality-improvement processes.
- Collection, analysis and reporting of surveillance data on health care associated infections (HAIs) is associated with a reduction in infection rates, morbidity and mortality.
- Process measurements are usually easier to measure, less ambiguous and more widely applicable than outcome indicators.
- Some outcome measurements are not appropriate for all agencies due to the effect of confounders that are not associated with or controlled by patient safety activities, and the inability to risk adjust for these effects.
- Other outcome measures — for example, the incidence of health care associated methicillin-resistant *Staphylococcus aureus* bacteraemia — appear to be reliable and have driven practice change, leading to significant improvements in patient safety.
- Effective methods of feedback are needed.
- There is insufficient evidence to determine the value of public reporting of HAI in assisting in a reduction in HAI in health-care facilities.

Recommendation on surveillance and quality improvement

1. All health facilities require HAI surveillance systems because these are proven to reduce infection rates when local data collection results in timely feedback.

1.1 Background

Surveillance is ‘the ongoing, systematic collection, analysis, interpretation, and dissemination of data regarding a health-related event for use in public health action to reduce morbidity and mortality and to improve health’.^[1] Surveillance methods are ‘distinguished by their practicability, uniformity, and rapidity, rather than by complete accuracy’.^[2]

Surveillance is important for wider systems of quality management, but the main purpose of collecting reliable surveillance data is to improve quality within a service or facility. Collecting such data can provide the impetus for change and make it possible to evaluate the effectiveness of an intervention. There is a surveillance cycle, described as ‘data collection–data analysis and interpretation–data dissemination’.^[3] This cycle readily integrates with the quality-improvement cycle, which is ‘plan–do–check–act’ (developed from Shewhart’s 1930s work^[4] and popularised by Deming and others).^[5,6] Surveillance for quality improvement can measure outcomes (eg adverse or positive health events) or processes (eg hand hygiene) that are linked to outcomes.

Australian health-care facilities surveillance survey

For this document, the Australian Commission on Safety and Quality in Health Care (ACSQHC) commissioned an update of a 2001 survey of infection control practitioners.^[7] An online survey targeting Australian Infection Control Association (AICA) membership was conducted. The full survey data are reported in Appendix 1; the key findings were.

- there is a lack of standardised and strategic approaches to health care associated infection (HAI) surveillance across most states and territories
- the professional time given to infection control and the level of expertise varies widely between facilities and affects the ability to perform surveillance
- most relevant facilities perform surveillance of bloodstream infection (BSI), surgical site infection (SSI) and multiresistant organisms
- most facilities undertake process surveillance of health-care worker (HCW) immunisation and hand hygiene compliance
- there are significant deficiencies in current practice; for example, lack of surveillance programs for *Clostridium difficile* and antibiotic use.

1.2 Quality surveillance

Surveillance data for quality improvement must be of high quality. The characteristics that qualify data as evidence for action include:^[8]

- representativeness — the data fairly represent the thing measured
- accuracy — the data reflect what is intended to be measured
- precision — the data and the target of measurement correspond closely
- authoritative — the data are appropriate for drawing a meaningful conclusion
- clarity — the data are presented in a form that the target audience can understand.

Data of this nature are more likely to arise from surveillance processes:

- that involve all stakeholders in design and implementation
- for which there are agreed organisational objectives, and processes that are relevant to the population served
- that use trained personnel to collect and manage data, and that provide them with appropriate information technology support
- that use definitions of surveillance events that are unambiguous, practical, specific and can be validated
- that have reliable and practical methods for detecting events
- for which the processes that determine an outcome are thoroughly understood
- for which appropriate denominators are collected for risk adjustment
- for which reporting links measurement to prevention efforts, and meets the needs of both clinicians and managers.

It is not feasible to conduct hospital-wide surveillance for all events; therefore, targeted (priority-directed) surveillance that focuses on specific events, processes, organisms, medical devices or high-risk patient populations is recommended. In the United States, the Centers for Disease Control and Prevention (CDC) also recommends that HAI surveillance should be conducted by

infection control professionals in a way that is active, patient-based, prospective and priority-directed, and that yields risk-adjusted incidence rates.^[9]

The two main methods of surveillance — process surveillance and outcome surveillance — are discussed below.

1.3 Process surveillance for hospital-acquired infections

A health-care organisation can be viewed as a system: a network of interdependent components (structures, people and processes) that work together to achieve the organisation's objectives. HAIs are a major patient-safety problem that can be related to structures, processes and people's behaviour. A key objective of health-care facilities is to ensure that processes that affect the safety of patients or HCWs are subject to measurement and quality control.

Process surveillance involves auditing practice against a certain standard, guideline or policy. Realising that no single intervention will prevent any HAI, 'bundles' or packages of evidence-based interventions have been developed and are increasingly being used in process surveillance.

The relationship of process measures to outcomes is sometimes controversial,^[10] but process measures that are linked by evidence to important outcomes have distinct advantages over outcome measures.^[11, 12, 13, 14] Process measures:

- are unambiguous and do not require risk adjustment
- can predict outcomes
- can easily be acted on because potential improvements are usually the responsibility of the clinical service
- can be captured quickly
- are sensitive because many episodes of inappropriate care do not cause harm.

Process surveillance may be an adjunct to outcome surveillance; alternatively, it can entirely replace outcome surveillance for practices or locations that have too few adverse outcomes for statistical analysis. For example, process surveillance only may be appropriate for small hospitals (where the number of patients at risk of infection may be too small to calculate valid infection rates).

Examples of published process indicators of high value include:

- aseptic insertion and management of peripheral or central intravascular devices
- HCWs' compliance with hand hygiene and the techniques they used
- perioperative and intraoperative practice such as antibiotic prophylaxis, normothermia, euglycaemia and appropriate hair removal
- HCWs' uptake of immunisation.

1.4 Outcome surveillance for hospital-acquired infections

Outcome surveillance involves measuring adverse events, a proportion of which are preventable. The sensitivity and specificity of event definitions and the reliability of data collection need to be considered when developing methods to detect adverse events. It is important to create a balance between avoiding false positives (specificity) and picking up true positives (sensitivity), given that true positives are rare events in the overall patient population.

Outcome surveillance with laboratory-based data is used in the signal events system that was designed by Queensland and is implemented in Queensland and South Australia (see Chapter 12 Smaller hospitals).

It has been suggested that HAI is special in terms of patient safety measurement:

Perhaps the only valid outcome measures of harm are the rates of health care-acquired infections.^[15]

However, Australia currently has no system-wide approach to measurement of patient mortality caused by or associated with HAI. These deaths are unlikely to be reported using existing mechanisms such as adverse event reporting systems. Mortality from infection may be seen as ‘anticipated’ even though the occurrence of the infection that led to the death was unanticipated.

A further challenge in measuring patient deaths is differentiating between patients who die *with* an HAI and those who die *from* an HAI or suffer serious injury *due to* an HAI (ie attributable injury or death). One new approach is to evaluate such patient deaths to determine whether mortality was unexpected, and then analyse the contributing factors to determine preventable root causes that might be modified in future. In this approach, infection events (usually deaths or BSI) are considered and investigated individually. Although mandated by the United Kingdom’s National Health Service, evidence of the value of this approach is lacking.

1.4.1 Analysis and interpretation of outcome data

Surveillance data may be expressed as:

- time-series of counts or proportions (rates)
- incidence over time
- point prevalence.

It is advisable to employ statistical analysis of variation over time through use of control charts.^[16, 17, 18] As most HAI surveillance measures statistically infrequent events, there is variation from month to month in counts and rates. Where this variation shows no trend over a longer period (ie is invariant around a mean over time), it is called ‘common-cause variation’. Use of control charts makes it possible to detect ‘special-cause variation’; this is used to describe changes in the data that indicate a significant shift in the mean, perhaps due to a particular factor, such as a change in process (eg a sterilisation failure or a new surgeon whose practice is above average). Changes detected may still represent false-positive signals; therefore, data need to be checked before action is taken.

Risk adjustment

The common assumption that outcome surveillance data will be useful for comparing different facilities cannot be relied on without careful validation of the surveillance system. Comparison of data requires as a minimum:

- use of identical definitions for numerators (events) and denominators (risk adjusters)
- use of identical methods at a similar intensity to detect events, including similar opportunities for patient observation (eg comparable lengths of stay)
- ongoing systems of training and audit to ensure that definitions and detection are applied consistently across facilities
- risk adjustment of rates, as appropriate.

A critical issue in comparing infection rates is the choice and use of risk adjustment. This is important because the causes of HAIs are complex. Infection is due partly to a patient's intrinsic risks (eg age, sex and immune status) and partly to a patient's extrinsic risks (eg duration of procedure, skill of the surgeon, skin preparation and prophylaxis). Using these factors, which differ in importance, infection rates can be risk adjusted.

Some studies have demonstrated a high degree of accuracy in the use of risk-adjustment models.^[19] Other studies have found that the models cannot adequately capture all the relevant factors present in complex patients who are at high risk of complications.^[20, 21, 22, 23, 24, 25, 26] A range of preferred attributes of the risk-adjustment approach have been identified that are, by design, under the control of the organisation performing the analysis.^[20]

Risk adjustment also requires the collection and analysis of specific data, thus increasing the resources required. The risk index developed by the United States National Healthcare Safety Network (NHSN) (formerly the National Nosocomial Infections Surveillance System (NNIS)) is used worldwide for analysis and reporting of SSI. However, there is discontent with the system, and increasing evidence that the index does not perform well for several procedures (see Chapter 3 Surgical site infection); better indices are required.^[27]

Achieving comparability within a country or state may be easier than achieving it across different countries. Germany and the Netherlands have similar surveillance systems, but direct comparison reveals inconsistent and inexplicable differences in SSI data.^[28]

1.5 Reporting surveillance to the health-care community

The purpose of analysing, interpreting and reporting on surveillance data is to promote action for health. The style and content of reports should be determined by their audiences. These may include:

- the populations under surveillance (patients and health professionals)
- the surveillance community that generated, analysed and interpreted the data
- health-care executives
- the media
- the general public.

Reporting of surveillance data may have temporary effects on performance and outcomes, due to the 'Hawthorne effect' (ie a temporary, usually positive, change in behavior or performance in response to a change in the environment; for example, attention being drawn to an issue). The impact of reporting should not be relied on: focused quality improvement activities are required in addition to surveillance.

1.5.1 The surveillance community

The surveillance staff are usually the first line in overseeing improvements in work practice, and they require timely feedback of aggregated, analysed data. Such feedback fosters motivation; it also promotes the reporting of data anomalies and missing data, which can highlight improvements needed in surveillance processes or use of definitions. Outcome surveillance should be validated periodically through case detection. Surveillance staff and clinicians should discuss and agree on thresholds or targets for surveillance that are consistent with published or benchmarked best-practice results.

1.5.2 Clinicians

It is important to provide regular reports to clinical staff (medical, nursing and allied health), including reports of continuing good performance. One survey of the views of Australian surgeons on surgical site surveillance revealed a lack of confidence in surveillance data.^[29] They did not consider surveillance to be accurate or useful because of the difficulty in standardising diagnoses; they also found the exclusion of post-discharge infections unacceptable. For clinicians to trust the results, the rigor of a surveillance process and its validation needs to be explained regularly. Clinicians should decide, preferably ahead of time, what action should be taken when surveillance anomalies occur. Results should be reported in the context of statistical measures that evaluate variation over time (eg control charts) and show when rates or counts are statistically above targeted values.

1.5.3 Managers

Sustainable improvements in practice require the intervention and ongoing support of health-service managers. Managers are increasingly being held accountable for the attainment of key performance indicators related to HAI. They require regular reporting of indicators in control chart formats, with adequate explanation of the data and its sources, its analysis, and the targets and actions taken in response to poor performance or apparent outbreaks.

1.6 Reporting surveillance results to the public

In the context of surveillance, public reporting is defined as ‘the public release of identifiable hospital-level data on health-care performance’.^[11] In relation to HAIs, publicly reported data may include outcome data (eg SSI rates) or process measures of infection control (eg hand-hygiene compliance rates). In the following section, literature on public reporting in health care is examined in brief, with reference to its significance to the issue of HAI reporting.

1.6.1 The case for public reporting

There are three major reasons for placing data in the public domain:^[30]

- stimulation of quality improvement
- promotion of public trust and clinician accountability
- support for patient choice.

Stimulation of quality improvement

HCWs who are aware that performance data will be released externally may make a greater effort to improve their performance. Public reporting generally appears to increase efforts to improve quality.^[31] When the reporting methods of Wisconsin hospitals were randomised to being either not reported, reported confidentially or reported publicly, the hospitals whose results had been reported publicly adopted more quality-improvement programs.^[32]

Promotion of public trust and clinician accountability

A culture of accountability has been called for by those striving to change the approach to HAI from benchmarking to continuous improvement, with an ideal of ‘zero tolerance’ wherever possible.^[33] Publication of surveillance results can form part of a framework of accountability. Together with legislation and regulation (eg audit, accreditation, licensing and inspection), publication can serve to promote public trust. Reporting data also fulfils a provider’s duty to disclose pertinent information to the public.^[34]

The Canadian Health Services Research Foundation considers public reporting to have two forms:^[35]

- executive accountability — that is, typical ‘public’ reports, which are not designed with the public in mind and are simply being ‘made public’, rather than being designed to ‘speak to the public’
- democratic accountability — that is, a reporting system that
 - has an explicit purpose and consequences
 - makes clear who is being held accountable, for what, to whom and with what (if any) consequences or rewards for performance and improvement
 - requires passive reporting to be replaced by more interactive ways of engaging with the public audience, carefully explaining the results.

Support for patient choice

To support patient choice, public reporting needs to identify institutions and be structured so that patients can make a practical choice between institutions. Ideally, the information should be displayed using a reporting framework tailored to the particular needs of consumer groups and to making specific decisions.^[34] This is often not the case. For example, an analysis of 333 measures of organisational quality publicly reported in California showed that 86% of patients would be unable to find quality measures related to their planned surgical procedures.^[36]

Websites that compare hospitals are highly variable in quality and frequently lack current data.^[37] Users are often not comfortable with the site format and find it hard to locate information.^[38] Techniques are available to improve the meaningfulness of information for consumers (eg using narrative).

Public reporting and pay-for-performance

Pay-for-performance in health care rewards providers for quality of care. To date, most pay-for-performance programs have been targeted at individual providers.

Like public reporting, pay-for-performance is an incentive strategy designed to improve provider performance and involves the sharing of information with providers.^[39] Neither strategy has been well studied. Their success depends on a range of factors, including:^[39]

- who receives the incentive
- magnitude of the incentive
- cost of compliance
- relevance of quality measures to the provider’s practice
- ease with which consumers and referring providers can understand the data
- patient cooperation
- non-financial results for the provider (eg satisfaction or reputation).

Because they are seen as complementary, public reporting and pay-for-performance are sometimes introduced together.^[21] The costs of administration of pay-for-performance are greater, as is its potential to create or perpetuate inequities.^[40, 41] There is greater physician support for pay-for-performance than for public reporting, and this has led to suggestions that, if both are to be introduced, they should not be introduced at the same time.^[41]

As of 1 October 2008, Medicare in the United States will decline to pay extra for eight specific conditions that could generally be avoided ‘if the hospital followed proven preventive procedures or common sense precautions’.^[42] Three of these conditions relate to HAIs: infections caused by prolonged use of catheters in the bladder or the blood vessels, and SSI after coronary artery bypass surgery. It was suggested that ‘other life-threatening staphylococcal infections may be added to the list in the future’.^[43] According to a *New York Times* editorial^[42]:

The effort won’t save much money at first, and it will impose additional testing and documentation burdens on many hospitals, but it should promote better care.

Other insurers are taking similar action to that taken by Medicare.^[44]

Where public reporting is introduced, health-care institutions must be prepared to explain, discuss and debate the meaning of surveillance data. This may require training of knowledgeable media spokespersons and the provision of other resources.

1.6.2 The case against public reporting

Public reports typically incorporate risk-adjustment models to enable comparisons to be made between hospitals that treat severely ill patients and hospitals that treat less ill patients.^[19, 45] However, data quality still remains a concern to many.^[19, 24, 46, 47, 48, 49, 50]

Possible undesirable consequences arising from publication of data on health-care performance may include:^[30]

- a focus on short-term goals
- reluctance to experiment for fear of poor performance
- prioritising of narrow objectives over inter-organisational goals
- a focus on an assessed area at the expense of a non-assessed one.

1.6.3 What do consumers want?

Research in the United States and United Kingdom indicates that consumers want more information about performance of hospitals.^[21] Telephone polling of more than 6000 consumers in the United States indicated that hospital infection rates would influence decision making for 94%.^[51] Cleanliness of the hospital was also important. The authors concluded that consumers need information in addition to the current public reports on infection rates, which are generally designed for HCWs.^[51] Patients prefer detailed locally relevant information, low levels of data aggregation and access to information via a trusted intermediary (eg their general practitioner or an information officer).^[30]

There is limited information on the needs of Australian consumers. Consumers who were asked about performance-reporting formats for the private sector had concerns about industry barriers to choice and were suspicious about comparative data when there was no trusted coordinating body.^[34] The Victorian Hospital-Acquired Infection Surveillance (VICNISS) Coordinating Centre conducted focus groups with consumers, who indicated that they wanted local rather than international data, but felt that they often have little choice in relation to public hospital treatment (P Russo, VICNISS, pers comm, March 2008).

One Australian study suggested that ‘the complexity of outcome data would seem to exclude the majority of consumers and perhaps should be directed only to providers (whether publicly or privately)’.^[52] This would seem a dated view in 2008, when the aim is generally to present data in ways that consumers can understand and find relevant. For example, the United States Agency

for Health Research and Quality has a website dedicated to informing consumers about health-care quality and argues that reporting agencies should commit to long-term public education programs to create demand for information.^[35]

1.6.4 Evidence for the value of public reporting of HAI

More research on the effects of public reporting is needed. Most of the data are from the United States and concerns outcome measurements after cardiac surgery. Observational studies suggest that declines in mortality are more rapid in states with public reporting of morbidity and mortality following cardiac surgery.^[53] More recent reviews have been less conclusive.^[54, 55] In the northwest United Kingdom, public reporting was associated with a decreased risk-adjusted surgical mortality rate, and there was no evidence of avoidance of high-risk patients.^[56]

Proposed guidelines have recently been produced for transparent reporting of outbreaks and intervention studies of HAI.^[57] Public reporting appears to neither improve HAI prevention and control practices, nor prevent the occurrence of HAI, but more research is needed.^[58]

While there may be a case for voluntary participation during a development phase, public reporting may need to be mandatory to have any effect.^[21] This places responsibility on the regulator to ensure that reporting is useful and cost-effective. Because many stand to lose or gain from public reporting, the priorities and objectives of the reporting system must be clearly specified and understood by all stakeholders (eg medical clinicians, nurses, consumers, managers and infection control staff) and the accuracy, value and purpose of reported data agreed.^[11]

1.6.5 Current status of public reporting of HAI

International

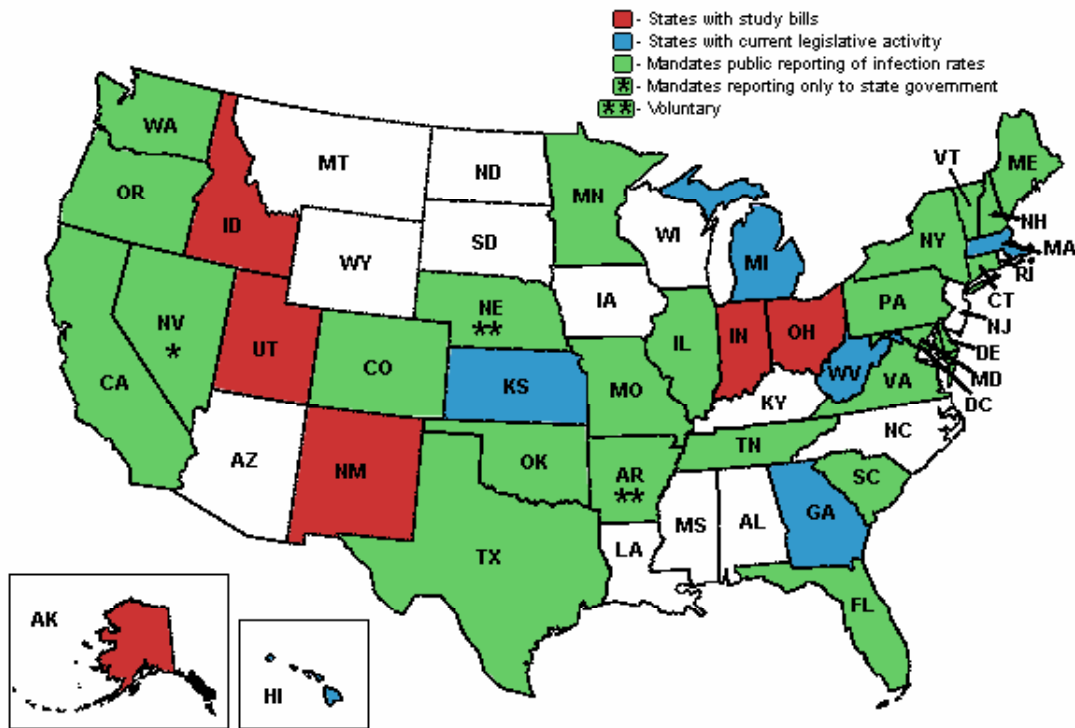
United States

More than half of the states undertake mandatory public reporting of infection rates. Several others have voluntary reporting programs or mandatory reporting only to government, while most of the rest have legislative activity moving towards requiring mandatory public reporting and pay-for-performance (Figure 1.1).^[59] Reporting and release mechanisms for HAI vary, as do the data sources and measures to be reported. In many states, HAI rates remain confidential to health departments.^[60, 61]

Europe

Most European HAI surveillance systems are voluntary and confidential. In the Netherlands, a court decision has allowed the HAI data from the Prevention of Nosocomial Infections through Surveillance (PREZIES) network to remain confidential; the aim is to avoid placing hospitals participating in the network at a disadvantage compared to those choosing not to participate. In France, public reporting began in 2006 and focuses on process indicators concerning infection control activities.

In the United Kingdom, mandatory reporting of methicillin-resistant *Staphylococcus aureus* (MRSA) BSIs has been in place since 2001. In 2003, *C. difficile* associated disease in patients more than 65 years old and vancomycin-resistant enterococcus (VRE) bacteraemia became reportable, followed by orthopaedic surgical infection rates in 2004. Rates of infection stratified by hospital and trust are published regularly on the internet. The Health Protection Agency summarised data to the end of 2006 for all reportable indicators.^[62]



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Figure 1.1 Mandatory reporting of infection rates in the United States

Australia

Victoria

Discussions about introducing public reporting at the level of single health-care institutions have taken place at departmental and consumer levels. At present, feedback on de-identified, hospital-level data goes directly to participants. Aggregated data are reported publicly in an annual report.

New South Wales

Mandated collection of targeted HAI data began in 2003. The data are published in an aggregated format on the New South Wales Health website, and reports are provided to area health services on their individual hospitals. The New South Wales HAI Quality Program is undergoing several changes, although there are no immediate plans for mandatory public reporting at individual hospitals (J Bendal, Manager, NSW Health Department HAI Prevention and Control Unit, pers comm, 2000).

Western Australia

Hospitals have contributed data to Healthcare Associated Infection Surveillance Western Australia (HISWA) since 2005. Building on the success of this program, four key indicators have been selected for mandatory collection by public hospitals in Western Australia in 2007 and 2008. Public reporting has been discussed among contributors and health department executives. While there are no immediate plans for its introduction, it is likely that hospitals will be identified in mandatory indicator report feedback to all contributing public hospitals (A Peterson, HISWA, pers comm, December 2007).

Tasmania

Hospitals are required to submit Australian Council on Healthcare Standards (ACHS) data, which are then published in annual reports. Future state-wide surveillance options are presently being explored (A McGregor, Staff Specialist Infectious Diseases, Royal Hobart Hospital, pers comm, December 2007).

South Australia

While there are no immediate plans to introduce public reporting, there is an extensive voluntary surveillance program for BSI, MRSA and other multiresistant organisms. The program, which includes both public and private hospitals, has a high participation rate. Data are reported monthly in an aggregated format on the program website. Hospital-level data are reported back to hospitals directly (I Wilkinson, Manager Infection Control Service, Communicable Diseases, Department of Health, South Australia, pers comm, December 2007). South Australian data include contributions from eight private hospitals.

Queensland

In 2000, the Centre for Healthcare Related Infection Surveillance and Prevention (CHRISP), on behalf of Queensland Health, established voluntary reporting of HAI data from 23 of the largest public hospitals in Queensland. Patient de-identified data are analysed by CHRISP for each individual hospital and aggregated. A hospital de-identified report is provided to Queensland Health; in addition, six-monthly reports, which include the aggregate as well as individual hospital data, are provided to the participating hospitals. All other hospitals undertake signal infection surveillance, which is currently not reported to CHRISP. At present, there are no plans for public reporting (D Olesen, Director, Centre for Healthcare Related Infection Surveillance and Prevention, pers comm, 2007).

1.7 The impact of surveillance

United States

The scientific value of surveillance as part of a hospital infection control program was powerfully demonstrated in the Study of the Efficacy of Nosocomial Infection Control (SENIC).^[63] SENIC validated the efficacy of infection control surveillance programs. The study found that the hospitals with the lowest nosocomial (hospital-acquired) infection rates had strong surveillance and prevention programs. It concluded that to prevent HAIs, hospitals need regular feedback from analysis of surveillance data to link measured rates with practices and prevention efforts. The conclusions from SENIC have been supported and demonstrated in numerous published studies from individual facilities in the United States and elsewhere.

NHSN/NNIS is the longest standing multicentre HAI-surveillance system. The number of participating hospitals has grown from less than 20 in 1970 to more than 300 in 2002.^[64] System participants use standardised definitions, standardised surveillance component protocols and risk stratification for calculation of infection rates, and are provided with national benchmark infection rates for comparisons within and between hospitals. These methods, combined with a prevention program, have significantly reduced BSIs, urinary tract infections and pneumonia in intensive care unit (ICU) patients and SSIs in surgical patients.

In a 2003 report, the international neonatal ICU network of Vermont Oxford found that HAI and blood culture contamination rates across multiple neonatal ICUs were significantly reduced through HAI surveillance, process audit and sequenced quality improvement.^[65] However, United States data from a different network of 12 neonatal ICU units did not show significant changes in infection between 1992 and 2002.^[66, 67] Further information is given in Chapter 11 (Neonatal intensive care unit acquired infection).

Europe

Multifacility, within-country surveillance systems and their impact have been evaluated in Denmark, the Netherlands and Germany, and summarised by Gastmeier (see Table 1.1).^[68] The four most extensive reviews from the Netherlands and Germany indicated that surveillance systems have been effective, with reductions of 24–57% for SSI and 20–29% for HAI in ICUs.

Table 1.1 Effectiveness of national surveillance networks in Europe

Surveillance component	National or regional surveillance system	Period (years)	Units (hospitals) included	Method or comparison	Relative risk (RR)/odds ratio (OR) (95% confidence interval)
SSI	Denmark	2	13	2nd vs 1st year	No preventive effect
SSI	The Netherlands	5	37	4th/5th vs 1st year	4th year: RR = 0.69 (0.52–0.89) 5th year: RR = 0.43 (0.24–0.76)
SSI	Germany	4	130 (86)	Multivariate analysis	3rd year: OR = 0.76 (0.69–0.85)
ICU	Germany	3	150	3rd vs 1st year	VAP: RR = 0.71 (0.66–0.76) CVC-BSI: RR = 0.80 (0.72–0.90)
NICU	Germany	3	48	Multivariate analysis	Primary bloodstream infections: OR = 0.73 (0.60–0.89)

CVC-BSI = central venous catheter-associated bloodstream infections; ICU = intensive care unit; NICU = neonate intensive care unit; SSI = surgical site infection; VAP = ventilator-associated pneumonia
Source: Gastmeier (2007),^[68] reproduced with permission

The German Krankenhaus Infektions Surveillance System (Nosocomial Infection Surveillance System (KISS)) reported a reduction of 25% in the number of SSIs between 1997 and 2004 as a direct result of infection control efforts, underpinned by standardised surveillance.^[69] There was also a significant reduction (24%) in the overall rate of ventilator-associated pneumonia (VAP) from 1999 to 2003.^[70] Neonatal units participating in the KISS surveillance system observed a significant reduction (24%) in BSI rates, which was attributed mainly to surveillance participation and data feedback without other planned interventions.^[71]

In the United Kingdom, mandatory surveillance of MRSA BSI has been in effect since 2001. These surveillance data underpin a multifaceted effort to reduce HAI MRSA infection.^[72] The most recent data indicate that there has been an uninterrupted decline in infection notifications for the past five quarters.^[73] The MRSA bacteraemia rate for April–September 2007 was 1.24 cases per 10,000 inpatient days compared with 1.57 cases in the previous six months and 1.77 cases for April–September 2006. These reductions are statistically significant. The highest reduction occurred in London teaching hospitals, which historically had had the highest rates. For SSIs following orthopaedic procedures, rates decreased from 1.45% (2004–05) to 1.12% (2006–07).^[74]

1.7.1 Impacts of surveillance on quality

In recent years, there has been a movement towards ‘zero tolerance’ of HAIs, with the aim of eliminating all preventable HAIs. This has resulted in the emergence of collaborative programs

developed by quality improvement organisations, such as the Institute for Healthcare Improvement (IHI) in the United States. All such programs use surveillance data as the reference point for the impact of various process improvements.

In 2004, IHI launched the *100,000 Lives Campaign*, an initiative to prevent 100,000 unnecessary deaths within 18 months in the United States. The campaign proposed that hospitals implement and measure compliance with ‘bundles’ of evidence-based interventions for BSI, VAP and SSIs. These programs combine process surveillance, outcome measures and quality-improvement models. They facilitate compliance by ensuring the support of hospital administrators and leaders as part of ‘systems thinking’. Individual hospitals reported striking success in reducing infection rates.^[75]

Other projects (in Pennsylvania, United States) have demonstrated that collaborative quality-improvement initiatives can substantially reduce infection rates. In one prospective, single-institution study, catheter-related BSIs were virtually eliminated by the implementation and auditing of new care processes.^[15] Similar collaborative initiatives resulted in a decrease of 68% in the catheter-related BSI rate in 69 ICUs in Pennsylvania.^[76]

In the United States, the National Surgical Infection Prevention Project was designed to decrease SSIs by increasing the use of proven surgical infection prevention practices and outcome surveillance.^[77] This year-long collaborative improvement effort involved 44 hospitals and resulted in a decrease in SSI rates from 2.3% to 1.7%. Hospitals improved in process measures related to appropriate prophylactic antimicrobial selection, timing and duration, normothermia, oxygenation, maintenance of normal perioperative glycaemia, and appropriate surgical-site hair removal before surgery.

Similar initiatives have begun in Australia including:

- collaboration between Safety and Quality Investment for Reform and HISWA in Western Australia¹
- Safer Systems Saving Lives (Department of Human Services, Victoria)²
- Central Line Associated Bacteraemia in Intensive Care Units project (New South Wales Health, New South Wales Clinical Excellence Commission)³
- Intensive Care Antimicrobial Resistance Epidemiology (ICARE) Project (Centre for Healthcare Related Infection Surveillance and Prevention (CHRISP)/Queensland Health).⁴

1.8 Current surveillance systems

International

National surveillance for HAI is increasingly the norm in developed countries. The impetus for standardised national systems started with the NHSN/NNIS system that was set up in 1970 in the United States under the Centers for Disease Control and Prevention (CDC). Jarvis, in a recent review concerning the achievements of the organisation, states, ‘The NNIS data show that national surveillance of healthcare-associated infections combined with an intervention prevention program can reduce infection rates, reduce morbidity and mortality and improve patient safety’.^[33]

¹ <http://www.safetyandquality.health.wa.gov.au/squire/cvc.cfm>

² http://www.health.vic.gov.au/sssl/interventions/central_line.htm

³ <http://www.cec.health.nsw.gov.au/moreinfo/CLAB.html>

⁴ <http://www.health.qld.gov.au/chrisp/icare/about.asp>

The definitions developed by NHSN/NNIS, often with minor modification, have underpinned most other national and cross-national surveillance efforts. Countries with sophisticated national systems include the Netherlands, Belgium, Brazil, Canada, Denmark, France, Germany, Norway, Sweden and the United Kingdom. Most of the organisations involved publish reports of aggregate data (in print and on the internet) and provide confidential benchmarking information back to individual hospitals and services. Nearly all surveillance is targeted towards specific infection outcomes, rather than hospital-wide surveillance. In many systems, hospitals join up voluntarily.

HELICS, an international network encouraging the collection, analysis and dissemination of reliable data on the risks of HAIs in European hospitals, was formed in the late 1990s. The organisation is now partly subsumed under the Improving Patient Safety in Europe (IPSE) project, which started in 2004, and is funded by the European Commission. The IPSE project will run until the middle of 2008. Considerable efforts have been made to date in harmonising data on HAIs and antibiotic resistance in Europe. Based on this experience, the IPSE project aims to resolve persisting differences in preventive practices and outcomes.

The European Society of Clinical Microbiology and Infectious Diseases (ESCMID) has a European Study Group on Nosocomial Infections, which supports directed surveillance programs with a pan-European approach. The group includes countries from Russia to Ireland, and also contributes expertise to the IPSE project. In 1994, the ICARE project was initiated under the CDC-NNIS to assess the impact of antimicrobial use on antimicrobial resistance in hospitals. The scope of this ongoing project has since expanded from an initial focus in ICUs to the wider hospital environment. More recently, European efforts to assess the impact of antibiotic use on hospital resistance have become increasingly sophisticated (see Chapter 15 Antimicrobial usage: monitoring and analysis), coordinated by the ESCMID's European Study Group on Antibiotic Policies.

Australia

Data from a review of the status of current jurisdictional-level surveillance systems are shown in Tables 1.2–1.4. Most jurisdictions use similar or identical definitions for SSI and BSI.

Table 1.2 Australian surveillance programs and methods by state

State	Definitions used	Risk adjustment of SSI rates	Mandatory participation	Public release of hospital-level data	Small hospital program	Private hospitals included
New South Wales	AICA	Hospital peer group	Yes	No	Yes	No
Queensland	AICA	NNIS	No	No	Yes	No
South Australia	AICA		No	No	Pilot	Yes
Tasmania			No	No	No	No
Victoria	NNIS	NNIS	No	No	Yes	No
Western Australia	AICA	No	No (except MRSA)	No	No	Yes

AICA = Australian Infection Control Association; MRSA = methicillin-resistant *Staphylococcus aureus*; NNIS= National Nosocomial Infections Surveillance System (now the National Healthcare Safety Network (United States)); SSI = surgical site infection
Source: Richards and Russo (2007)^[76]

Table 1.3 Surveillance programs by state — outcome indicators

State	SSIs	ICU BSIs	Non-ICU BSIs	MROs	Bloodborne virus exposure
New South Wales	Limited procedures	Adult Paediatric, Neonatal	Haematology Oncology Non-line BSIs	MRSA, VRE, MRAB, VISA Infected/colonised Sterile/non-sterile sites	Yes
Queensland	NNIS procedures	No	As above	MRSA, VRE, ESBL, MRAB	Yes
South Australia	No	No	By specialty	MRSA, VRE, VISA, ESBL, MRPA Infected/colonised	No
Tasmania	No	No	No	No	No
Victoria	NNIS procedures	Adult Paediatric, Neonatal	Small hospitals	No	Small hospitals
Western Australia	Joint arthroplasty	Adult Paediatric	Haematology Oncology Outpatients	MRSA <i>C. difficile</i>	No

BSI = bloodstream infection; ESBL = extended spectrum beta lactamase; ICU = intensive care unit; MRAB = multiresistant *Acinetobacter baumannii*; MRPA = multidrug-resistant *Pseudomonas aeruginosa*; MRSA = methicillin-resistant *Staphylococcus aureus*; MRO = multiresistant organism; NNIS = National Nosocomial Infections Surveillance System (United States); SSIs = surgical site infections; VISA = vancomycin-intermediate strains of *Staphylococcus aureus*; VRE = vancomycin-resistant enterococcus
Source: Richards and Russo (2007)^[76]

Table 1.4 Surveillance programs by state — process indicators

State	Surgical antibiotic prophylaxis	Antibiotic use	Staff influenza vaccination	Other staff immunisation	Hand hygiene	IV care
New South Wales	No	Pilot	No	No	No	No
Queensland	No	No	Yes	No	No	No
South Australia	No	Yes	No	No	No	No
Tasmania	No	Pilot	No	No	No	No
Victoria	Yes	Pilot	Yes	Small hospitals	No	Small hospitals
Western Australia	No	Pilot	No	No	No	No

IV = intravenous

Infection control clinical indicator surveillance

The ACHS, in concert with various medical groups, has developed more than 400 surveillance indicators across 23 different clinical areas. The aim is to facilitate the measurement of important aspects of health-service delivery, with any trends observed acting as ‘flags’ for further investigation. In 2006, 681 facilities (public and private) from Australia and New Zealand contributed indicator data, but only 265 facilities contributed data against the infection control indicators. About 185 of these 265 facilities came from New South Wales because, until recently, all of that state’s mandatory infection control indicators were submitted through the ACHS system.

The Version 3 infection control indicators were last defined in 2004 and published in 2005.^[79] The latest indicators were developed by a collaborative expert group, with support from AICA. Where possible, the indicators are now based on the NHSN/NNIS definitions for HAI. They do not include processes for risk adjustment of SSI, but do include:

- 18 indicators for SSI
- 10 indicators for central intravascular line associated BSI, including indicators for ICUs, haematology and oncology units, and outpatient IV services
- 4 indicators for BSI associated with haemodialysis vascular access
- 2 indicators for early onset neonatal BSI or meningitis
- 2 indicators for late onset ICU neonatal BSI
- 4 indicators for inpatient morbidity due to MRSA (stratified by whether BSI was present)
- 2 indicators for occupational exposure to blood and body fluids (parenteral and non-parenteral exposures).

The methods used to collect these data are not closely specified by the definitions and may vary widely. There has been limited training of staff on the application of the definitions of surveillance and on best-practice methods for detection.

Another issue is that data are submitted every six months, with aggregate numerator and denominator values provided by each facility. This makes validation of data submissions difficult, and the retrospective nature of reporting as well as the long data collection periods prevent timely analysis and feedback.

While the potential deficiencies in the ACHS surveillance process would seem to preclude reliable comparisons across facilities, the ACHS regularly publishes comparative reports that statistically identify the scope for improvement based on analysis of rate data and its distribution across facilities. The validity of these detailed analyses will remain questionable until the ACHS is able to address key surveillance system issues, including validation of data submissions and the training of surveillance staff.

1.9 Conclusion

Appropriate surveillance can substantially reduce HAI, morbidity and mortality.

Timely targeted feedback is critical for effective surveillance. Risk adjustment needs to be considered when outcome measures are used; process measures can provide a useful alternative. The role of public reporting is unclear.

Currently, Australia has a patchwork of policy, process and practice in surveillance. Improving the consistency of practice and coverage would help to keep patients safe from HAI.

Online resources

Government advocacy.

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Part B — Specific infection sites or populations

2 Bloodstream infection

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Key points

- Bloodstream infections (BSIs) are common, and cause significant illness and death; more than half of these infections are associated with health-care procedures.
- Each year in Australia, there are likely to be more than 12,000 BSIs associated with health care.
- Studies in Australia document that 17–29% of patients with hospital-acquired BSIs die while still in hospital. Patients who develop BSIs are also more likely to suffer complications during their hospital stay that result in a longer hospital stay and an increased cost of hospitalisation.
- *Staphylococcus aureus* is the most common cause of health care associated BSIs. In Australia, there are about 7000 *S. aureus* BSI episodes per year, most of which are associated with health-care procedures and are thus potentially preventable.
- The use of intravascular catheters is the most common medical procedure associated with health care associated BSIs. These catheters are associated with more than 3500 BSIs per year in Australia.
- People who are immunocompromised, on haemodialysis or in intensive care units (ICUs) are more likely to develop health care associated BSIs and require special preventive measures to be taken.
- Quality-improvement programs in Australia and overseas that have involved surveillance and then implementation of improved policies and procedures have resulted in sustained falls in the incidence of health care associated BSIs. For example, over three years the incidence of methicillin-resistant *Staphylococcus aureus* (MRSA) in the United Kingdom and of intravenous (IV) sepsis at the Canberra Hospital has fallen by 50%.

Recommendations on bloodstream infection

1. A mandatory continuous national surveillance system is required to collect and report an agreed minimum dataset for:
 - *S. aureus* bacteraemia, including MRSA
 - central line associated BSI in all ICUs
 - haemodialysis access associated BSI.
2. Australian expert consensus is required to agree on national definitions for IV device-associated BSIs and methods for calculation of infection rates.
3. All health-care settings should take action to monitor and reduce the incidence of IV device-associated BSI.

2.1 Background

Bloodstream infections (BSIs) with bacteria (bacteraemia) or fungi (fungaemia) are common. BSIs are associated with significant morbidity and mortality. Although not the most common of health care associated infections (HAIs), BSIs are particularly problematic and are one of the most important contributors to the morbidity and mortality caused by HAIs, and the economic cost of these infections.

Health care associated BSIs occur as complications following medical and surgical procedures, such as abdominal surgery or the insertion of intravascular catheters. These infections used to be mainly acquired during hospitalisation, but this situation is changing as increasing numbers of people are managed at home with intravascular catheters, have medical procedures performed as outpatients or are discharged early from hospitals with percutaneous invasive medical devices in place.

This chapter examines BSIs in terms of the harm they cause to patients and the impact they have on health-care systems, and discusses approaches to BSI surveillance and current surveillance systems under the following sections:

- BSIs in general (Section 2.2)
- BSIs associated with:
 - a particular microorganism — *Staphylococcus aureus* — because of the high mortality and morbidity associated with this bacterium, and because it is the most common bacterium associated with HAIs (Section 2.3)
 - a particular type of medical procedure — use of IV catheters — because these types of devices are the most common causes of health care associated BSIs (Section 2.4)
 - particular populations: immunocompromised individuals, those on haemodialysis and people cared for in intensive care units (ICUs) have more frequent infections and contribute significantly to the overall burden attributable to this type of infection (Section 2.5).

2.2 Health care associated bloodstream infections — general overview

2.2.1 Harm to patients from bloodstream infections

Harm results to people with BSIs because many of those with such infections die (the associated mortality rate is about one-third) and because many people who survive develop complications. Patients may also bear increased costs from BSIs; for example, through increased medical expenses and time lost from work. An example is shown in Box 2.1

Box 2.1 Case study 1

Staphylococcal bloodstream infection contributing to mitral valve damage, cardiac arrest and death

Mr J, aged 62 years, presented to a small suburban hospital with chest pain that was diagnosed as a myocardial infarct. An intravascular catheter was inserted in his right arm to facilitate standard drug therapy for this condition. On the third day, his arm around the catheter was inflamed and painful and he also developed a fever.

Laboratory investigations revealed the presence of the bacterium *Staphylococcus aureus* in the patient's blood and on the tip of the intravascular catheter. The presence of the catheter was the most likely cause of the infection.

Box 2.1 Case study 1 (continued)

Treatment was started with an intravascular antibiotic and Mr J was transferred to a tertiary referral hospital. His fever persisted and an echocardiogram on day five showed damage to the mitral valve of his heart caused by bacterial infection. The dose of the antibiotic was increased and his fever slowly settled over the next seven days.

Mr J had another catheter inserted to provide long-term intravascular treatment, and continued on high-dose antibiotics with the aim of providing a full six weeks of therapy. Unfortunately, after two weeks he became increasingly short of breath and was found to have developed cardiac failure and pulmonary oedema. This was treated with appropriate cardiac drugs but his breathlessness worsened and on the fifth week after admission an echocardiogram showed a markedly leaking mitral valve.

A mitral valve replacement was performed but there was great difficulty in attaching the artificial valve because of damage to the original valve and surrounding tissue. Mr J spent another two weeks in intensive care on a ventilator before finally being discharged to a normal medical ward, although he continued to have a leak around the prosthetic mitral valve. His breathlessness improved with further medical therapy and he was able to be discharged approximately three months after originally coming into hospital.

Once back at home, Mr J's shortness of breath gradually worsened and the leak around his mitral valve also became more severe. Repeat surgery was considered, but he had a sudden cardiac arrest from which he could not be resuscitated.

2.2.2 Epidemiology

International

United States

In the United States:

- health care associated BSIs are common — a study of 24,179 episodes of hospital-associated BSIs in 49 hospitals between 1995 and 2002 found a rate of 6.0 infections per 1000 admissions^[1]
- numbers of BSIs (both health-care associated (HCA) and those not associated with health care) are increasing — for example, one study showed a rise from 82.7 per 100,000 of population in 1979 to 240.4 per 100,000 of population in 2000, an increase of 8.7% per year^[2]
- patients who develop an HCA BSI are more likely to die during their hospital stay^[3, 4, 5]
- patients who survive an HCA BSI are likely to stay in hospital longer than those who do not contract such an infection^[6]
- deaths from BSIs (HCA and non-HCA) are increasing — BSIs are now the eighth leading cause of death in the United States.^[7]

England

Data from England show that the average rate of hospital-acquired bacteraemia between 1997 and 2001 was 5.4 cases per 1000 'patients at risk' (those admitted for 24 hours or more) in teaching hospitals and 2.8 cases per 1000 patients at risk in non-teaching hospitals.^[8]

Australia

Data from five Australian hospitals show that large numbers of health care associated hospital-onset BSIs occur each year, with a rate of between 4.8 and 10.6 cases per 1000 hospital discharges (see Table 2.1). The rate in smaller hospitals is unknown. In Australia in 2004–05, there were more than 7.02 million admissions to hospitals,^[9] of which 3.2 million were overnight

admissions. Thus, even if the rate of sepsis in all hospitals in Australia was as low as 2.5 per 1000 patients admitted overnight, it would translate into more than 7500 people with hospital-acquired BSIs in Australia per year. Based on figures from the United Kingdom and United States, the actual rate is likely to be at least 4 cases per 1000 hospital discharges. Thus, there are likely to be at least 12,000 episodes of BSI associated with health care each year in Australia. The most common source for these infections is IV catheters (especially central venous catheters).

Table 2.1 Comparison of data by source of hospital-acquired bloodstream infection (five Australian hospitals, percentage)

Site of infection	Hospital 1 2.5 years (1998–2000)	Hospital 2 6.25 years (1994–2001)	Hospital 3 3 years (1993–1995)	Hospital 4 3 years (1996–1998)	Hospital 5 5 years (2002–2006)
Intravascular device	48	48	33	37	29
Unknown source	17	11	38	18	13
Genitourinary	9	9	9	14	10
Respiratory	5	8	7	5	7
Gastrointestinal	11	8	0	15	15
Skin	6	11	2	8	8
Cardiovascular	2	1	0	1	1
Musculoskeletal	<1	3	0	1	2
Other system	2	0	11	1	14
Average number of hospital onset cases per year	117	142	130	229	120
Discharges per year (excluding day-only admissions)	21,000	29,500	18,400	21,700	20,943
Rate of hospital onset episodes per 1000 discharges	5.5	4.8	7.1	10.6	5.7

Source: Canberra Hospital, unpublished data and AICA (2001)^[10]

If both community-onset and hospital-onset infections are examined, then *Escherichia coli* is the most frequently isolated organism in BSIs. However, *Staphylococcus aureus* is the bacterium most commonly involved with hospital-onset BSIs, and a large proportion of these are methicillin-resistant *S. aureus* (MRSA) (discussed in Section 2.3). Fungi, in the form of *Candida* spp, are also important,^[11] with more than 80% of cases being hospital acquired.^[12]

Unpublished data over a five-year period (2002–06) are available from the Canberra Hospital in the Australian Capital Territory. During this period, there were 1633 BSIs, 601 of which were associated with inpatient health care. The period involved 256,276 separations, of which 104,718 patients stayed overnight. The average BSI rate was 6.4 per 1000 total admissions. This rate includes all community as well as hospital-onset episodes. If day-only patients are excluded, and only hospital-onset BSI is included, then the rate of BSIs is 5.7 per 1000 admissions per year. The

patients at Canberra Hospital included people of all ages, from neonates to the elderly. Males developed significantly more BSIs than females (61% versus 39%). The patient's clinical outcome was noted for all significant BSI episodes (on day seven or on discharge — whichever occurred first). The crude mortality rate was 8.3% on day seven. Most patients (64.6%) appeared to be at or near recovery on day seven. However, a significant number of patients (22.3%) showed evidence of ongoing sepsis on day seven.

In Table 2.2, hospital-onset episodes only are examined for the Canberra study and are compared to a previous study from Western Australia.^[10]

Table 2.2 Predominant microorganisms^a involved with hospital-onset bloodstream infections (Canberra and Western Australian hospitals)

		The Canberra Hospital (2002–06) %	Western Australian teaching hospital (1993–95) %
Gram positives	<i>Staphylococcus aureus</i>	21.8	23.1
	Methicillin-sensitive	14.5	–
	Methicillin-resistant	7.3	–
	Coagulase negative staphylococci	13.5	12.9
	<i>Streptococcus</i> species	7.5	4.4
	<i>Enterococcus</i> species	8.4	4.1
Gram negatives	<i>Escherichia coli</i>	13.4	11.9
	<i>Klebsiella</i> species	5.6	8.7
	<i>Enterobacter</i> species	2.4	7.8
	<i>Pseudomonas</i> species	6.0	8.7
	<i>Stenotrophomonas maltophilia</i>	1.1	n/a
Fungi	<i>Candida</i> species	6.2	1
	Total gram positives	54 (n = 383)	47 (n = 193)
	Total gram negatives	36 (n = 253)	48 (n = 196)
	Total fungi	6.3 (n = 45)	3.4 (n = 14)
	Total anaerobes	4.2 (n = 30)	2.2 (n = 9)

n/a = not available

^a Excludes episodes caused by bacteria and fungi where numbers were relatively small.

Source: Canberra Hospital, unpublished data and AICA (2001)^[10]

In the Australian Capital Territory study described, each significant episode of bacteraemia was classified by the primary source of infection or body system involved, as shown in Table 2.1. Infections caused by IV catheters were the largest group, followed by infections that involved the gastrointestinal and genitourinary tract. Initially, IV catheter or IV device associated BSI was the highest source of infection; however, over the five-year period there was a drop in numbers of more than 50%, which was directly related to the active surveillance and intervention programs (see Section 2.4).^[13]

2.2.3 Harm to patients

In studies of outcomes, it is desirable to use a control group (eg case–control study) wherever possible, because patients who develop health care associated BSIs are much more likely to have severe underlying diseases. The underlying disease itself, rather than the infection, may be the cause of increased costs and death. A term that is used to distinguish the contribution of sepsis from other causes of death is ‘attributable mortality’; that is, the proportion of mortality that can be attributed to the direct effects of the infection. The attributable mortality is estimated through case–control studies of mortality. For example, a study from Israel found that sepsis was the major factor contributing to death of patients with BSI.^[14] The mortality rate at one month was 26%, compared to 7% in a matched control group. Most of this increased mortality occurred within the first 30 days following sepsis, suggesting that, although the severity of underlying disease had an influence, the acute sepsis was the major contributor.

Mortality and health status of survivors

A recent prospective longitudinal cohort study looked at the mortality and health status of survivors of BSIs; the project was a component of a larger longitudinal BSI surveillance project in the Australian Capital Territory.^[12, 15] Over three years (1998–2000), 628 adult patients with BSIs were followed; 57 (9.1%) had died by the end of the first week. Follow-up at six months was completed for 200 adults and mortality at this stage was 34.5%. At one month, of the survivors who had left hospital and were interviewed (85 adults), 60% stated that their work and leisure activities were still greatly affected.^[12]

There were two main findings from this study:

- In respect to deaths, acute sepsis-related factors were most important in contributing to the probability of early death compared to the presence of other complicating medical diseases, and continued to be so for one month or more. This is contrary to the idea that underlying severity of illness and comorbidity load are the dominant risk factors for death after onset of infection, rather than the infection itself.
- In respect to the onset of new morbidity and disabilities resulting from these acute infections, half of the survivors (being 31% of the initial cohort) continued to have reduced health when followed for six months. This is in contrast to the widely held perception that these infections are brief episodes, after which either early death or complete recovery prevails. Reduced health after infection and its ongoing influence was an important risk factor for both future poor health status in survivors and longer term mortality.

These findings suggest that sepsis carries long-lasting sequelae, although the exact nature of these continuing effects was not identified. The study demonstrated that BSIs result not only in high short-term mortality, but also in considerable longer term mortality and profound alteration in health status for many survivors.

In a study of five hospitals in New South Wales and Western Australia (see Section 2.2.2), 24% of patients died during their initial hospital admission.

2.2.4 Impact on health-care systems

Health care associated BSIs lead to increased costs through significantly increased length of stay, and the increased use of medication and procedures needed to treat the infections.

Patients who survive BSIs are likely to stay in hospital longer. As an example, in the United States in 2000, the additional cost of uncomplicated BSI associated with urinary tract infection was estimated at an extra US\$2836 per episode.^[6]

The occurrence of BSIs due to IV catheters almost doubled in the 1990s in the United States. This increase in BSIs was associated with an increased prevalence of MRSA.^[16] The median increase in length of stay associated with BSI caused by MRSA was 12 days, compared to only 4 days for methicillin sensitive *Staphylococcus aureus* (MSSA). The attributable median total cost for MRSA BSI was US\$27,083, compared to US\$9661 for MSSA BSI.

Chapter 17 includes a rigorous analysis of 48 published estimates of excess length of stay due to BSI. The mean additional stay in five studies that used statistical procedures to control for differences was 7.07 days (SD 6.74). Section 2.3.2 further discusses the costs associated with *S. aureus* BSI episodes and includes data from South Australia.

2.2.5 Surveillance methods

Detection

Most modern microbiological blood-culture systems reliably detect BSI. However, the indications for taking blood cultures are not standardised or always followed, meaning that some patients with BSI are never sampled. Furthermore, the sensitivity of detection is highly dependent on the volume of blood collected.^[17] Asepsis during blood-culture collection is also important in order to avoid contamination by skin bacteria and other potential contaminants (ie false-positive results). Potential contaminant organisms (eg coagulase-negative staphylococci) represent 25–35% of positive cultures, and only a minority of such events represent true infection. This contrasts with more virulent pathogens, such as *S. aureus*, where false-positive isolation is infrequent. A further factor is variable blood culture collection practice across facilities; that is, whether more than one set of blood cultures is taken to investigate sepsis. This not only influences the sensitivity of the process but also the application of definitions of ‘significance’, such as the new definition for potential contaminant organisms from the United States National Healthcare Safety Network (NHSN) (formerly the National Nosocomial Infections Surveillance System (NNIS)) (see Definitions, this section). As part of surveillance processes for BSI, it is important to develop standard approaches to blood-culture collection, to ensure asepsis during collection and also to ensure the collection of more than one set of samples from patients with potential sepsis.

Most microbiology laboratories liaise directly with clinicians about any patient with a BSI to ensure that patients are receiving appropriate treatment. That process, together with information gathered by infection control professionals, means that a large amount of data is already collected and can be used to help in classifying BSI events.

Issues with collecting and classifying data

Compared with the large number of episodes occurring every year in Australia, there are relatively few published studies about BSIs in Australia. This is due to costs of data collection, lack of trained staff and difficulties in collecting accurate data.^[18, 19, 20, 21, 22, 23, 24, 13] However, we know from studies in Australia and overseas that about one-half of these life-threatening illnesses are acquired in hospital; the remainder originate in the community, although nearly all these patients are admitted to hospital. Because nearly all patients with BSIs are in a hospital for at least part of their illness, data collection should be easier because information systems for pathology and microbiology laboratories will contain details of nearly all patients with BSIs.

However, the situation is more complex because of the difficulty of classifying many BSIs. For example:

- today, many episodes that were traditionally defined as ‘community-acquired’ are associated with health-care procedures

- data based on retrospective review of clinical notes are often inaccurate.

Accurate data collection requires the collection of data prospectively, at or around the time of each episode. It usually also requires the visit of a doctor or an infection control practitioner to the patient's bedside or ward to ascertain important clinical details, such as why and where the infection arose, and whether the patient had 'sepsis' at the time the blood was collected.

Definitions

Assessment of significance

In Australia, there are national guidelines to assess the significance of blood-culture isolates. These guidelines, which were developed by the Australian Infection Control Association National Advisory Board (AICA-NAB),⁵ include a definition of BSI. These AICA definitions have largely been adopted across Australia; they allow the assessment of whether any microorganism cultured is likely to be 'significant' or 'contaminant'. They can be used to define infections occurring in hospitals as well as those infections that occur in people living in the community at the time their infection developed. The guidelines also define all health care associated BSIs, including those that occur in non-inpatients.

The NHSN/NNIS system from the United States has definitions for HAIs that are widely accepted for determining the significance of blood isolates and that form the basis of definitions in use in Australia.^[25] However, those definitions are mainly relevant for the determination of ICU-associated infections, such as central line associated BSIs. A change to this definition regarding 'significance' was made in January 2008, when the criterion that referred to patients with a single blood-culture isolate of a potential contaminant organism was removed.^[26] It is now a requirement under this definition that potential contaminant organisms⁶ can only be accorded significance if the following criteria are met:

- the 'same' organism is cultured from *two* or more blood cultures drawn on separate occasions within two days
- the patient has a range of compatible symptoms or signs.

The range of potential contaminant organisms was expanded in the 2008 definition. All current BSI surveillance systems in Australia use, in part, the previous NHSN/NNIS definition of significance and these should now be reviewed to see whether changes are necessary to ensure that the data collected can be compared to those collected using the NHSN/NNIS system.

Definitions used in neonatal BSIs are not as standardised as those used elsewhere (see Chapter 11 for discussion).

Assessment of health care associated status

In the NHSN/NNIS program, health care associated events in ICUs are defined as occurring more than 48 hours after ICU admission or within 48 hours of ICU discharge. The AICA-NAB definition of BSI⁷ extends this to separately define both inpatient and non-inpatient categories of health care associated BSI. The former defines inpatient events as those that occur more than 48 hours after admission to hospital (ie not incubating on admission) or within 48 hours of discharge.

⁵ [http://www.health.gov.au/internet/safety/publishing.nsf/Content/A4114B5692D8A24FCA2571D8000978D0/\\$File/bsidefinejun05.pdf](http://www.health.gov.au/internet/safety/publishing.nsf/Content/A4114B5692D8A24FCA2571D8000978D0/$File/bsidefinejun05.pdf)

⁶ *Corynebacterium* spp, *Bacillus* spp (but not *B. anthracis*), *Propionibacterium* spp, coagulase-negative staphylococci, viridans group streptococci, *Aerococcus* spp and *Micrococcus* spp.

⁷ [http://www.health.gov.au/internet/safety/publishing.nsf/Content/A4114B5692D8A24FCA2571D8000978D0/\\$File/bsidefinejun05.pdf](http://www.health.gov.au/internet/safety/publishing.nsf/Content/A4114B5692D8A24FCA2571D8000978D0/$File/bsidefinejun05.pdf)

The widespread emergence of community-associated strains of MRSA and movement of hospital strains into some community institutions, such as residential care, prompted the development of a more targeted definition for *S. aureus* BSI by the Australia New Zealand Co-operative on Outcomes in Staphylococcal Sepsis (ANZCOSS)⁸ in 2007.^[27] This definition is based on a definition used by the United States Centers for Disease Control and Prevention (CDC) for designating MRSA as ‘community’ MRSA.^[28] Each event is described first by its onset status (in the community or in an inpatient more than 48 hours after admission). For all community-onset events, the event is then examined for the presence of risk factors for health care and community acquisition of *S. aureus*. This approach enables better identification of events that initially appear to be community onset but are in fact health care associated. A recent Australian study found that only 46–61% of health-care acquired *S. aureus*-BSI episodes were inpatient associated (ie hospital acquired).^[29] Thus, in these hospitals, about one-third of all health care associated episodes were acquired either by outpatients or by short-stay patients. A similar situation is evident in the United States, where more than half (62%) of all community-onset *S. aureus*-BSI episodes were health care associated, with IV catheters the most common site of infection.^[30]

To adequately assess health care associated status, all BSI episodes need to be reviewed (ie including community-onset events, because many of these can be associated with health-care procedures or medical treatment). Data based on retrospective review of clinical notes are often inaccurate.

Assessment of primary source and intravascular line association

In both the AICA-NAB and NHSN/NNIS systems, those BSIs that meet the criteria for significance (see above) and are not secondary to a diagnosed primary site of infection (eg a local abscess or pneumonia) are defined as laboratory confirmed BSIs (LCBSI). In the NHSN/NNIS definitions, patients with an LCBSI who have an intravascular device in situ within 48 hours of the onset of infection are designated to have intravascular catheter-associated infection. This may lead to an overdiagnosis of episodes due to intravascular catheters.

The definition of intravascular catheter association used by the NHSN/NNIS haemodialysis-BSI surveillance system is separately specified, and differs from the LCBSI definition.^[31]

Validation

All surveillance systems for BSI need to address validation processes and ensure that surveillance staff apply the designated definitions consistently.

The systematic application of the criteria used for defining episodes as ‘significant’ or as ‘contaminants’ are important, especially in those settings where a high proportion of BSIs are due to potential contaminant organisms such as coagulase-negative staphylococci.

Reporting

If different hospitals, units or patient groups are being compared, it is important to take into account and document the details of the types of patients and their underlying illnesses that are admitted to different types of units or hospitals. Otherwise, conclusions from comparisons are likely to be erroneous when units or hospitals treating dissimilar types of patients are compared.

Denominators

Reporting of health care associated *S. aureus* BSI has usually been against occupied bed days (referred to as ‘patient days’ in the United States), but excluding day-only admissions (eg United Kingdom, New Zealand, Australia). This, however, ignores the risk exposure from day-only and

⁸ <http://www.asainc.net.au/meeting>

outpatient groups who also experience *S. aureus* BSI events. However, for consistency with established surveillance systems, it would appear advisable to ensure that any reporting includes data that will allow this denominator to be calculated, in addition to any other rates that might be calculated and reported.

Other ways that episodes are reported are as the number of BSIs per 1000 discharges^[32] or, as expressed in the United Kingdom, per 1000 'patients at risk' (ie episodes per 1000 patients who are admitted overnight).^[33] Subgroups of patients in high-risk areas, such as ICU, can also be looked at using these types of denominators; for example, in an adult ICU, cases increased rapidly over a 10-year period.^[34] In Australia, such data have not been extensively published.

More precise data and rates can sometimes be obtained if additional data are collected (eg the length of time a catheter is in place) that can be used as denominators. An example is the New South Wales Hospital Infection Standardised Surveillance (HISS) program, which gathered data on IV catheter sepsis. In the 10 public hospitals enrolled in the program, the rate of IV device-related BSIs for all lines was 2.1 per 1000 line days (95%CI, 1.1 to 3.6), whereas the rate for central lines was 4.7 per 1000 line days (95%CI, 2.2 to 8.6).^[22, 23] However, because collecting such additional data is labour intensive and depends on excellent clinical records, it is often not possible to collect it, especially if whole-of-hospital data are collected.^[33, 13] Section 2.3.3 discusses the best denominators and numerators to use in the case of *S. aureus* BSIs.

NHSN/NNIS recommend reporting of ICU-associated, central line associated BSI per 1000 patient central line day denominator. In counting this denominator, patients with multiple central lines in situ accrue only one day of line exposure per calendar day. This type of reporting is, however, difficult to do in other areas, particularly in any hospital-wide system because it is difficult and labour intensive to collect data on central line days.

In Australia, AICA-NAB in conjunction with the Australian Council on Healthcare Standards (ACHS) developed a suite of related central line associated BSI indicators for other services, such as haematology, oncology and outpatient IV units. These report central line associated BSI events per 1000 central line days. Peripherally and centrally-inserted central line associated BSI events are reported separately under these indicators.^[35]

AICA-NAB also incorporated the five NHSN/NNIS indicators for haemodialysis access associated BSI, and indicators for ICU and non-ICU associated MRSA BSIs into the ACHS Version 3 indicators.^[35]

2.3 Staphylococcus aureus bloodstream infections

2.3.1 Harm to patients

S. aureus BSI episodes are common and serious causes of morbidity and mortality worldwide.^[7, 29] In the pre-antibiotic era, most cases occurred in young patients without underlying disease and the associated death rate was 82%.^[7]

In Australia, it is estimated that there are about 7000 episodes of *S. aureus* BSI per year (35/100,000 population). Most of these are associated with health-care procedures and are thus potentially preventable.^[29] Approximately one-half of all *S. aureus* BSIs have a hospital onset. In the remainder, the patient is living in the community when they become ill (ie community onset) but, of these, about one-third are related to health-care procedures.^[29]

Mortality remains high, even with advanced medical care and antibiotics.^[16, 7, 36, 37, 38, 29] In a meta-analysis of 31 international studies, estimates of death rates for MRSA varied from 0.0% to 83.3% (median 34.2%), while those for MSSA varied from 3.6% to 51.7% (median 25.0%).^[38]

In Australia, the rate of *S. aureus* BSI is:

- similar to the rate reported in England (35 per 100,000 people per year with 19,244 episodes in 2003)^[39, 40]
- lower than the rate reported in the United States, on the basis of the rate derived from the figures available in the only comparative study (55/100,000 people per year)^[30, 29]
- higher than the rates reported in:
 - Denmark^[41, 42]
 - Wales^[40]
 - Ireland.^[43]

It is unlikely that all episodes in those years from Wales and Ireland were reported, given the voluntary nature of their reporting schemes at that time. England changed in 2002 from a similar voluntary reporting scheme to a compulsory scheme, and the numbers of reported episodes increased by almost 50%.^[44, 29]

Antibiotic-resistant Staphylococcus aureus bloodstream infections

Increasing numbers of serious infections are caused by strains of MRSA. In the United States, more than 10% of all BSIs in hospitals are due to MRSA, and these patients have worse outcomes than those with infections caused by methicillin-sensitive strains. A recent study in the United States showed that the rate of invasive MRSA infection was 31.8 per 100,000 people per year, with more than 80% of these being BSIs.^[45] In England, the rate of MRSA BSI infection was 16 per 100,000 people per year. In one Australian study, estimates of the national rate of MRSA BSI have been about 9.5 per 100,000 people per year.^[29, 46, 47] In another Australian study, based on data derived from pathology services and state systems (see Table 2.3), the incidence of health care associated MRSA BSI varied from 0.6 to 13.3 per 100,000 of population per year across different states and territories.^[47] Even though the data for New South Wales and Victoria were underestimates, it was still apparent that the incidence in those states was five to eight times higher than that seen in Western Australia, the state with the most stringent MRSA control program.^[47]

Table 2.3 Health care associated methicillin-resistant *Staphylococcus aureus* bloodstream infections in Australia

State	Health care associated MRSA bloodstream infections	Year(s) of data	Rate per 100,000 population
Northern Territory (Darwin)	16	2006	13.3
New South Wales/Australian Capital Territory	437–602	2003–05	6.2–8.5
Queensland ^a	133	2005	3.4
South Australia ^a	37	2006	2.4
Tasmania ^a	3	2006	0.6
Victoria ^a	270–330	2000–06	5.4–6.6
Western Australia ^a	22	2006	1.1
Total	918–1143		4.5–5.7

MRSA = methicillin-resistant *Staphylococcus aureus*

^a Figures from these jurisdictions include private hospital event estimates.

Note: Figures from New South Wales and Victoria are minimum estimates because of incompleteness of current reporting in these states.

Source: Ferguson and Van Gessel (2008) [47]

The proportion of *S. aureus* BSI caused by MRSA varied in different European countries in 2002. In Denmark it was 1%, the Netherlands 1%, Austria 11%, Germany 19%, Spain 23%, France 33%, Italy 38%, Greece 44% and the United Kingdom 44%.^[48] In comparison, in Australia (1999–2002) it was 26%.^[29]

In the United Kingdom, there has been mandatory measurement of all BSIs caused by *S. aureus* (including MRSA) since 2001.^[49] These surveillance data have underpinned a multifaceted effort to reduce health care associated MRSA infection that included a root cause analysis of each episode.^[50] Peak numbers of MRSA BSI occurred in the six-month period from October 2003 to March 2004 (3955 episodes). This rate fell by more than 40% (to 2376 episodes) from April to September 2007. The MRSA bacteraemia rate for April to September 2007 was 1.24 cases per 10,000 inpatient days.^[49]

A retrospective review quantified the number of cases, their place of acquisition and the proportions caused by MRSA in 17 hospitals in Australia from 1999 to 2002.^[29] Overall, of 3192 *S. aureus* BSI documented, 1571 (49%) had their onset in the community. MRSA caused 40% of hospital-onset *S. aureus* BSI and 12% of community-onset episodes. The median rate for *S. aureus* BSI was 1.48 per 1000 admissions (range 0.61–3.24), with a median rate for hospital-onset *S. aureus* BSI of 0.7 per 1000 admissions and a median rate for community-onset *S. aureus* BSI of 0.8 per 1000 admissions. In terms of infections per 10,000 occupied bed days, the median *S. aureus* BSI rate was 4.3. The median rate of hospital-onset MRSA was 1.3 per 10,000 occupied bed days (range 0–3.9); the latter figure is similar to the rate seen in the United Kingdom in 2007 (see above). The Australian review found that about one-quarter (26%) of all *S. aureus* BSI episodes were caused by MRSA, with most (77%) having a hospital onset. A total of 12% of all community-onset *S. aureus* infections were MRSA: this represented about one-quarter of all the MRSA BSI episodes. These findings are similar to those of a recent study from the United States, which showed that 15% of community-onset *S. aureus* BSI episodes were MRSA.^[30] Another recent United States study found that most (58%) cases of invasive MRSA infections were in patients for whom the onset of infection occurred while they were living in the

community and who had health-care risk factors. Most of these people were also infected with a strain that suggested a health-care origin of the organism (USA100 genotype).^[45]

The Australian Group on Antimicrobial Resistance (AGAR) studied the epidemiology and outcomes of *S. aureus* bacteraemia using 17 hospital-based laboratories in 2005–06. A total of 1511 cases of bacteraemia were documented, of which 66% occurred in males and 32% originated from vascular access devices. Bacteraemia had a community onset in 60% of cases, although 31% of these were health care associated. Overall, 57% of episodes were health care associated. MRSA was the pathogen in 24% of cases. Of the MRSA episodes, 53% were of the typical multiresistant hospital type and 29% were of the community-associated type. Outcomes were available for 51% of cases and, in those, the all-cause mortality at seven days or discharge (whichever came earlier) was 11.2%. Age was strongly associated with mortality: the rate for patients aged more than 60 years was 18%.^[52]

Most of the community-onset strains in the Australian study were multiresistant or phenotypically consistent with the endemic MRSA (EMRSA) strain 15. This means that they were likely to have been acquired by patients who had had previous contact with a hospital or nursing home. About one-quarter of these community-onset MRSA infections were, however, caused by other phenotypes of MRSA that were not multiresistant; thus, they were more likely to have been true community-acquired episodes of MRSA bacteraemia. Increasing numbers of MRSA infections not associated with prior health-care contact have been reported in Australia.^[53, 54, 55]

2.3.2 Impact of *Staphylococcus aureus* bloodstream infection on health-care systems

S. aureus BSI episodes lead to considerable additional health-care costs.^[16, 37]

Staphylococcal bacteraemia causes serious complications, including endocarditis, osteomyelitis and septic arthritis, as illustrated by the case study in Box 2.2. Complications of infection frequently result in prolonged hospital admission and increased costs. In a non case–controlled and observational study in one hospital in Western Australia, the average length of stay for patients with *S. aureus* bacteraemia was 26.5 days.^[29]

Box 2.2 Cost of *Staphylococcus aureus* bloodstream infection in South Australia

A prospective matched cohort study was conducted at the Royal Adelaide Hospital during 1999–2000 to determine the cost and outcomes that could be attributed to health care associated *Staphylococcus aureus* bloodstream infection (BSI) episodes.^[56] At the time, no Australian data were available to compare with those published in the United States and other countries.^[32, 16, 57, 58, 37]

Because the method of financing hospitals and medical care differs significantly between Australia and the United States, the costs quoted in these studies are not directly applicable to the Australian setting. Also, many of the published studies were of poor quality in terms of their method of economic analysis and they were often based on small numbers of cases.

The study involved a three-month follow-up of 70 consecutive patients with *S. aureus* BSI, admitted over the period June 1999 to July 2000. The crude mortality rate at 90 days was 27%. The mortality rate directly attributable to *S. aureus* BSI was 10%, and *S. aureus* BSI was considered a contributing factor in a further 10% of patients. Complications of bacteraemia were experienced by 36% of patients, including multiple organ failure in 9 patients and metastatic infection at other body sites in 11 patients. The rate of complications was significantly higher in the subgroup of patients with *S. aureus* BSI, due to methicillin-resistant *Staphylococcus aureus*.

Cost of *Staphylococcus aureus* bloodstream infection in South Australia (continued)

In the matched analysis, the median excess length of stay was 13 days (equivalent at that time to \$16,500). However, when the potential confounding effect of length of stay before infection was taken into account, the median difference in excess length of stay was reduced to 11.5 days (\$12,430) per case. The study also considered the notional reimbursement according to the diagnosis related group (DRG⁹) case-mix formula. From the perspective of the hospital budget, the shortfall in notional case-mix reimbursement for the 70 cases was \$730,000 or \$10,360 per case. However, this figure underestimates the true cost of infection because the complex formula used for DRG assignment and cost weighting already includes some allowance for the development of complications of care.

In 2006, there were 159 cases of *S. aureus* BSI reported to the South Australian health care associated infection surveillance system. This equates to about \$2 million excess cost attributable to this one infection, together with the loss of 32 lives and about 330 years of healthy life in South Australia each year. The opportunity cost was the loss of approximately 1400 patient days that could have been used to treat other patients if these infections had been prevented. These costs justify the investment of significant resources in interventions designed to prevent health care associated BSI.

2.3.3 Methods for surveillance of *Staphylococcus aureus* bloodstream infection

A recent Australian study found that the traditional method for determining those episodes of infection that were health care associated (>48 hours post-admission to hospital) substantially underestimates the number of episodes of bacteraemia that are health care associated.^[29] In 971 episodes of *S. aureus* BSI where full data from three teaching hospitals were available, 64–75% of the total *S. aureus* BSI episodes were health care associated. However, only 46–61% of the episodes were acquired while the patient was an inpatient (ie >48 hours in hospital). Thus, in these hospitals, about one-third of all health care associated episodes were acquired either by outpatients or by short-stay patients. These latter episodes are thus better defined as ‘non-inpatient, health care associated’. On the basis of the data in this study, about two-thirds of all *S. aureus* BSI episodes in Australia were probably associated with health-care or medical procedures (ie all hospital-onset episodes and about one-third of community-onset episodes).

A similar situation is evident in Denmark where, in 2002, at least 59% of all *S. aureus* infections were associated with health-care procedures.^[42] A study from the United States published in 2001 showed that more than half (62%) of all their community-onset *S. aureus* BSI episodes were health-care related, with IV catheters the most common clinically apparent site of infection.^[30]

Choice of denominators and numerators

One of the issues that arises when calculating rates for *S. aureus* BSI is what to include in the numerator and in the denominator when rates are calculated.

The numerator (ie number of cases of *S. aureus* BSI) can be one of the following:

- only episodes that have a hospital onset
- all health care associated episodes; that is, all episodes that are hospital onset plus those from the community that are health care related (eg associated with an IV catheter).

If all health care associated episodes are to be included in the numerator, it is usually necessary to also include those patients who were not inpatients at the onset of their sepsis or who may have been admitted as day-only patients.

⁹ Diagnosis related group is a system for classifying hospital cases into one of about 500 groups that are expected to have similar use of hospital resources.

In the case of the denominator, one option is to use occupied bed days and also include day-only cases because these will also be represented in episodes of *S. aureus* BSI (eg with dialysis or IV therapy, which will often have been day-only cases). However, most definitions used to date — for example, from the United Kingdom, New Zealand and Australia — have excluded day-only patients from the denominators.

Using different denominators thus creates difficulties in making comparisons over time or between hospitals, states or countries. However, although the values of the rates will change when different values are used in the numerators and denominators, the trends in any graph will often stay the same, as shown in Figure 2.1 Hence, the use of any particular denominator is probably of less importance than ensuring that there is consistency in what is used.

Figure 2.1 shows rates of health care associated *S. aureus* BSI that have occurred at the Canberra Hospital between 1998 and 2006 calculated with different denominators. The graphs in this figure all show the same trend with time. There was a peak in episodes in 2000 because the hospital had higher MRSA rates at that time. Action was then taken and MRSA numbers decreased. Another rise in MRSA also occurred in 2006.

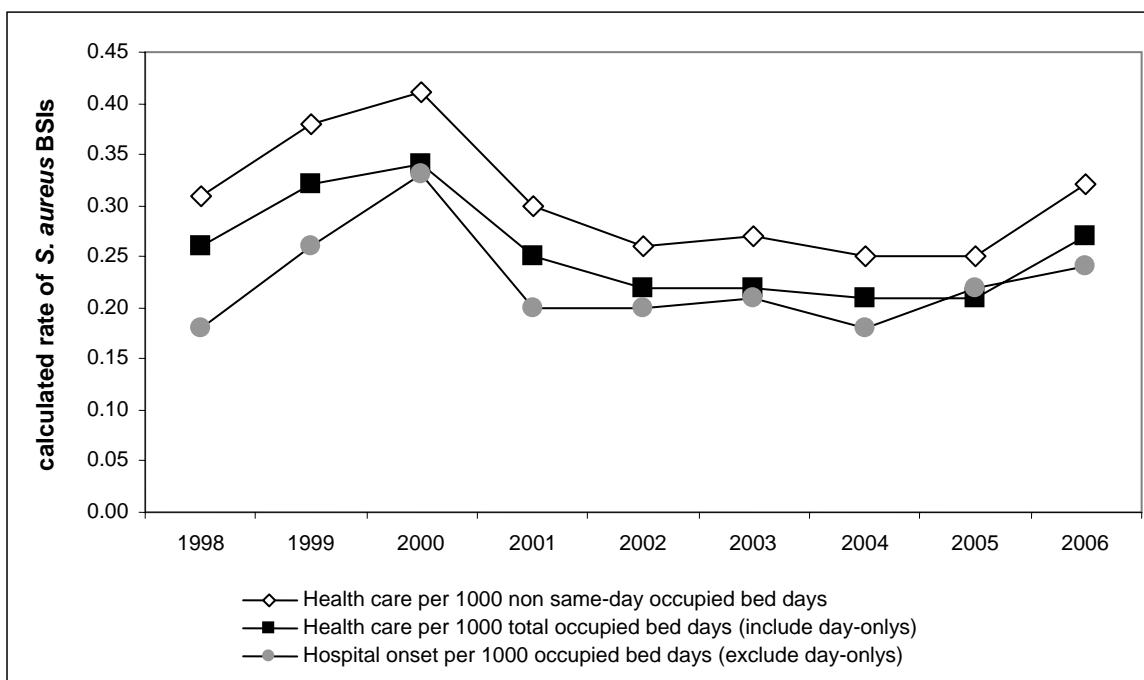


Figure 2.1 Effect of denominator on calculation of rate of health care associated *Staphylococcus aureus* bloodstream infections at Canberra Hospital, 1998–2006

BSI = bloodstream infection; *S. aureus* = *Staphylococcus aureus*

2.3.4 Current surveillance systems and results

South Australia, Western Australia and Queensland conduct surveillance of health care associated *S. aureus* BSI, and New South Wales started to do this in 2008. Examples of current *S. aureus* BSI surveillance programs conducted by some selected hospitals, in South Australia, by AGAR (ANZCOSS) and in New Zealand are provided, together with recent results. For a description of other international systems, see Chapter 6.

South Australia

Seven major South Australian public hospitals have contributed BSI data to the South Australian Department of Health since 1997. Surveillance for BSI was expanded in 2002, and the number of contributors increased to 14 metropolitan hospitals (including both private and public). Until 2002, the definitions used for this surveillance included only hospital-onset episodes (ie occurred >48 hours after admission). From 2002 onwards, the national definitions developed by AICA were adopted, and these include non-inpatient health care associated episodes.

Figures 2.2 and 2.3 show the trend in *S. aureus* BSI for the two time periods. Figure 2.2 clearly illustrates the rise and then fall of MRSA as a percentage of all health care associated *S. aureus* blood isolates over the 10-year period. Data for this chart include hospital-onset episodes only. Figure 2.3 presents the data as rates, using overnight occupied bed days as the denominator. The numerator includes all health care associated episodes, both inpatient and non-inpatient.

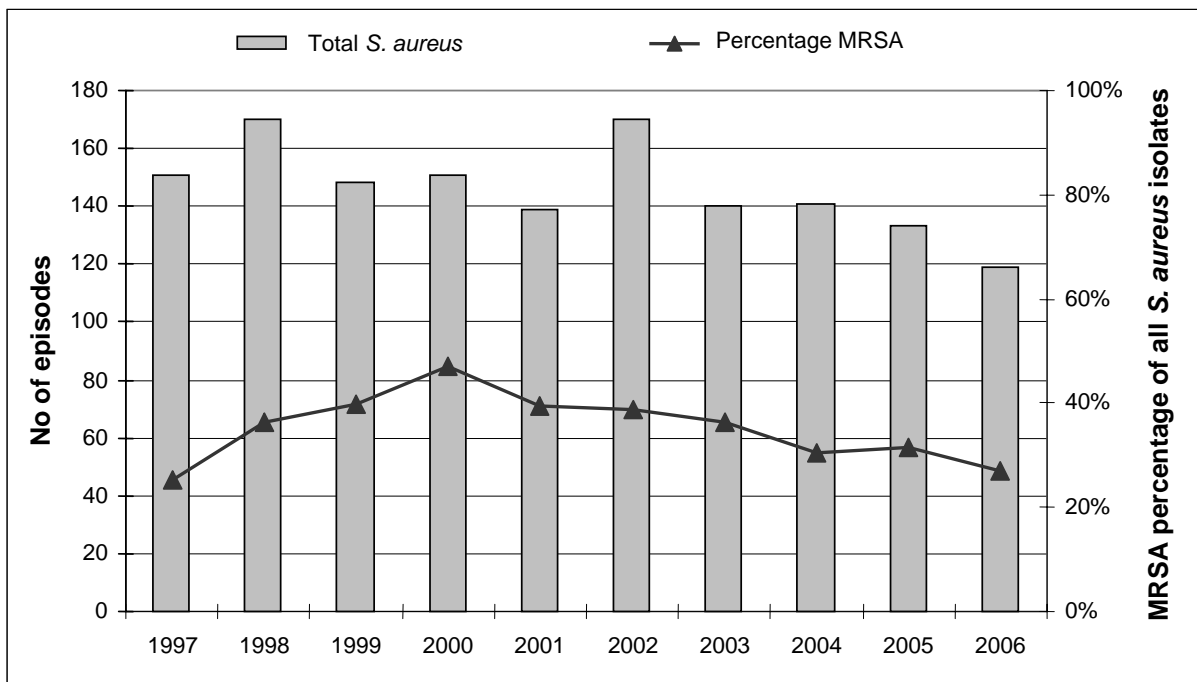


Figure 2.2 *Staphylococcus aureus* bloodstream infections for seven major South Australian metropolitan hospitals

MRSA = methicillin-resistant *Staphylococcus aureus*; *S. aureus* = *Staphylococcus aureus*

Overall, in South Australia since 2002, in the 14 hospitals undertaking health care associated *S. aureus* BSI surveillance, the aggregate rate per 10,000 occupied bed days has fallen from 2.1 to 1.43 — a fall of more than 30%. In the type 1 hospitals (tertiary referral), the rate has fallen more substantially, from 3.10 to 1.86 per 10,000 occupied bed days — a fall of more than 40%.

The aggregate rate of *S. aureus* BSI in 2006 for these 14 hospitals was 1.43 per 10,000 occupied bed days (range 0–2.35). Using separations as a denominator, the aggregate rate was 0.79 per 1000 separations (range 0–1.58).

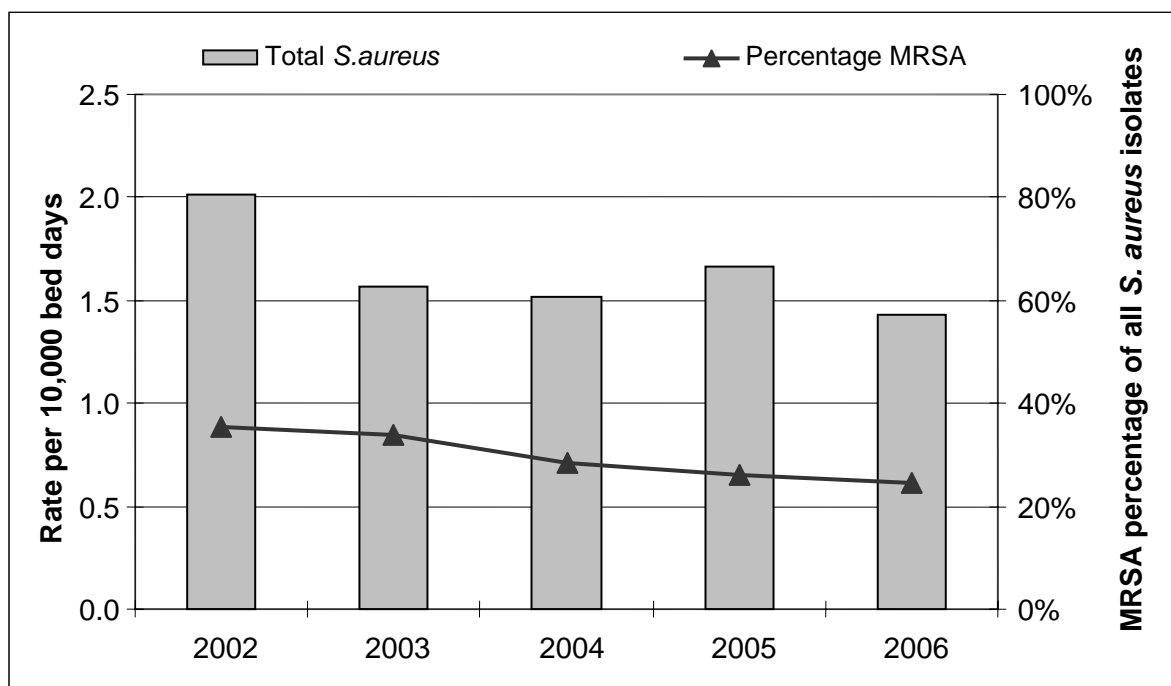


Figure 2.3 Rates of total *Staphylococcus aureus* and methicillin-resistant *S. aureus* (MRSA) bloodstream infection for 14 South Australian hospitals

Table 2.4 shows the difference in rates of health care associated MRSA BSI between the larger tertiary hospitals and the smaller acute hospitals, separated into inpatient (hospital-onset) and non-inpatient (community-onset) episodes.

Table 2.4 Rate of methicillin-resistant *Staphylococcus aureus* bloodstream infection by hospital type — South Australia

		2004		2005		2006	
		Number of episodes	Rate per 10,000 OBDs	No. of episodes	Rate per 10,000 OBDs	No. of episodes	Rate per 10,000 OBDs
Type 1 hospitals ^a	IP	31	0.56	37	0.65	24	0.41
	NIP	6	0.11	6	0.11	6	0.10
Type 2 hospitals ^b	IP	8	0.16	4	0.08	8	0.15
	NIP	1	0.02	0	0.00	1	0.02

IP = inpatient episodes, NIP = non-inpatient episodes; OBD = occupied bed day

^a Type 1 = tertiary referral hospitals >300 beds

^b Type 2 = acute care <300 beds

The decline in rates of *S. aureus* BSI in South Australian hospitals over the past five years is associated with multiple interventions within the major metropolitan hospitals, including:

- the widespread introduction of alcohol-based hand hygiene from 2002
- the establishment of a state-wide link nurse program in 2003, following its successful operation in two of the larger metropolitan hospitals

- regular feedback of surveillance data on MRSA, BSI and antibiotic usage to contributors of data
- the development of an intensive MRSA screening and control program in one of the largest hospitals.

The Canberra Hospital, Australian Capital Territory

Data from 1998 to 2006 are available from an ongoing surveillance program at the Canberra Hospital, a 500-bed tertiary referral hospital. In 2006, there were 56,294 separations, of which 33,004 were same-day patients. There were 152,367 occupied bed days for non-same-day patients. The study prospectively followed all episodes of *S. aureus* BSI that were hospital-onset, plus all non-inpatient health care associated episodes as well as community-onset episodes. Rates were calculated using the denominator of occupied bed days, but excluding day-only patients; rates varied from 0.25 to 0.41 per 1000 bed days. Figure 2.1 shows the variations that occurred from year to year.

Over the 9-year study period, there were 615 *S. aureus* BSI episodes, of which 124 were caused by MRSA (20.1%). Numbers of *S. aureus* BSIs varied from 55 to 79 episodes per year. Of these, those that were community-onset varied from 14 to 40 per year, non-inpatient health care associated from 4 to 18, and inpatient health care associated from 21 to 45. In 2005, there were 67 *S. aureus* BSIs, of which 33 episodes were inpatient health care associated and 3 were non-inpatient health care associated. The rate of health care associated sepsis was 0.72 per 1000 separations, or 1.7 per 1000 separations if day-only cases were excluded.

The Austin Hospital, Melbourne

Data on BSIs collected at the Austin Hospital in Melbourne were presented at a recent meeting of the Australasian Society for Infectious Diseases (ASID¹⁰) and are shown in Figure 2.4.

The BSI definitions used were as follows:

- *inpatient Austin-associated S. aureus BSI* — used to refer to episodes that occurred more than 48 hours after admission to Austin
- *non-inpatient Austin-associated S. aureus BSI* — used to refer to episodes that occurred less than 48 hours after admission but in which the patient had an indwelling medical device or neutropenia due to chemotherapy, or to episodes that occurred within 30 days of surgery or within 48 hours of invasive instrumentation
- *Austin-associated episodes* — used to refer to inpatient episodes plus all health care associated community-onset episodes.

There were a total of 102 *S. aureus* BSI episodes in 12 months, with 57 of them being Austin-associated episodes (35 inpatient and 22 non-inpatient) and 45 being community-associated episodes.

¹⁰ <http://www.asid.net.au/hicsigwiki/images/6/61/FriGB2-31345Dendle.pdf>

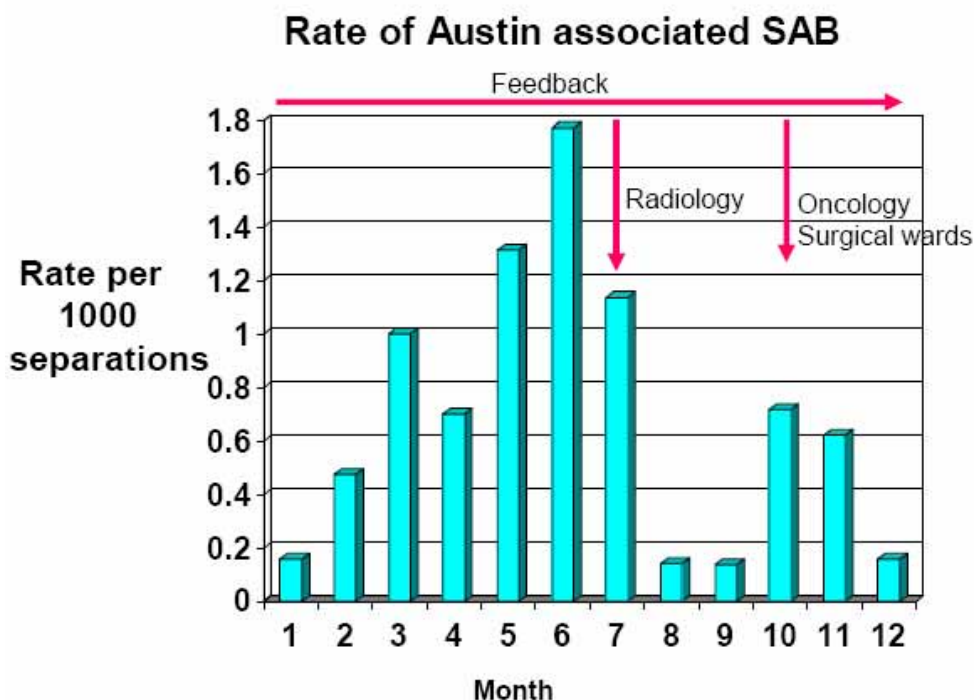


Figure 2.4 Rate of Austin-associated *Staphylococcus aureus* bloodstream infections

Source: <http://www.asid.net.au/hicsigwiki/images/6/61/FriGB2-31345Dendle.pdf>

The overall rate of Austin-associated *S. aureus* BSI was 0.7 per 1000 separations. However, in the first six months it was 0.9 per 1000 separations and during the six-month period after the *S. aureus* bacteraemia surveillance program was introduced, it dropped to 0.5 per 1000 separations — a reduction in rates of 58%, which represented prevention of 15 Austin-associated *S. aureus* BSI episodes.

Australian Group on Antimicrobial Resistance

To gain a clearer picture of outcomes from *S. aureus* BSI in Australia, a retrospective study was conducted by AGAR in 2005–06 in 17 tertiary hospitals.^[59] Mortality was measured at seven days after blood culture collection or at discharge if this occurred sooner. Of 1511 cases, 60% had their onset in the community, but one-third of these were health care associated. Overall mortality at day seven was 11.2% in the cases where this information was collected (see also Section 2.3.1).

Australia New Zealand Co-operative on Outcomes in Staphylococcal Sepsis

A prospective trans-Tasman study of *S. aureus* BSI outcomes started in 2007: ANZCOSS).^[60, 61] Data are being collected on all significant *S. aureus* BSIs, including antibiotic treatments and mortality outcomes. Data are entered by 26 hospital laboratory services over an internet interface. By December 2007, 1052 entered cases had completed 30-day follow-up; 78 of these episodes were from New Zealand. In 60.1% of cases, *S. aureus* BSI had its onset in the community, and 17.0% of these were MRSA. By contrast, MRSA was seen in 28.7% of hospital-onset infections. MRSA collectively caused 21.7% of all *S. aureus* BSI episodes, of which:

- 12.5% were multiresistant
- 7.2% were of the non-multiresistant, community-associated type
- 2.0% were health care associated EMRSA-15-like strains.

A total of 10.6% of *S. aureus* BSI cases were caused by penicillin-susceptible strains. Infections associated with indwelling devices were the most commonly recorded clinical association (19.9%). The 7-day all-cause mortality was 11.6% and the 30-day mortality was 20.7% ($n = 1002$). Mortality was similar for community-onset and hospital-onset infections. On univariate analysis, 30-day mortality was significantly higher if:

- the patient:
 - was more than 70 years old ($P < 0.0001$)
 - was of European (Caucasian) origin ($P = 0.003$)
 - had sepsis syndrome ($P < 0.00001$)
- the infection:
 - was not device-associated ($P = 0.02$)
 - was caused by multiresistant MRSA ($P = 0.0001$) rather than by strains with other susceptibility profiles.

If the patient was treated mainly with vancomycin, then mortality was higher (26.7% mortality vs 18.5%, $P = 0.005$), even for infections caused by methicillin-sensitive strains ($P = 0.004$).

New Zealand

A system to measure health care associated *S. aureus* BSIs per 1000 inpatient bed days started recently across all regions of New Zealand. Figure 2.5 displays recently published rates.¹¹

¹¹ District Health Board Hospital Benchmark Information, NZ
[http://www.moh.govt.nz/moh.nsf/pagesmh/6838/\\$File/dhb-hospital-benchmark-information-report-aprjun07.pdf](http://www.moh.govt.nz/moh.nsf/pagesmh/6838/$File/dhb-hospital-benchmark-information-report-aprjun07.pdf)
accessed 6/3/08

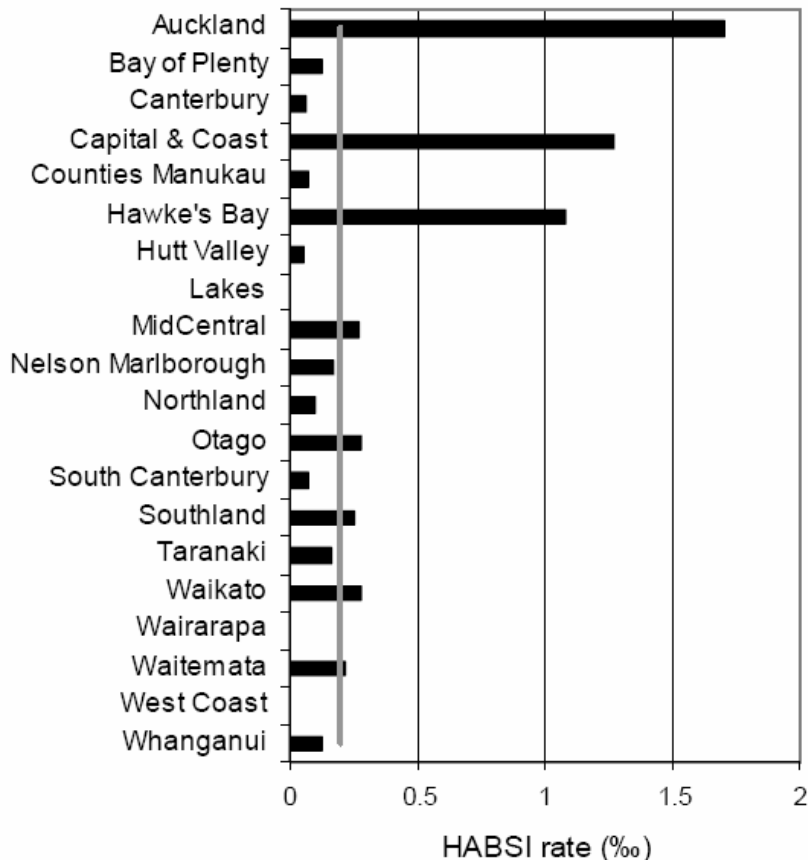


Figure 2.5 Hospital-acquired *Staphylococcus aureus* bloodstream infections, New Zealand (April–June 2007)

HABSIs = Hospital acquired bloodstream infection

Notes:

1. The grey line denotes the nationwide rate for these infections.
2. Auckland District Health Board has reported a rate against the number of patients rather than the number of bed days.

2.4 Intravascular catheter-associated bloodstream infections

Intravascular catheters are the most common cause of health care associated BSI in developed countries.^[21, 62, 63, 64, 65, 66, 67, 8] In the United States, it is estimated that 250,000 cases of central venous catheter-associated BSIs occur annually.^[67]

Catheter-associated BSIs are a particular problem in intensive care patients (see Chapters 10 and 11) and immunocompromised patients who depend on artificial vascular access (see Section 2.5). The most frequent and serious microbiological cause of catheter-associated BSI is *S. aureus* (MSSA and MRSA) (see Section 2.3), followed by coagulase negative staphylococci and *Candida* species (see Table 2.5).

Table 2.5 Number of microorganisms causing intravascular catheter-related bloodstream infection episodes, by year

Microorganism ^a	1998	1999	2000	2001	2002	2003	2004	2005	Total (%)
<i>Staphylococcus aureus</i>	26	30	29	20	20	14	13	13	165 (31)
Methicillin-sensitive	24	25	19	16	14	11	11	10	130 (25)
Methicillin-resistant	2	5	10	4	6	3	2	3	35 (7)
Coagulase-negative staphylococci	42	14	24	9	8	22	8	11	138 (26)
<i>Candida</i> spp	8	1	4	4	1	0	8	8	34 (6)
<i>Klebsiella</i> spp	7	3	6	7	1	3	1	3	31 (6)
<i>Stenotrophomonas maltophilia</i>	6	8	2	3	0	1	2	1	23 (4)
<i>Enterobacter</i> spp	4	2	5	4	1	1	2	0	19 (4)
<i>Escherichia coli</i>	2	2	1	1	2	0	4	0	12 (2)
<i>Pseudomonas</i> spp	4	3	3	3	2	0	2	4	21 (4)
Other ^b	17	14	11	6	7	7	10	12	84 (16)
Total	116	77	85	57	42	48	50	52	527 (100)

Spp = species

a In 31 episodes, more than one significant organism was isolated.

b The most common 'other' isolates were: Viridans streptococci, 12; *Acinetobacter* spp, 10; *Proteus* spp, 10; *Enterococcus* spp, 10; *Serratia* spp, 8; *Corynebacterium jeikeium*, 4.

In Australia in the early 1990s, about 2% of all central venous catheters and 0.04% of peripheral venous catheters were estimated to be associated with BSIs, resulting in more than 3000 catheter-related episodes per year.^[62] These episodes occurred in all areas of the hospital, as well as in patients living in the community.

In Australian teaching hospitals in the early 1990s, the average rate for catheter-associated BSIs was 1.6 per 1000 admissions.^[62] In New Zealand between 1995 and 1997, a rate of 2.4 per 1000 admissions was seen in the Auckland Health hospitals.^[65] In England, in a more recent study, the rate for IV sepsis was 2.3 BSIs per 1000 admissions in teaching hospitals and 0.9 per 1000 admissions in non-teaching hospitals.^[8]

A study from France examined episodes of catheter-related BSI in critically ill patients in an ICU.^[68] The condition complicated 1.2 of every 100 ICU admissions, and 53% of the catheter-related BSI cases were associated with septic shock. Accrued ICU mortality rates in those with sepsis were 50%, compared with 21% in matched patients without sepsis.

Although catheter-related BSIs have not always been shown to be associated with a marked increase in mortality, they are associated with increases in length of stay and cost.^[69] For example, in Spain, catheter-related BSIs were found to be associated with an increase in the length of stay of 19.6 days.^[69] If this length of stay occurred in a major Australian hospital, where

average bed costs usually exceed \$700 per day, it would equate to an additional cost of at least \$14,000 per infection.

Groups in the United States, Germany, Brazil, Australia and Switzerland have shown in ICU studies that active surveillance and interventions can substantially reduce the numbers of BSIs associated with central lines (see Chapter 10).^[70, 64, 71, 72, 73, 74, 75, 76] A study in the United States showed this can also be done for the ‘whole of hospital’. In a 200-bed hospital in Iowa, a decrease of 35% occurred in primary BSIs after the introduction of an 11-member IV team (1.1 to 0.7 per 1000 patient days).^[77]

The efficacy of a whole-of-hospital approach was highlighted in a recent Australian study that followed the introduction of a quality improvement program in a teaching hospital. The prospective study looked at all patients with positive blood cultures at a 500-bed tertiary referral hospital from 1998 to 2005 and identified those associated with IV catheters (ie BSI occurring in a patient with one or more IV lines in whom no other identified source of sepsis was apparent). Over the 8-year study period, there were 491 BSI episodes associated with IV lines, mainly central lines of all types (see Table 2.6). Based on the quantities of IV devices purchased, the rates of line-associated BSI were 8.8 per 1000 central lines (0.9%), 4.9 per 1000 peripherally-inserted central lines (0.5%) and 0.25 per 1000 peripheral lines (0.03%).

Table 2.6 Intravascular device types associated with bloodstream infection episodes (1998–2005) at the Canberra Hospital

Intravascular device type	Number of bloodstream infection episodes
Central venous line (non-tunnelled)	186
Central venous line (tunnelled)	75
Central venous line (non-tunnelled, dialysis access)	70
Peripheral venous line (ie peripheral cannula)	36
Umbilical central venous or arterial line	27
Arteriovenous fistula (artificial-goretex)	22
Central venous line (non-tunnelled, midline type)	18
Central venous line (implanted) (ie Portacath)	20
Peripherally-inserted central line (ie PICC)	28
Others ^a	9
Totals	491

PICC = peripherally inserted central catheter

^a 3 arterial catheters, 2 arteriovenous fistula, 2 temporary pacemakers, 1 Swan-Ganz catheter and 1 femoral sheath

Source: Collignon et al (2007) ^[13]

At day seven, there was a 4% mortality for patients with episodes of IV-catheter sepsis (20 of 490 episodes). A subgroup of 44 patients was followed for six months, and cumulative mortality in this subgroup was 12% at 1 month and 39% at 6 months. The reported mortality associated with these BSIs around the world is variable.^[67] While many of these deaths are likely to be related to the patients’ severe underlying diseases, sepsis was also a major contributing factor.^[62, 67]

This Australian study formed part of a quality improvement program that involved weekly team meetings and assistance to help clinical areas develop and implement targeted interventions.^[13] This intervention was associated with a fall in the rate of catheter-associated BSI from 2.3 in

1998 to 0.9 per 1000 admissions in 2005.^[46] BSI episodes caused by IV catheters fell from 110 per year in 1998 to 48 episodes in 2005 (32% of all BSI episodes to 15%; >50% reduction). Rates per 1000 discharges fell from 2.3 to 0.9 (for trend $P < 0.0005$). The decline in BSIs arising from IV catheters was associated with multiple interventions, instigated by individual units, usually in consultation with the infection control service after the units had received feedback and advice about their rates and numbers of IV device associated sepsis.

The Canberra-based program involved more than just data collection. The project nurse visited the wards and discussed each BSI episode with the medical and nursing staff involved, which provided prompt feedback. The combined interaction of all the elements (eg surveillance, the immediate presence and feedback by the project nurse, and the introduction of preventive strategies) was the likely reason for the dramatic reduction in sepsis observed at this hospital, a point also made by others.^[71] The Australian study also showed the value of ongoing surveillance programs.^[13] On two occasions, new ‘peaks’ in sepsis were detected (see Figure 2.6), specific interventions were implemented, and IV catheter-associated bloodstream infection rates returned to the previous lower levels.

There can be advantages in reporting IV catheter sepsis using denominators that are easier to collect than catheter-line days (eg discharges or patient days, expressed as episodes per 1000 discharges or patient days).^[64, 8] Expressing infection rates as catheter-line days only does not allow acknowledgment that timely removal of lines reduces risk,^[75] so may lead to the continued overuse of these catheters.

2.4.1 Current surveillance systems

International

Many countries now collect standardised central line associated BSI rates in accordance with the NHSN/NNIS approach recommended for ICUs (see also Chapter 10).

Australia

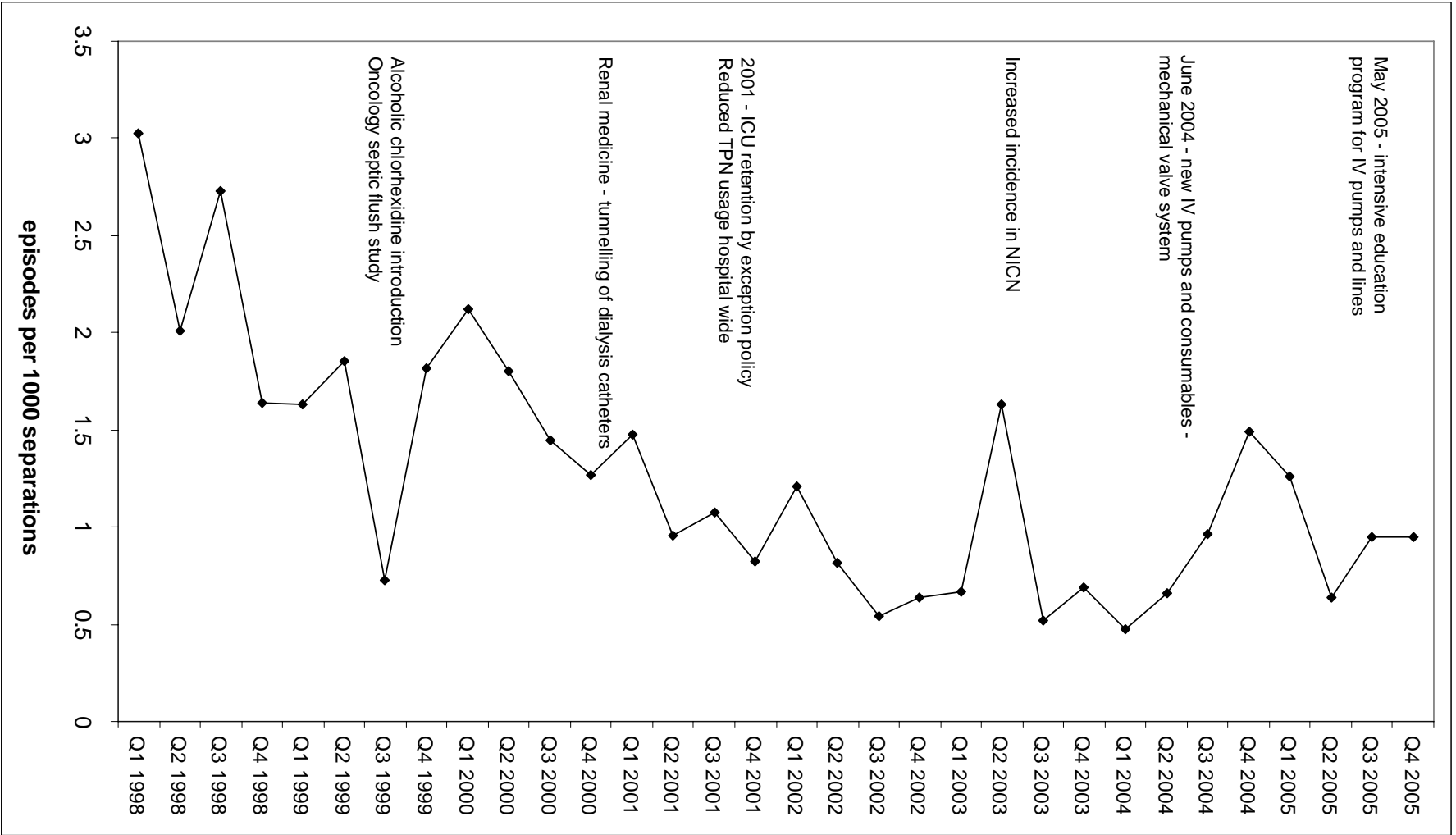
In most ICUs in most jurisdictions, data are collected on central line associated BSI rates using the NHSN/NNIS approach. Such data are collated on a jurisdiction-wide basis in Victoria, New South Wales, South Australia and Western Australia.

Some facilities collect data against the wider range of ACHS (Version 3, 2005) central line associated bacteraemia (CLAB) indicators in patient groups outside of ICUs. However, there are concerns around the accuracy of these surveillance. The South Australian surveillance program collects data on haematology and oncology patient CLAB rates, and the Western Australian program collects CLAB rates for local haematology, oncology, outpatient IV therapy and haemodialysis units.

2.5 Bloodstream infections in the immunocompromised and in specific patient groups

2.5.1 Background

This section covers only harm to patients from BSIs in the immunocompromised, focusing on different patient groups: patients admitted to ICU, patients requiring haemodialysis, and haematology–oncology populations. It does not deal with impact on health-care systems, surveillance or current surveillance systems.



ICU = intensive care unit; IV = intravenous; NICN = neonatal intensive care nursery; Q = quarter; TPN = total parenteral nutrition

Figure 2.6 Intravascular device-related bloodstream infections, 1998–2005

A national study in the United Kingdom demonstrated that a large proportion of all hospital-acquired BSIs in teaching hospitals were observed in general medicine and surgery units (26.8% of total).^[8] However, the study also showed that immunocompromised populations contributed significantly to the overall burden, as follows: haematology (18.9%), general ICU (13.0%), nephrology (7.0%) and oncology (4.3%).

Similar results were found from monitoring of IV catheter related BSIs at an Australian tertiary referral hospital (1998–2005). The monitoring showed that patients in the haematology unit comprised 20.9% of total infections, followed by the those in the renal unit (15.3%), ‘medical services (other)’ (11.8%), neonatal ICU (10.4%) and oncology unit (8.9%).^[13] As a proportion of all BSIs, the relative contribution to disease burden by immunocompromised patients is probably also influenced by the existence and size of specialty units within individual referral centres.

Immunocompromised patients have an increased risk of developing health care associated infections, including BSIs.^[78] Morbidity and attributable mortality are also higher in these groups. Differences in infecting organisms may be seen, with opportunistic pathogens (eg fungal BSIs) playing a more significant role. Resources required to manage BSIs in immunocompromised patients are likely to be significant, although Australian data reporting length of hospitalisation and additional costs in these populations are lacking.

2.5.2 Intensive care unit patients

Since the implementation of methodologies for surveillance of health care associated infections based on those of the NHSN/NNIS, many international centres have monitored catheter-related BSIs in ICU patients. In Australia, surveillance for these infections is performed in a number of states and reported using a denominator of per 1000 central venous catheter days.^[79, 80]

2.5.3 Patients infected with human immunodeficiency virus

The incidence of health care associated infection is higher in patients with acquired immune deficiency syndrome (AIDS). Of all health care associated infections in this population, BSIs are the most frequently reported, with most being associated with central venous catheters.^[81] There is no current standardised method for monitoring of BSIs in human immunodeficiency virus (HIV)-positive patients in Australia; therefore, data regarding incidence and outcomes are not available.

2.5.4 Patients requiring haemodialysis

BSIs in patients requiring haemodialysis are frequently associated with IV devices or vascular access for dialysis via arteriovenous fistulae, and are most frequently due to *S. aureus*.^[82] Health-care costs and mortality are increased in haemodialysis patients who develop dialysis-associated BSI. For example, a United States study estimated that *S. aureus* bacteraemia in this population was associated with a mortality rate of approximately 20%, with a mean additional health-care cost of approximately US\$24,000.^[83]

Risk for infection varies according to the device type, with uncuffed catheters associated with the highest risk and native arteriovenous fistulae with the lowest risk.^[84] Australian data support these findings, with rates of device-associated BSI of 0.4 per 1000 patient days for native fistulae, compared to 20.2 per 1000 patient days for non-tunnelled catheters.^[85] A key challenge in dialysis services is to maximise the use of arteriovenous fistula haemodialysis access through timely patient preparation. The availability of reliable BSI surveillance data provides the impetus for optimising access strategies in the interest of reducing the number of bloodstream events associated with access.

The impact of surveillance in patients requiring haemodialysis has been demonstrated by a large dialysis centre in the United Kingdom. Rates for bacteraemia and antibiotic usage were significantly reduced following the implementation of a surveillance strategy based on protocols used in the United States.^[86] Also in the United States, participation in outpatient haemodialysis surveillance was extended to all outpatient haemodialysis centres in 2007.^[87] The NHSN/NNIS haemodialysis module recommends reporting according to type of dialysis access, and data are captured to distinguish non-access primary sources for BSI from access-associated infections.

Haemodialysis access associated BSI rates have been reported in NSW via the ACHS system up until 2007. The Australian and New Zealand Society of Nephrology is considering the adoption of such indicators across Australia as a key performance indicator for dialysis services in 2008.

2.5.5 Haematology–oncology patients

Over the past three decades, a change in pattern of infection has been observed in patients rendered neutropenic by therapy, and reductions in gram-negative and increases in gram-positive BSIs have been observed.^[88] Changes in antimicrobial susceptibility have also been observed. The prevalence of non-*albicans* species of *Candida* and the proportion of fluconazole-resistant *Candida albicans* isolates is increasing due to widespread use of antifungal azole prophylaxis.^[89] Internationally, widespread use of fluoroquinolone prophylaxis for neutropenic patients has been associated with the emergence of resistant gram-negative isolates.^[90, 91] The emergence of resistant bacterial isolates — including vancomycin-resistant enterococci (VRE),^[92] MRSA^[93] and multiresistant gram-negative organisms^[92] — is likely to have happened at the same time as the circulation of endemic and outbreak strains within non-haematology populations in individual health-care institutions.

In haematology–oncology patients, central venous catheter insertion contributes to risk for developing BSI.^[94] Neutropenia is also a significant risk factor for infection.^[95] In haematology patients, central line associated BSI has been associated with an attributable mortality of 12%.^[96]

In Australia, an increased rate of BSI has been reported in association with a needle-less mechanical valve connector system in haematology–oncology patients at a single centre.^[97]

Internationally, surveillance for BSIs in haematology and oncology populations has largely focused on central line associated BSIs. The application of existing NHSN/NNIS definitions for line-associated BSI is problematic in this population for various reasons, some of which are as follows:

- Collection of blood cultures from existing central lines rather than from new venipunctures creates the dual risk of contamination from intraluminal line colonisation (ie false positive result) or contamination of an uninfected or uncolonised line through the process of blood culture collection.
- Neutropenic patients may develop a BSI from a gut source without direct clinical evidence of mucositis or gastrointestinal disease. In such a setting, a patient who also has a central line in situ may then be designated as having a line-associated BSI. Notwithstanding this, many centres around Australia have successfully applied the old NHSN/NNIS definition in surveillance of line-associated BSI. The current ACHS guidelines include specific indicators for haematology and oncology services for both centrally-inserted and peripherally-inserted central line associated BSI.^[35]

2.5.6 Other immunocompromised populations

There is no standardised strategy or Australian data specifically reporting results of surveillance for BSIs in patients receiving long-term total parenteral nutrition or solid organ transplant

recipients. The decision to monitor these and other immunosuppressed populations must therefore be based on the needs of individual health-care institutions, adapting accepted methodology used for other populations.

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3 Surgical site infection

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Key points

- Surgical site infections (SSIs) are associated with substantial morbidity, mortality and costs.
- Surveillance of SSIs, coupled with prompt feedback of data from the infection prevention team to treating clinicians, can achieve major reductions in SSI rates.
- Reporting of risk-adjusted, procedure-specific SSI rates is a measure of quality of surgical care.
- Surveillance methods based on the United States National Healthcare Safety Network (NHSN) (formerly the National Nosocomial Infections Surveillance System (NNIS)) have been widely used internationally. Australian state surveillance programs use the NHSN/NNIS definitions.
- Australian states and territories differ in the extent of SSI surveillance, the resources available, and the approaches to mandatory reporting of data and to risk adjustment of infection rates.
- An Australian national surveillance database of SSI rates would primarily be of value if it was timely and allowed valid comparisons of infection rates between hospitals. An agreed national approach to risk adjustment is required before a useful national database can be established. Ongoing local support is needed to promote data quality and ensure that programs are responsive to local needs.
- Benefits of such a database would be:
 - a greater understanding of the nature and extent of SSIs after many types of surgery
 - efficiencies and economies in educational activities and support
 - development of improved surveillance methods.
- Validation studies are essential to develop confidence in data, but have only recently been undertaken for SSI surveillance data.
- There is no widely accepted method of post-discharge surveillance.
- Surveillance of surgical antibiotic prophylaxis and feedback of hospital performance with respect to national guidelines has led to some improvements in clinical practice.

Recommendations on surgical site infection

1. Local surveillance of SSI and infecting pathogens should be undertaken.
 - Surveillance should include all coronary artery bypass graft surgery, major joint prosthesis insertion, and other important surgeries (in terms of surgical frequency, or SSI morbidity; for example, lower segment caesarean section) and procedures locally noted to have higher than expected SSI rates.
 - Standard NHSN/NNIS surveillance methodology (ie definitions of infection and detection methodologies) should be used.
 - Staff need to be trained in data collection, audit and surveillance.
 - Post-discharge surveillance data requires the development of a validated, cost-effective method.
2. Risk-adjustment methodologies for SSI surveillance to facilitate national benchmarking are required.
3. Surgical antibiotic prophylaxis should be used as a key national hospital quality-of-care measure.

3.1 Background

The development of infection in a surgical wound is probably the most widely recognised presentation of a health care associated infection (HAI), and indeed of any adverse event occurring in hospital. Of all hospital-acquired infections, surgical site infections (SSIs) have the greatest impact on length of hospital stay.^[1, 2] Not surprisingly, surveillance of wound infections has been the longest established element of hospital infection surveillance programs, commencing before the significance of hospital-acquired bloodstream infections (BSIs) and pneumonia was fully appreciated.

3.2 Harm to patients

The risks and hazards of SSIs differ between surgical procedures. For example, in major joint prosthesis replacements, infection rates are low, but the consequences of infection are enormous. The patient often requires further surgery, removal of the prosthetic joint, replacement with another joint, and months of intravenous antibiotic therapy, followed by oral antibiotic therapy. In other procedures, such as caesarean sections, the infection rates are substantially higher, but the consequences are less severe, with patients often not even requiring readmission.

Reported SSI rates vary internationally depending on the procedure that is performed and the surveillance methods that are applied. For example, in Spain the estimated rate of occurrence of SSIs following hip replacement is 2.2%,^[3] in England it is 14.3% following limb amputation,^[4] and in Japan it is 18% following rectal surgery.^[5]

A 1984 Australian national prevalence study found that 6.3% of 29,000 patients acquired an infection during their hospital stay; most commonly, this was an SSI or an infection of the urinary or respiratory tract.^[6] In 1998, New South Wales Health funded the two-year Hospital Infection Standardised Surveillance (HISS) pilot study. In this study, 15 hospitals used Australian Infection Control Association (AICA) definitions for wound infection to target core inpatient groups.^[7] The study revealed aggregated SSI rates of 1.7% for coronary artery bypass graft (CABG) of the chest and leg, 2.1% for CABG of the chest only, 7.1% for vascular surgery, 1.3% for hip prosthesis, 6.1% for knee prosthesis and 12.5% for colorectal surgery.

A Victorian study — in which the Victorian Hospital-Acquired Infection Surveillance (VICNISS) program adapted the United States National Healthcare Safety Network (NHSN) (formerly the National Nosocomial Infections Surveillance System (NNIS)) program definitions — demonstrated higher SSI rates than the United States NHSN/NNIS hospitals for CABG, hip and knee surgery.^[8] This was attributed to the inclusion of all 29 Victorian public hospitals in the VICNISS study rather than a select group of hospitals with a long history of active surveillance that voluntarily participated, as was the case in the United States study. Appendix 3 lists the NHSN/NNIS definitions for surgical site infections.

A number of different microbial species cause SSIs. Most commonly, skin flora (eg *Staphylococcus aureus* and coagulase-negative staphylococci) are responsible for SSIs that follow clean procedures.^[9, 10] In contrast, contaminated procedures may be associated with polymicrobial infection and flora normally found in the viscus that is opened (eg gram negative infections following rectal surgery).^[11] The choice and timing of prophylactic antibiotics also affect the spectrum of organisms causing SSIs.^[12]

3.3 Impact on health-care systems

SSIs are associated with significant morbidity, mortality and costs. A large study from the United States that quantified the impact of SSIs on mortality and health-care costs found that patients who developed SSIs in the 1990s had:^[13]

- median additional hospital stays of 6.5 days
- excess direct costs of US\$3089
- an SSI-attributable mortality rate of 4.3% (relative risk 2.2).

Re-hospitalisation within 30 days of discharge was required by 41% of patients with SSIs, compared to 7.4% of controls. The re-hospitalised patients had median additional hospital stays of 12 days and excess direct costs of US\$5038.

Of all the infections identified in a 1984 Australian study,^[6] SSIs had the greatest impact on cost and length of hospital stays, a finding consistent with the United States Study on the Efficacy of Nosocomial Infection Control (SENIC).^[11] Based on the Australian study's assumption of an extra four-day stay in hospital and a 6.3% rate of infection, hospital-acquired infections in Australia in 1988 resulted in 20,000 occupied bed days (OBDs), at an estimated cost of \$500,000 per day (\$180 million per year). Similar findings have been reported in the United States, United Kingdom and Canada.^[14]

However, major changes in health care in the 24 years since the 1984 Australian study was undertaken limit confidence in using this data to calculate current estimates of the costs to the Australian health-care system. Changes include increased hospital throughput, decreased average length of hospital stay for many procedures, increased laparoscopic surgery with lower infection rates, and possibly increased comorbidities in inpatients.

The impact of SSIs on the health-care system varies considerably between different procedures. SSIs after two common surgical procedures — CABG surgery and major joint prosthesis replacement — have substantial consequences for patients and for health-care costs. In a two-year retrospective case-control study at the Alfred Hospital in Melbourne including 108 SSIs after CABG, patients with SSIs spent a mean of 2.89 days in an intensive care unit (ICU) compared to 1.53 days for controls ($P = 0.035$). In general wards, patients with SSIs spent a mean of 10.8 days in an ICU compared to 4.7 days for controls ($P = 0.0001$). The total excess cost related to increased length of stay and antibiotic treatment was \$12,419 per SSI patient. For patients with deep sternal site infections, the mean excess cost was \$31,597 per patient.^[15] In a multicentre study in Victorian public hospitals, the average cost of an SSI following hip arthroplasty infection was \$34,138, and following knee arthroplasty infection it was \$40,940.^[16]

3.4 Surveillance methods

Many centres around the world have adopted standardised surveillance methods based on the NHSN/NNIS system.^[17, 18, 19, 20] SSI surveillance methods, particularly the approach to risk adjustment, vary across Australian states and territories.^[8]

3.4.1 Definitions of surgical site infections

All Australian state surveillance programs use essentially the same definitions for SSIs. The definition developed by the AICA National Advisory Board (AICA-NAB) is the same as the widely used NHSN/NNIS definition. However, the NHSN/NNIS separates SSIs into three categories: superficial, deep and organ/space infection (see Appendix 3). In contrast, in the AICA

definition, the last two categories are reported as a single category: deep incisional/organ space infection.

The usefulness of the SSI categories — superficial, deep or organ/space — and validity of reporting may differ between surgical procedures.

In a multicentre validation study of data submitted to the VICNISS Coordinating Centre following CABGs, Friedman and colleagues noted that infection control staff found it more difficult to identify superficial SSIs than deep ones.^[57] This is in agreement with Cardo and colleagues' findings that infection control staff had more difficulty finding incisional infections than deep ones.^[21]

3.4.2 Detection of surgical site infections

Inpatient surveillance of surgical site infections

The detection of SSIs in hospital is usually performed by infection control professionals (ICPs) trained in the use of surveillance definitions and methods. Detection of SSIs requires active, patient-based, prospective surveillance. The ICP must ensure that all operative procedures are included by using accurate case-finding methods and recording the corresponding denominator data. The ICP should seek out infections during a patient's stay by screening a variety of data sources:

- patient charts, including medical history and temperature charts
- a range of databases, including laboratory, pharmacy, admission, discharge, transfer, radiology, imaging and pathology databases
- interviews with the patient's care team, including nurses, physicians and wound managers.

To minimise the ICP's data collection burden, others (eg operating room staff) may be trained to collect the denominator data and to screen data sources, but the ICP must make the final decision.^[22]

Use of administrative databases for surgical site infection surveillance

In efforts to reduce the burden of case finding, several studies have investigated the use of medical records or coding of discharge diagnosis as a more efficient means of detecting SSIs. These methods in general have proved unsatisfactory. Administrative databases contain limited clinical information, and data quality depends on accuracy of coding and is subject to variation between hospitals, compromising comparisons.^[23]

In a data comparison identifying hospital-acquired infections collected by medical records staff and by hospital surveillance systems, only 43% of infections were identified by medical records staff.^[24] Medical records staff failed to identify infections clearly recorded in medical records 16% of the time. Cadwallader and colleagues noted that clinical coders encounter conflicting information, resulting in variable quality.^[25] The accuracy of clinical coding depended on clarity of documentation in the medical record. A recent report used the Western Australian Data Linkage System to review the incidence of SSIs in patients undergoing total hip replacement or total knee replacement surgery in hospitals in Western Australia.^[26] Case finding by these administrative databases requires an understanding of the surveillance case definitions on the part of the health-care professional who is reporting through the summary or coding; also, it removes the advantage of an external observer (usually the ICP), transferring the responsibility of reporting infections to those directly involved in the patient's care.

Post-discharge surveillance of surgical site infections

Although post-discharge surveillance is likely to increase case detection of SSIs,^[27, 28] it is limited by the intensity of required resources. No method of post-discharge surveillance has found widespread acceptance. It has been suggested that procedure-specific post-discharge surveillance may be warranted for procedures that typically require a short hospital stay.^[20]

Post-discharge SSI was found to be more common than in-hospital infection in a New South Wales study,^[29] and increasing in incidence in a 12-year surveillance study in Tasmania.^[30] The Centre for Healthcare Related Infection Surveillance and Prevention (CHRISP) in Brisbane measured a post-discharge infection rate of 8.46% in a variety of surgeries but showed that the additional costs were minor.^[31] The same group showed (surprisingly) that patient-reported post-discharge infection was overdiagnosed in patients who received education on signs and symptoms of wound infection.^[32]

3.4.3 Risk adjustment of infection rates

Hospitals assess infection control programs by using surveillance data to compare their SSI rates with a benchmark, with other hospitals or with themselves over time.^[33] Rate comparison requires the use of uniform definitions and surveillance protocols, consistent and accurate case finding, risk adjustment to control for risk factors and a sample size that is sufficiently large.^[34, 35]

Risk indices

Risk stratification involves subdividing patients into groups with similar risks.^[36, 35] Numerous factors contribute to the risk of SSI and before infection rates can be meaningfully compared between hospitals, the influence of these factors must be considered. A risk index is used for adjusting SSI rates for the most important risk factors.

An effective risk index should:^[37]

- comprise a small number of criteria that are easy to obtain and measure
- categorise patients into a small number of categories
- minimise variation in risk among patients within a category, while maximising variation between categories.

The NHSN/NNIS risk index, which was developed in the mid-1980s, has been widely used to stratify SSI rates.^[38] Although it is generally thought to perform well across a broad range of operative procedures,^[39] the NHSN/NNIS risk index is not perfect. For example, it discriminates poorly between procedures such as CABG^[40, 41] and caesarean sections.^[42] Haley and colleagues^[1] note that the NHSN/NNIS risk index was not constructed from a multivariate analysis, and was developed after being applied to a single database. One element of the NHSN/NNIS risk index is the 'T' time (ie the 75th percentile of the duration of the operative procedure under surveillance). Haley and colleagues are critical of the 'T' time, which is difficult to apply appropriately if patients undergo several procedures during one operation. The authors are also dubious about the utility of the American Society of Anesthesiologists (ASA) score to measure patient comorbidity. Others criticise the ASA score's lack of objectivity and scientific precision, as well as the inability of anaesthetists to apply the score consistently.^[43, 44, 37, 45]

Attempts at identifying new risk indices need to take the recommendations of Haley and colleagues into account.^[1] A Dutch group^[46] used a c-index (a measurement of predictive performance) to compare the NHSN/NNIS risk index to a model derived from logistic regression, using readily available risk-factor data from existing information systems. Although the new model required collection and analysis of extra data, it demonstrated better predictive values than

the NHSN/NNIS risk index for five common procedures. The group concluded that the extra resources required were justified if the models were more acceptable to clinicians, a factor that becomes vitally important with the advent of public reporting of infection rates.

Variable discriminatory ability of the NHSN/NNIS risk index has been reported in Australia and outside the United States.^[46, 47, 48, 49]

A recent review of a large Queensland database revealed that, in more than 43,000 patient records of 13 common surgical procedures, the NHSN/NNIS risk index was not sufficiently discriminatory to be useful.^[47] Significant risk factors identified in the study were an ASA score greater than 2, duration of surgery, absence of antibiotic prophylaxis and type of procedure performed. The authors concluded that the NHSN/NNIS risk index may not be optimal, and recommended improving local risk indices by further research into patient and procedure-level risk factors.

A Victorian study using SSI data from VICNISS correlated well with the NHSN/NNIS risk index for some procedures, but poorly for CABG procedures.^[48] Following multivariate analysis, a CABG-specific index was developed that performed better than the NHSN/NNIS risk index. The study's alternative scoring system showed an approximate doubling of infection with each point in a scale, where one point was allocated for diabetes, one for a body mass index (BMI) of 30–35, and two for a BMI of greater than 35. This model, though yet to be validated, clearly indicates that procedure-specific indices based on local data may provide a more meaningful method of stratifying data than the NHSN/NNIS risk index.

Standardised infection ratio

The standardised infection ratio (SIR) is a simple measurement that is frequently overlooked as an alternative to risk stratification of SSI rates. The SIR has been proposed as the preferred method of risk adjusting rates for comparisons and can be used to compare rates within a hospital over time, against a benchmark or against another hospital.^[50] However, because these comparisons all rely on benchmark data, the SIR's utility depends on the accuracy of the benchmark. As Gustafson points out, the SIR gives greater precision and better estimates of true rates when dealing with small numerators and denominators.^[50] Gustafson shares concerns with Geubbels^[46] about public reporting of infection rates, and notes that the SIR is perhaps the easiest measurement for consumers and other stakeholders to interpret.^[50] An SIR greater than 1 indicates more infections than expected, and an SIR less than 1 indicates fewer infections than expected.

3.4.4 Reporting using control charts and cumulative sum reports

Some Australian hospitals monitor their SSI rates within their hospitals using control charts (see Chapter 1) and cumulative sum reports.

3.4.5 Validation of surveillance data

Validation of SSI surveillance data is the only independent determinant of data accuracy and is essential for determining the reliability of aggregated data from multiple sources.^[33]

There are surprisingly few studies validating surveillance of hospital-acquired SSIs. Previous studies that compared SSI data collected by infection control staff to a 'gold standard' estimated sensitivity to be 80.7–89.7% and specificity to be 97.5–99.8%.^[51, 52, 21]

A recent German NHSN/NNIS study reviewed data on bloodstream and lower respiratory tract infections, and estimated the sensitivity to be 66.0% and specificity to be 99.4%.^[53] The positive predictive value (PPV: the proportion of patients reported as having an infection that actually

have the infection) for SSIs was 85.0%, and the negative predictive value (NPV: the proportion of patients reported as not having an infection that actually do not have the infection) was 98.4%. The Netherlands Prevention of Nosocomial Infections through Surveillance (PREZIES) group reviewed more than 800 records relating to SSI surveillance.^[54] Sensitivity and specificity estimates were not calculated, but the PPV was 97.0% and the NPV was 99.0%. A Scottish study calculated the PPV for SSIs at 94.6% and the NPV at 99.4%. Estimates of sensitivity and specificity were provided, but the method used to calculate these was possibly flawed.^[55]

According to Gastmeier, several European validation studies were limited to one or a few facilities and focused on only one aspect of surveillance. For these reasons, and because methodology was diverse, results were not comparable.^[56] It is not clear what levels of sensitivity and specificity are acceptable for a surveillance network. Gastmeier proposed that experience gained from these studies should be used to ‘develop a protocol that is meaningful and cost-effective for performing validation studies’.^[56]

An Australian study from the VICNISS Coordinating Centre reviewed data from SSI surveillance following CABG surgery.^[57] For patients identified as having an SSI at any site, the estimated sensitivity was 55.0%, the specificity was 100%, the PPV was 96.0% and the NPV was 97.0%. For patients with a sternal wound infection only, the estimated sensitivity was 62.0%, the specificity was 100%, the PPV was 91.0% and the NPV was 98.0%.

3.5 Current surgical site infection surveillance

3.5.1 International surveillance

The NHSN/NNIS definitions and methods have been widely used (at times with local modifications) in programs in Germany, Belgium, France, Japan, the United Kingdom, Thailand and several South American countries.^[17, 18, 19, 20] Use of similar infection surveillance protocols would allow comparison of data between countries, but reliable comparisons between countries may not be possible for all procedures and infection sites. A large comparative study of data from the Netherlands and Germany that used NHSN/NNIS-based methodology demonstrated a number of factors with potential to affect comparability of surveillance data. Factors included differences in:^[54]

- intensity of post-discharge surveillance
- duration of hospitalisation
- proportion of participating hospitals in individual countries (with potential for sample bias)
- wound class and ASA classification
- nature of data validation studies in individual countries.

Although similar infection surveillance protocols were used, comparison was most reliable for deep SSIs during hospitalisation, rather than for superficial SSIs. Comparison of SSI surveillance data from Italy with data from the United States and Hungary was limited by differences in the intensity of post-discharge surveillance between countries.^[58]

3.5.2 Australian surveillance

Almost all surveillance programs for SSIs in Australian hospitals (see Table 3.1) are based on the SSI definitions and methods of the NHSN/NNIS, but reports and approach to risk adjustment vary between programs.

Queensland and Victoria use the NHSN/NNIS risk index, but New South Wales, which is the only state with mandatory surveillance, compares infection rates with those in similar hospitals by hospital ‘peer group’.

Table 3.1 Surveillance of surgical site infections in Australian states and territories

State	Definitions used	Risk adjustment of SSI rates	Mandatory participation	Public release of hospital-level data	Surgical procedures under surveillance	Private hospitals included
New South Wales	AICA/NNIS	Hospital peer group	Yes	No (aggregate)	Limited procedures	No
Queensland	AICA/NNIS	NNIS	No	No	Surgical procedures by NNIS categories	No
South Australia	AICA/NNIS	NNIS	No	No	–	Yes
Tasmania	AICA/NNIS	None	No	No	Limited procedures	No
Victoria	AICA/NNIS	NNIS	No, but used as a Department of Human Services hospital performance indicator	No (aggregate)	Surgical procedures by NNIS categories	No, but planned
Western Australia	AICA/NNIS	None	No	No	Joint arthroplasty	Yes
Australian Capital Territory	AICA/NNIS	None	No	No	Joint arthroplasty, cardiac surgery, caesarean section	Yes

AICA = Australian Infection Control Association; NNIS = National Nosocomial Infections Surveillance System; SSI = surgical site infection

Small hospital surveillance programs exist in New South Wales, Queensland, South Australia and Victoria. South Australia and Western Australia also include private hospitals in their programs. While Victoria and Queensland have invested substantially in setting up independent coordinating bodies, surveillance programs in other states are run by state health departments.

The Australian Commission on Safety and Quality in Health Care (ACSQHC) sponsors the *Safer Systems — Saving Lives* program in New South Wales, South Australia, Tasmania and Victoria, and the *Delivering a Healthy WA* program in Western Australia. These programs follow the approach of ‘bundling’ several infection control measures, each of which has been shown to be effective on its own. This approach has been highly successful in North America, with the *1000,000 Lives*, the *Protecting 5 Million Lives from Harm* and the *Safer Health care Now!* programs (Canada). The Australian programs use less rigorous measures of infection than

previous SSI surveillance programs; also, they include standardised implementation and audit of evidence-based measures that reduce infection (eg appropriate antibiotic prophylaxis and hair removal). In some jurisdictions, funding has been provided to clinical teams instead of infection control teams. It remains to be seen whether this approach will be as successful in Australia as it has been in North America.

Victoria and New South Wales are the only states that currently report SSI data publicly. VICNISS reports aggregated data using the NHSN/NNIS risk index,^[59] whereas New South Wales stratifies data using the peer grouping of hospitals assigned by the Australian Council on Healthcare Standards (ACHS).^[60]

3.5.3 Registries of major surgical procedures

Registries have been established by the relevant surgical specialty association for two of the most important surgical procedures performed in Australia: cardiac surgery and major joint prosthesis placement.

The Australasian Society of Cardiac and Thoracic Surgeons Victorian Cardiac Surgery Database Project

The Australasian Society of Cardiac and Thoracic Surgeons (ASCTS) and the Victorian Department of Human Services (VDHS) have together developed a program to collect data on cardiac surgery in Victorian hospitals.

The ASCTS database project was initiated in 2001. All 16,000 cardiac surgical procedures conducted in Victorian public hospitals up to December 2007 have been systematically collected for the registry. About 70% of these are isolated CABGs.

Key performance indicators for the registry are:

- 30-day mortality following isolated CABG
- rate of deep sternal wound infection
- rate of return to theatre for haemorrhage
- ventilation time
- length of ICU and hospital stay.

Public reports of the above performance indicators are published annually and are freely available to the public.¹² The registry is based in the Monash University Department of Epidemiology and Preventive Medicine, and is associated with the National Health and Medical Research Council (NHMRC) Centre for Patient Safety. There is a steering committee, consisting of surgeons representing each contributing hospital, a statistician or epidemiologist, a VDHS representative and a project manager.

Data are collected at each participating site on a customised database format supplied by the ASCTS data centre. Starting from May 2008, data are now entered via the ASCTS web portal, providing real time data query and reporting capabilities. Auditing and cross-checking have ensured that the ASCTS database has high quality data collection (>98%) and complete capture at all sites.

The ASCTS registry is currently expanding to include all public hospitals in New South Wales and six additional surgical units from South Australia, Queensland and the Australian Capital

¹² <http://www.health.vic.gov.au/specialtysurgery/cardiac.htm>

Territory. About 70% of all hospitals conducting cardiac surgery will contribute to the registry in 2008, and the aim is to engage all units in Australia in the registry by 2010.

The National Joint Replacement Registry

The Australian Orthopaedic Association established a National Joint Replacement Registry, which began data collection in 1999. The registry collects a defined minimum dataset that enables outcomes to be determined on the basis of patient characteristics, prosthesis type and features, method of prosthesis fixation and surgical technique used. The principal measure of outcome is revision surgery, but mortality is also monitored. The Australian Government Department of Health and Aging continues to fund the registry.

Benefits of, and issues with, registries

The two registries discussed above collect detailed retrospective information on patients undergoing these major surgical procedures. However, the SSIs reported to registries are not consistently documented using AICA-NAB or NHSN/NNIS definitions, and are often reported by the treating surgical team rather than the hospital infection-prevention team.

A recently reported collaborative study between the VICNISS Coordinating Centre and ASCTS illustrated the potential advantages and difficulties of collaboration between state hospital infection control groups and registry groups.^[57] These possible advantages and difficulties included:

- the need to ensure that all relevant surgical procedures were captured by both the registry and state databases
- the benefits of multicentre research, including potentially major improvements in surveillance risk adjustment using data already collected in the registries
- the identification of reporting problems within the registry or state database
- the limitations to ongoing collaboration between the databases of VICNISS and ASCTS caused by requirements for ethics committee approvals from multiple hospitals for data exchange.

3.5.4 Benefits of surgical site infection surveillance

SSI surveillance has demonstrated benefits. For example, the SENIC study, carried out in the 1980s, showed that infection control programs that were effective in reducing SSIs included the following components:^[1]

- organised surveillance, including feedback of data to hospital staff involved in patient care (in this case, reporting SSIs to surgeons)
- control activities to ensure that the appropriate preventive practices were carried out
- an adequate number of trained infection control staff to collect and analyse data and to supervise the infection control program
- involvement of a physician or microbiologist with special skills in infection control.

Programs with these key components reduced rates of surgical wound infections by 35%. These findings provided the evidence justifying the development of expanded hospital infection programs with active SSI surveillance in the United States, and subsequently in health-care systems in other developed countries.

In Germany, voluntary participation in active SSI surveillance on 119,114 operations performed between January 1997 and June 2004 was associated with a sustained and significant reduction in the incidence of infection.^[61, 62] In multiple logistic regression analyses of pooled data for all operative procedures, a department's participation in the surveillance system was a significant independent protective factor for SSIs. Compared with the surveillance in the first year, the SSI risk decreased in the second year (odds ratio (OR) 0.84) and third year (OR 0.75). There was no change in the fourth year. The SSI incidence was reduced by one-quarter as a result of the surveillance-induced infection control efforts.

A similar reduction in incidence was seen following the commencement of surveillance by centres in France. Using a large SSI surveillance network in southeast France from 1995 to 2003,^[63] the change in SSI rate over time was modelled. Overall SSI rates were reduced by 45% over a period of nine years. This was interpreted as a 5% decrease in the SSI rate per year. This decrease was constant over the study period and was observed for almost all types of surgical operations (orthopaedic, gastrointestinal, urology etc). In a northern France network of volunteer surgical wards,^[63, 64] the crude SSI incidence decreased from 3.8 to 1.7 over six years, and the NHSN/NNIS-adjusted SSI incidence decreased from 2.0% to 1%. In a more recent French report^[61] of a regional program, there was a significant reduction — from 2.5% to 1.3% — in the SSI rate after caesarean section between 1997 and 2003.

A Tasmanian study demonstrated not only that a surveillance program resulted in a reduction in SSIs over 12 years, but that interrupting the program for 15 months halted the reduction.^[30] The study also showed that while in-hospital SSI rates declined, post-discharge rates increased. This perhaps reflects changes in hospital practice and increasing pressure on hospital bed space, with shorter stays resulting in a shift of infections to the post-discharge period. However, changes in the average length of stay over the period of the study were not documented. These results are a reminder that surgical practice has changed substantially in the more than 30 years since SENIC started.

Post-discharge surveillance strategies are likely to increase SSI detection.^[27, 28] However, such strategies are limited by the level of resources required and no single strategy has found widespread acceptance. Some studies have suggested that procedure-specific post-discharge surveillance may be warranted for procedures that typically require a short hospital stay.^[20]

3.5.5 Surgical antibiotic prophylaxis

Administration of antibiotics is recommended before certain types of surgery to reduce the incidence of SSIs. Antibiotic prophylaxis according to expert guidelines is a category 1A recommendation from the Centers for Disease Control and Prevention.^[65]

Process indicators such as correct use of surgical antibiotic prophylaxis are extremely useful for measuring hospital performance, particularly as there is no need for risk adjustment and all hospitals should be able to achieve high levels of compliance. When measuring infrequent outcomes such as SSIs, surveillance of large numbers of surgical procedures is required to generate meaningful infection rates. Through measuring the process of antibiotic prophylaxis, useful data can be gained from surveillance of much smaller numbers of procedures and then used to drive improvement in practice.

In Victoria, the VICNISS Coordinating Centre collects data on choice of antibiotic, timing of the first dose and duration of administration for those procedures for which prophylaxis is recommended. Data are judged as either 'concordant' or 'not concordant', based on the Australian national guidelines.^[66] Choice of antibiotics is assessed as 'concordant' if it complies exactly with the guidelines or as 'adequate' if it is judged to cover the likely range of pathogens.

This approach is taken because clinical information on patients, such as allergies, is not collected, and antibiotic choice may be influenced by local experience of hospital pathogen.

Reports on compliance with the three measures described are distributed to hospitals on a six-monthly basis. Hospitals appear to have found this useful and the reports have generated considerable interest and some improvements.^[8]

No other states or territories in Australia routinely collect and report on data on surgical antibiotic prophylaxis.

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4 Neonatal infection — early onset

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Key points

- Sepsis occurring in the first week of life (early onset sepsis (EOS)) can be a devastating problem; it has an incidence of about 1–2 per 1000 live births and case mortality rates of 8–10%.
- Group B streptococci and Enterobacteriaceae (eg coliform bacteria such as *Escherichia coli*) are the main causes of EOS in more developed countries.
- Intrapartum antimicrobial prophylaxis has lowered the incidence of early onset group B streptococci sepsis by 50–80%.
- Surveillance of EOS is important to demonstrate the effectiveness of preventive efforts and to detect significant changes in incidence or emergence of antibiotic resistance.

Recommendation on neonatal infection — early onset

1. All birthing services should measure and report the incidence of and mortality from early onset bacterial sepsis (including meningitis).

4.1 Background

Sepsis occurring in the first week of life (early onset sepsis (EOS)) can be a devastating neonatal problem. Such infection usually derives from the maternal genital tract, being acquired during or before birth, in the presence of prolonged rupture of membranes. Less commonly, infection occurs by direct transfer of bacterial or viral pathogens across the placenta before birth. EOS is commonly due to bacteria such as *Streptococcus agalactiae*, other beta-haemolytic streptococci (eg *S. pneumoniae*, *S. pyogenes*) and gram-negative bacteria such as *Escherichia coli*. Perinatal viral infection with herpes simplex, varicella, enterovirus and other viruses is much less common and may present later. Such infections tend to be subject to specific notification and investigation.

The assessment and management of the newborn at risk of vertical infection is largely empiric. It revolves around a general theme of using antenatal risk factors to identify those infants most at risk and then applying an ‘infection screen’ (ie using antenatal risk factors to identify those infants most at risk and then collecting blood cultures and other tests) before prophylactic antibiotic therapy. Similarly, there is a range of postnatal symptoms and signs that may suggest that an infant is at risk and hence lead to further investigation and prophylactic treatment. Although this overall scenario is consistent, the specific details of its delivery vary considerably from centre to centre, and sometimes from clinician to clinician. Clinical practice often varies widely when there is no clear best practice and little evidence on which to base firm policy. This is the case for neonatal infection.

The clinical approach to dealing with EOS varies from an aggressive approach, where a high proportion of newborns receive antibiotic therapy, to a more relaxed approach, where antibiotics are seldom prescribed. There is no clear evidence to support either end of the spectrum, as shown by a 2004 Cochrane review.^[1] The review did not find discernable variations in mortality or morbidity from the different approaches, although no systematic comparative studies have been carried out across different regional locations. Studies have not found adverse consequences from a high use of antibiotics during delivery.

The widespread adoption of peripartum antibiotic prophylaxis for prevention of EOS has raised questions about whether this approach leads to emergence of antibiotic resistance and changes to the ecology of this type of infection, with some studies finding increases in incidence of gram-negative infection. The emergence of new antibiotic resistant pathogens (eg community strains of methicillin-resistant *Staphylococcus aureus* (MRSA)) may also be driven by maternal antibiotic exposure. The degree to which such treatment influences the sensitivity of measures to detect EOS has not been studied in detail. Proven EOS is a relatively rare event; therefore, surveillance involving a national collaboration is the only way to obtain data to evaluate and drive best practice. A clear starting point in collecting such data is to agree on suitable definitions and the data to be collected (see Section 4.4).

4.2 Harm to patients

An extensive systematic review summarised the international literature on EOS epidemiology up to 2002.^[2] The review considered:

- the influence of changing approaches to intrapartum antibiotic prophylaxis
- the emergence of antibiotic resistance in Enterobacteriaceae that cause EOS
- whether EOS due to bacteria other than group B streptococci has become more prevalent.

Box 4.1 summarises the trends in EOS from the review. Intrapartum antimicrobial prophylaxis has lowered the incidence of early onset group B streptococci sepsis by 50–80%.

Box 4.1 Summary of trends in early onset sepsis in the intrapartum antimicrobial prophylaxis era

Substantial and robust decreases in the incidence of early onset group B streptococci infections have been shown in three countries with various strategies for intrapartum antimicrobial prophylaxis; declines are similar among term and preterm infants, including very low birthweight infants.

There is no evidence of an increase in incidence of all-cause early onset sepsis (EOS). In some instances, all-cause rates have actually declined. Studies with stable rates of all-cause sepsis started after group B streptococci prophylaxis strategies had already been implemented.

There is little evidence of sustained increases in the incidence of non-group B streptococci EOS. Any adverse effect is limited to preterm, low birthweight and very low birthweight populations.

There is evidence of an increase in the proportion of ampicillin resistance among *Escherichia coli* EOS cases occurring in low birthweight and premature neonates, but no evidence of an increase in babies born at term or in the general population of newborns.

Source: Moore et al 2003^[2]

Data published since 2002, including some from Australia, are summarised in Table 4.1. These data indicate no trends that contradict the summary provided in Box 4.1.

Mortality rates for proven EOS are substantial, varying from 8–10% in recent studies (see Table 4.1). Mortality is substantially higher in preterm neonates affected by EOS (~35%, depending on organism and birthweight cohort).

Table 4.1 Early onset sepsis — studies published since 2002

Location and references	Methodology	Incidence (per 1000 live births unless otherwise quoted)	Comments
United States 15 centres (National Institute of Child Health and Human Development Neonatal Research Network ^[3, 4])	Rates of blood-culture confirmed EOS <72 hours, live born surviving >12 hours, birthweight 401–1500 g only Contrasts three periods: 1991–93, 1998–2000 and 2002–03	Overall 19.3/15.4/17 for three periods Mortality rate: 37%/35% last two periods Gram negative infections 53% of total; <i>E. coli</i> incidence 3.2/6.8/7.0 Ampicillin resistant 85%/77% last two periods (no significant change) GBS 5.9/1.7/1.8	Overall incidence has not changed significantly No significant changes in mortality rate overall or by pathogen type Significant incidence change <i>E. coli</i> (initial increase between periods one and two) Significant fall in GBS incidence
Australia & New Zealand Initially 7 neonatal units (1992) increasing to 16 units. ^[5,6]	Rates of blood-culture confirmed EOS <48 hours, live born, all birthweights Contrasts changes over 10-year period: 1992–2001 Second study examined early onset meningitis across a similar study group and period	Overall EOS rate not quoted Mortality: overall rate not quoted, <i>E. coli</i> 36% <i>E. coli</i> (79% of total gram negative events); incidence 0.32 (all birthweights), 6.2 (<1500 g) Ampicillin-resistant not quoted GBS incidence 1.43 (1993)/0.25 (2001)/6.2 (<1500 g)	No significant changes in <i>E. coli</i> mortality rate No significant change in <i>E. coli</i> rates Significant fall in GBS incidence
Netherlands country-wide ^[7]	Contrasts changes (1997–2001) stratified for proven and probable GBS sepsis Very early (<12 hours), late early (12 hours–<7 days) and late (7–90 days) onset sepsis Proven (blood/cerebral spinal fluid) and probable (negative or absent systemic culture result) Capture–recapture technique	GBS incidence of proven very early onset, late early onset and late onset GBS sepsis was 0.32, 0.11 and 0.14 Maternal risk factors were present in 54% of the proven early onset cases. Mortality rate 8% (EOS proven) and 5% (late proven) GBS incidence: 1.10 (early proven EOS), 0.18 and 0.02, respectively	Non-significant decrease in incidence from 0.38 (1997–98) to 0.28 (1999–2001) Non-significant decrease in mortality rate from 7% (1997–98) to 4% (1999–2001) Meningitis under-reported

Location and references	Methodology	Incidence (per 1000 live births unless otherwise quoted)	Comments
United Kingdom, Ireland ^[8]	Invasive GBS infection occurring in babies <90 days of age across these countries EOS defined as onset within 0–6 days of birth Capture–recapture technique	GBS incidence 0.72 (early and late onset) EOS (0–6 days) GBS incidence 0.48 Maternal risk factors present in 58% of EOS cases Mortality rate 10.6% EOS GBS cases; case fatality higher in premature neonates	Regional incidence of EOS GBS disease of 0.21–0.73 per 1000 live births; different regional use of antibiotics may explain this variability

E. coli = *Escherichia coli*; EOS = early onset sepsis; GBS = group B streptococci

4.3 Impact on health-care system

The financial impact of EOS was examined in four reports that looked at the cost-effectiveness of different screening and prevention strategies for EOS due to group B streptococci.^[9, 10, 11, 12] These studies highlight the fact that, for intrapartum antibiotic prophylaxis, it is cost-effective to use risk factor approaches — for example, identifying mothers at greater risk of having a baby affected by EOS — or screening approaches based on detection of group B streptococci (GBS) during the last trimester. A recent study used a decision analysis model to compare costs and effects of different treatment strategies with no treatment, with a main outcome measure of cost per quality adjusted life year (QALY).^[12] The risk-based strategy had a cost-effectiveness ratio of €7600 per QALY gained. A combined screening and risk-based strategy had comparable results, whereas the screening strategy was more expensive (€59,300 per QALY gained).

4.4 Surveillance methods

4.4.1 Detection

The isolation of microorganisms from blood or cerebrospinal fluid (CSF) (ie proven EOS) remains the most specific method for diagnosing bacterial sepsis in the newborn but has low sensitivity.^[13] Such surveillance can be done by review of laboratory-confirmed blood or CSF infection, and correlation with postnatal age and clinical findings (see Section 4.4.3). It is likely that the increasing practice of intrapartum antimicrobial prophylaxis reduces the sensitivity of detection by blood culture, but this has not received systematic study. In addition, positive cultures are a rare event (1–5/1000 deliveries).

Many more infants (~25%) have clinical or biochemical signs of sepsis without blood culture positivity. Adoption of a ‘probable EOS’ definition that rests on the evaluation of clinical or biochemical and haematological criteria, without a requirement for a positive blood or CSF result, improves sensitivity but significantly lowers specificity.

4.4.2 Definitions

Proven EOS is indicated by a positive sterile isolate (usually blood or CSF) of a likely bacterial pathogen obtained from a neonate, with supporting evidence from haematological or biochemical parameters, or both. Most authors do not include positive cultures with skin flora organisms (eg coagulase negative staphylococci) as EOS events because these rarely represent true pathogens;

instead they are usually contaminants of blood culture. Infection that manifests within 48 hours of birth is usually defined as EOS, although the definition in some studies includes infection that manifests up to 72 hours of birth (see Table 4.2). Health care associated infections rarely present within 72 hours after birth.

Table 4.2 Definitions in use in early onset sepsis in neonates

Group/Country	Definition of early onset
Australasian Study Group for Neonatal Infections ^[5]	<48 hours, live births
Australian Council on Healthcare Standards (Australia) see Table 4.3,	<48 hours, live births
National Institute of Child Health and Human Development (United States) ^[3]	<72 hours, live births where neonate lives >12 hours
National Nosocomial Infections Surveillance System, (United States) ^[14]	'Maternally acquired' events defined as within 48 hours of birth
Netherlands ^[7]	'Very early' onset <12 hours 'Late early' onset 12 hours–7 days
Germany (German Surveillance system) ^[15]	<72 hours
United Kingdom/Ireland ^[8]	0–6 days

Table 4.3 Indicators for reporting of early onset sepsis from Australian Council on Healthcare Standards manual

Classification from manual		Definition
CI. 4.1 Early onset infection rate — inborn neonates	<i>Numerator</i>	Number of live babies born at the reporting hospital who develop bloodstream and/or cerebrospinal fluid infection within 48 hours of birth and who were born in the time period under study
	<i>Denominator</i>	Number of live babies born at the reporting hospital during the time period under study
CI. 4.2 Early onset infection rate — inborn neonates ≥ 37 weeks	<i>Numerator</i>	Number of live babies of >37 weeks gestational age born at the reporting hospital who develop a blood and/or cerebrospinal fluid infection within 48 hours of birth and who were born in the time period under study
	<i>Denominator</i>	Number of live babies >37 weeks gestational age born at the reporting hospital during the time period under study

Source: Australian Council on Healthcare Standards (ACHS) Infection Control Indicator Manual (version 3, 2005); unpublished, available through the ACHS

4.4.3 Validation

Detection of infection by blood or CSF culture is usually a reliable process; however, both false positive and false negative results occur.

Most neonates with early or late onset bacterial sepsis develop high colony count bacteraemia. However, quantitative studies indicate that low-density bacteraemia is also recorded for most pathogens. A review looked at key aspects of blood culture practice that might affect reliability of detection of sepsis.^[16] Laboratory-based work indicates that organisms at densities of <4 colony forming units (CFU)/mL inoculated at volumes of 0.5 mL or less are not reliably detected.^[17]

Either CSF or blood samples may be contaminated by skin flora during collection. Such contamination may be with bacterial species that are identical to those that cause true infection (ie staphylococci, streptococci or coliform bacteria). Contamination can be minimised by effective skin cleansing with antiseptics.

In most clinical practices, infants with proven EOS will undergo lumbar puncture to detect meningitis because, if detected, this may alter the antibiotic treatment plan. It is rare for meningitis to be diagnosed without a coincident blood culture isolate being obtained. Variability in lumbar puncture practice is therefore unlikely to affect measured EOS rates.^[18]

4.4.4 Reporting

Reporting of proven EOS generally uses an incidence measure of cases per 1000 live births. Because the incidence is much higher in pre-term neonates (gestational age <36 completed weeks), stratification by gestational age is advisable. Owing to the small numbers and relative rarity of EOS, surveillance data for EOS in neonates with a gestational age of less than 33 weeks may not be worthwhile. Use of appropriate run (control) charts against both local historical data and national data is recommended.

4.5 Current surveillance systems and data

4.5.1 International

The Netherlands,^[7] United Kingdom and Ireland^[8] conduct country-wide surveillance of EOS.

Most other surveillance is done across regional networks of birthing services.

4.5.2 Australia

Australia has no jurisdictional surveillance systems for EOS other than in New South Wales, where collection of the Australian Council on Healthcare Standards (ACHS) indicators has been recommended since 2005. This recommendation ceases in 2008. However, compliance with this requirement has been poor (only 2–3 units reporting).

Individual hospitals have contributed data against ACHS indicators 4.1 and 4.2 across Australia. Fifteen hospitals contributed data to this system in 2006.¹³ A mean rate of 1.5 events per 1000 live births was obtained (Indicator 4.1), 20th centile rate of 0.43, 80th centile rate of 2.6.

The Australasian Study Group for Neonatal Infections collects data from about 16 facilities across Australia and New Zealand. Their surveillance definition is slightly different to the ACHS indicator definition. These data are published periodically.^[19, 5]

¹³ http://www.achs.org.au/pdf/Australasian_CIR_8th_Edition.pdf (Accessed 12 February 2008)

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5 Health-care worker bloodborne virus exposure

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Key points

- There is international agreement that occupational exposure causes a substantial burden and cost to both health-care systems and individuals.
- International experience shows that occupational exposure surveillance can:
 - demonstrate trends in injury and exposure
 - enable early recognition of specific problems
 - be used to direct prevention efforts and risk management
 - permit ready assessment of the impact of prevention efforts.
- Australian health care and health-care workers will benefit from the establishment of an ongoing, standardised, aggregated national system for occupational exposure data.

Recommendation on health-care worker bloodborne virus exposure

1. A national surveillance system for monitoring trends in occupational exposure to bloodborne pathogens should be developed.

5.1 Background

An occupational exposure is defined as any contact with blood or other potentially infectious materials made by health-care workers (HCWs) during the performance of their duties. Occupational exposures typically occur via skin, eye, mucous membrane or parenteral contact. Needle-stick injuries are the most serious occupational exposures in terms of the potential to transmit bloodborne viral infection, as described in the following case study (Operating suite incident) . A needle-stick injury is a percutaneous injury with any sharp designed for use in health care; the sharp may or may not have been used on a patient.

This chapter:

- provides a brief overview of the epidemiology of occupational exposures to bloodborne viruses, with a specific focus on needle-stick injuries (Section 5.2)
- outlines the morbidity and financial impact of occupational exposures (Section 5.3)
- describes the surveillance of occupational exposures in Australia and abroad, including a review of Australian research relating to incidence, prevention and impact of needle-stick injuries (Section 5.4)
- discusses links to quality-improvement programs (Section 5.5).

Discussion of the prevention and management of occupational exposures is beyond the scope of this chapter.

Case study — Operating suite incident

A registered nurse was assisting an anaesthetist in the operating suite during the insertion of an intravenous cannula into a patient's hand. As the anaesthetist removed the stylet from the cannula, the patient moved unexpectedly, causing the stylet to pierce the nurse's thumb. The deep penetrating wound was washed immediately under running water, using the designated skin cleanser, as per hospital protocol.

The nurse immediately reported the incident to the assistant unit manager, who completed an online incident form on the hospital's electronic risk management reporting system. The reporting system instantly emailed the incident details to the relevant department head, the nurse unit manager, the risk assessment officer, occupational health and safety and the infection control department.

Both the nurse and the patient submitted to serology testing at the time of the incident to assist in determining the nurse's risk for bloodborne viral exposure. In the event of a positive source test being returned, the nurse would usually be offered a post-exposure prophylaxis drug regime.

The infection control department has a standalone blood exposure surveillance database that can generate quarterly reports in table and graph form. The quality and safety department and hospital board review these reports.

The infection control department analyses the aggregate data to calculate an occupational exposure rate. The rate is used to support the introduction of new policy and the purchase of safety devices, and to target specific areas in the institution where the rate is highest. Occupational exposure rates in the operating suite were high, and a working party implemented an online survey of all operating suite staff and their work or procedural practices to better understand the specific risks among these staff. Survey results indicated that some practices were unsafe and ongoing education was provided to change behaviours and practices to reduce risk.

5.2 Epidemiology

In 2003, the World Health Organization (WHO) estimated that every year, more than three million HCWs worldwide are exposed to a sharp object contaminated with hepatitis C virus (HCV), hepatitis B virus (HBV) or human immunodeficiency virus (HIV).^[1] Table 5.1 details reported rates of injury from selected countries.

Table 5.1 Reported rates of injury of health-care workers from selected countries

Country	Setting and year	Reported rate	Author
Dominican Republic	Two public hospitals and 136 public immunisation clinics, 2005	22.3% of HCWs reported at least one injury in the previous 12 months	[2]
France	375 medical centres, 2004	8.9 exposures per 100 hospital beds	[3]
Japan	1015-bed hospital, 1997–2004	3.6 exposures per 100 hospital beds	[4]
Kenya	250-bed rural mission hospital	22.6% of respondents reported at least one injury in the previous 12 months	[5]
Taiwan	16 hospitals, 1996–97	87.3% reported to have experienced a recent infection	[6]
United Arab Emirates	Emergency departments of four hospitals, 2005	19% of respondents reported at least one injury in the previous 12 months	[7]

HCW = health-care worker
Source: Jagger et al 1988 [8]

In Australia, the first report of occupational exposures to blood and body fluids was published by Mallon in 1992.^[9] The report detailed 332 cases of occupational exposure sustained by staff in a major teaching hospital in Perth between January 1990 and August 1991. The overall occupational exposure incidence was 6.1 per 100 full-time equivalent (FTE) years, with nursing and medical staff reporting the most frequent exposure (9.4/100 and 9.0/100 FTE years, respectively).

The rate of exposure to HIV antibody-positive patients in the study population was 0.24/100 FTE years. The needle-stick injuries and other blood-contaminated sharps injuries accounted for 83.4% (277/332) of the reports. The activities most often associated with occupational exposure were insertion and operation of parenteral lines (24%) and surgical procedures (15.4%). In findings similar to those of Mallon, Whitby reported an occupational exposure rate of 8.79 per 100 FTE years in a study of 1836 needle-stick injuries reported in a Brisbane hospital between 1990 and 1999.^[10]

In 1999, MacDonald and colleagues looked at the rate of percutaneous occupational exposures to blood or other body fluids that were voluntarily reported to the then National Monitoring of Occupational Exposure To Bloodborne Viruses System.^[16] Reports came from up to 56 hospitals between 1995 and 1997.^[11] The study found that the occupational exposure rates per 100 occupied bed days (OBD) were 23.8 (1995), 20.8 (1996) and 18.1 (1997).

Data collected from more than 200 public hospitals by the New South Wales Department of Health between 2003 and 2005 included reports of more than 5000 HCW occupational exposures, with an average of 1670 piercings of skin or mucous membrane with contaminated sharps. The rate has remained constant at between 0.031 and 0.039 injuries per 100 OBD.^[8]

Hunt and Murphy reported occupational exposure rates among nurses in operating theatres and in day surgery units in a New South Wales private hospital over a two-year study period.^[12] The baseline occupational exposure rates for operating theatre nurses were 2.53 per 1000 surgical procedures, while those for nurses in the day surgery units were 1.84 per 1000 surgical procedures.^[12] In 2002, an Australian Government Senate Committee estimated that 13,000 needle-stick injuries occur annually.^[13]

5.3 Morbidity and financial impact

Numerous pathogens have been transmitted to HCWs through sharps injuries; however, the three most commonly transmitted diseases are HBV, HCV and HIV.^[14, 15] The estimated risks of transmission from a single needle-stick injury exposure to HBV, HCV or HIV are 30%, 1.8% and 0.3%, respectively. Transmission depends on several factors, such as nature of the exposure, inoculum size, route of exposure and susceptibility of the HCW.^[14, 16]

Transmission of HIV through needle-stick injury is thought to have occurred in most countries,^[17] but data on the number of cases, circumstances and rate of occupational transmissions of bloodborne viral disease is limited due to its sensitive nature. The most recent reliable report on Australian cases of occupational transmission of bloodborne viral disease was published in 1999,^[11] however, specific details of the epidemiology of those and subsequent cases have not been made public.

The cost of occupational exposures and subsequent transmission of bloodborne viral infection in the Australian health-care setting has not been reported; however, the most recent estimate from the United States^[18] could reasonably be extrapolated to Australia. It states:

- estimated costs per exposure range from US\$71 to \$4838, depending on the infectious status of the patient
- seroconversion occurs infrequently; however, the responsibility of organisations to prevent exposures is consistent
- treatment of occupational exposures include costs in dollars, time and emotions
- determining cost is important to evaluate the cost–benefit of preventive interventions.

5.4 Surveillance

5.4.1 Surveillance methods

Professor Janine Jagger published the first scientific report of data relating to needle-stick injuries almost 20 years ago, in 1988. The report covered 326 needle-stick injuries occurring over a 10-month period in a university teaching hospital.^[8, 19] In 1993, Jagger pioneered surveillance and collection of occupational exposure data using the standardised database, the Exposure Prevention Information Network (EPINet); nearly 29,000 injuries and occupational exposures were reported to her research centre in the following decade from New South Wales.^[19]

As of mid-2007, EPINet, or modified versions of the program, has been adopted for use in more than 50 countries.^[17] In fact, most modern occupational exposure surveillance platforms are based on the detailed data fields of EPINet. An example is the National Surveillance System for Health Care Workers (NaSH) of the Centers for Disease Control and Prevention (CDC). Using the NaSH system, the CDC collected data on more than 20,000 HCW occupational exposures from June 1995 through December 2005. The system was replaced in 2006 by a specific module released as part of the CDC's larger integrated, secure, internet-based National Healthcare Safety Network (NHSN) (formerly the National Nosocomial Infections Surveillance System (NNIS)) surveillance system.

Global understanding of occupational exposures was substantially increased by the recent publication of large datasets collected in countries where this information was previously unreported. These include the Dominican Republic,^[2] France,^[3] Japan,^[4] Kenya,^[5] Taiwan^[6] and the United Arab Emirates.^[7]

International comparisons are still difficult because there is substantial variation in the methods used to collect and report occupational exposure data around the world. Some countries support national occupational exposure surveillance, while others encourage voluntary data submission. There is a lack of global consensus regarding the most appropriate collection method, and published data has been collected prospectively, retrospectively or as part of one-off point prevalence exercises or surveys of discrete convenience samples. In some countries, legislation mandates reporting of occupational injuries, whereas in others, it is assumed that the usual 40%–85% of injuries remain unreported.^[6, 14, 20] International comparisons and, in some cases, comparison of rates within specific countries are hindered by variability in the application of denominators used to determine occupational exposure rates.

5.4.2 Current occupational exposure surveillance in Australia

In 2005, Australia was criticised for failing to measure the extent of its national needle-stick injury problem. The development and maintenance of a standardised national database to shape and sustain large-scale prevention programs was recommended.^[21] Despite this criticism, efforts to standardise national surveillance have not been forthcoming and the reported datasets that exist in a few states indicate ongoing and unacceptable rates of injury are regularly sustained by Australian HCWs.

To date, few Australian jurisdictions undertake regular monitoring or reporting of sharps injuries or occupational acquisition of bloodborne viral disease from needle-stick injuries. There is no centralised system of monitoring, reporting or responding to occupational sharps injuries in Australia.

Version 3 of the Australian Council of Healthcare Standards (ACHS) Infection Control Indicators^[22] defines two exposure indicators:

- Indicator 6.1 — parenteral exposures sustained by staff (per 100 occupied bed days)
- Indicator 6.2 — non-parenteral exposures (per 100 occupied bed days).

A total of 172 hospitals provided data against these indicators in the latest ACHS report.^[23]

The report contrasts indicator results from 60 New South Wales facilities and a smaller number of facilities from Queensland (20), Victoria (20), South Australia (11) and Western Australia (11). The rates of parenteral exposure showed no significant differences among the states in 2006 (2435 reported injuries from 172 facilities, rate 0.041 per 100 bed days; 20th, 80th centile rates, 0.029, 0.048).

5.4.3 Public hospitals

New South Wales

New South Wales public hospitals are mandated to collect and report all occupational exposures on the EPINet system and against the ACHS Indicators 6.1 and 6.2 (described previously). In the past, aggregate data with location not specified were released on the New South Wales Health website. These data are no longer available and new systems of reporting are under consideration. To date, the validity, reliability or completeness of New South Wales data has not been examined.

Northern Territory

There is no official directive or mandate to report exposures in the Northern Territory. However, each quarter, raw numbers of occupational exposures reported in the Territory's five hospitals are presented to the Acute Care Quality Council.

Queensland

Queensland has no directive for compulsory reporting of needle-stick injuries. The Centre for Healthcare Related Infection Surveillance and Prevention group provides hospitals with tools and resources to assist collection and analysis of local data.

South Australia

There is no South Australian directive to collect or report needle-stick injury data, but most hospitals have an informal surveillance system in place.

Tasmania

The Tasmanian Department of Health and Human Services has no directive to collect or report needle-stick injury data to the government.

Victoria

Reporting and submission of needle-stick injury data is not mandated in Victoria. However, the Victorian Hospital-Acquired Infection Surveillance (VICNISS) project currently collects occupational exposure data as part of its surveillance program for public hospitals with fewer

than 100 beds (type 2 hospitals). There is no requirement for hospitals with more than 100 beds (type 1 hospitals) to report occupational exposure data to VICNISS.

VICNISS is currently working with the infection control committees of the Victorian Blood Exposures Group (ViBES) that collaborate to report exposures and produce aggregate numbers within the participating hospitals, to:

- extend the existing VICNISS program
- continue the work of ViBES in providing occupational exposure reports that do not identify individuals
- bring other Victorian public hospitals on board.

Western Australia

There is currently no official Department of Health requirement to collect or report needle-stick injury data in Western Australia. However, private hospitals inspected by the department's private sector licensing unit are expected to have needle-stick injury data.

5.4.4 Private hospitals

A group of larger private hospitals around Australia voluntarily benchmark ACHS clinical indicators, including needle-stick injuries, among themselves. This process was established with permission of the hospital administrators and is only reported internally at these hospitals. Some private hospital groups also compare needle-stick injury rates within their own groups. Some, but not all, use external benchmarks such as ACHS-reported clinical indicator rates as 'targets'.

No data are collected from general practice medical services, specialist medical services, private pathology services, the ambulance service or community health services, though the nature of routine work in these settings make needle-stick injury an occupational risk.

5.5 Linkage to quality-improvement programs

As explained, there is a failure in Australia to collect valid and reliable data and information relating to needle-stick injuries as part of a national aggregation. This situation limits the ability of Australian infection control professionals and jurisdictions to design, implement and evaluate interventions that appropriately target at-risk groups, procedures, equipment and practices.

As part of its Evaluation and Quality Improvement Program accreditation process, the ACHS requires participating organisations to monitor and report rates of recapping related needle-stick injuries, body fluid exposures and non-parenteral occupational exposures.^[18]

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Part C — Specific organisms

6 Multiresistant organisms

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Key points

- Antimicrobial resistance contributes to poor patient outcomes and threatens to undermine the great advances in treatment of infectious diseases that have occurred over the past 40 years.
- The relationship between antibiotics and antibiotic resistance is complex, and encompasses selection and dissemination of resistance determinants between human and bacterial hosts. Antibiotic resistance in the community is emerging as a significant problem worldwide, but Australia has few ways of measuring this nationally at present.
- Surveillance systems for multiresistant organisms have traditionally been laboratory based, with percentage resistance among laboratory isolates being the most frequently used summary measure. However, laboratory surveillance alone does not give a measure of the burden of disease caused by multiresistant organisms. Active prospective surveillance is required to:
 - measure the incidence of new antibiotic resistance in microorganisms
 - detect emerging resistance and outbreaks of cross-infection within an institution
 - monitor the success or otherwise of interventions designed to reduce the acquisition of multiresistant organisms.
- Standardised protocols for screening multiresistant organisms and definitions for surveillance indicators have been developed for Australia, and many hospitals have adopted these. Some states have established centres for data aggregation for at least some organisms, such as methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant enterococci (VRE), but only one state (South Australia) has expanded this to include other types of multiresistant organisms. MRSA is the most commonly reported multiresistant organism and is responsible for the greatest burden of disease.
- Antibiotic usage monitoring and analysis is necessary to improve antibiotic-prescribing patterns and reduce the main driver of resistance. This is particularly important in Australia, where the overall usage in tertiary referral hospitals is high compared to international benchmarks, such as the Scandinavian countries or the Netherlands.

Recommendations on multiresistant organisms

1. A feasibility study on reporting all health care associated MRSA infections, using the established Australian Infection Control Association definitions for multiresistant organism indicators, should be undertaken.
2. A comprehensive laboratory-based surveillance program for antibiotic resistance as recommended by the National Health and Medical Research Council is required.
3. A national surveillance program in high-risk patient groups (eg intensive care unit) for infections caused by gram-negative bacilli harbouring key resistances, including extended spectrum beta-lactamases, plasmid-mediated AmpC and metallo-beta-lactamases, is required.
4. Training programs for Australian laboratories to promulgate best practice methodologies for detecting and reporting resistance in organisms responsible for health care associated infections — MRSA, vancomycin-intermediate or vancomycin-resistant strains of *S. aureus*, VRE and multiresistant gram negative bacteria — are required.

6.1 Background

Antimicrobial resistance is one of the major threats to the great advances in treatment of infectious diseases over the past 40 years.^[1] Resistance was detected soon after the widespread use of antimicrobials in the hospital setting and the community started. The leading example of this was the emergence and dissemination of penicillin resistance in *Staphylococcus aureus*.^[2] Although resistance in the community is of great concern, hospitals are the major focus for the spread of highly resistant organisms. This is a consequence of exposing a high-density, high-acuity patient population in frequent contact with health-care staff to heavy antibiotic use, along with the attendant risk of cross-infection.^[3]

Antimicrobial resistance increases the morbidity and mortality associated with infections, and contributes to increased costs of care due to prolonged hospital stays and other factors, including the need for more expensive drugs.^[4] In Australia, approximately 12% of patients admitted to intensive care units (ICUs) develop severe sepsis; of these, 27% die in the ICU.^[5] Failure of early treatment due to antibiotic resistance greatly increases the risk of death.^[5, 6, 7, 8, 9, 10, 11]

The organisms with the greatest impact on the health-care system in developed countries are:

- methicillin-resistant *Staphylococcus aureus* (MRSA) (Section 6.3)
- vancomycin-resistant enterococci (VRE) (Section 6.4)
- multiresistant gram negative bacteria (MRGN) (Section 6.5).

The expansion of multiresistant *Mycobacterium tuberculosis* is of world-wide concern and may well have an increasing impact on health care in the developed world in the future.

Concern about antimicrobial resistance has been expressed at the highest levels of government in Australia and internationally.^[12] For example, Britain's House of Lords,^[13] the United States' Institute of Medicine^[14] and the Australian Government Department of Health's Joint Expert Technical Advisory Committee on Antibiotic Resistance (JETACAR) have all published reports drawing attention to the problem. In 1996, a group of United States experts published a consensus statement calling for action to address the problem and agreed on 10 strategic goals and related measures of process and outcomes.^[15] A strong central recommendation of all of these reports was the need to establish a valid and extensive surveillance system to detect the emergence and spread of antimicrobial resistance.

The scope of infection caused by antibiotic-resistant organisms ranges from infection caused by an organism intrinsically resistant to multiple antibiotics (eg *Pseudomonas aeruginosa* and *Acinetobacter* sp) to infection caused by organisms that have acquired or developed resistance to antibiotics usually used in their treatment (eg MRSA, VRE, MRGN and *Candida albicans*).

The relationship between antibiotics and resistant organisms is complex, encompassing selection and dissemination of resistance determinants between human and bacterial hosts. Central to the proposed methods of control of resistance is the prudent use of antibiotics, published in national guidelines for over 20 years.^[16] Active surveillance of antibiotic usage is paramount.^[17] Despite the difficulties of proving a cause-and-effect relationship, there are now many reports of resistance rising during increased antibiotic use and falling after reduction in use.^[18, 19, 20] For a more comprehensive discussion of this evidence, see Chapter 15 (Antimicrobial usage: monitoring and analysis).

6.2 Surveillance methods for multiresistant organisms

Traditional infection control surveillance has concentrated on particular sites of infection, such as surgical site infection (SSI) and catheter-associated urinary tract infections, leaving the microbiology laboratory to compile tables of resistance rates for all organisms isolated in the hospital. The Australian Infection Control Association (AICA) has proposed a standardised model for surveillance and screening for carriage of multiresistant organisms.^[21]

The differentiation between hospital- and community-acquired infections has an effect on the chosen strategy for surveillance, particularly for MRSA. If a laboratory-based data extraction system is chosen, information retrieved will only include the proportion of *S. aureus* isolates resistant to methicillin. Even if ‘time to isolation’ of the organism from hospital admission is available, this will not give a true indication of whether the isolate was acquired within the health-care system or in the community. This is important, because true community-acquired MRSA may be less amenable to reduction by hospital-based preventive strategies, whereas health care associated MRSA can be effectively reduced by various evidence-based infection control strategies. To determine whether an isolate is truly community acquired or health care associated requires some epidemiological or clinical input, and a corresponding increase in the resources required to collect this information.

6.2.1 Definitions

Surveillance definitions for MRSA and other multiresistant organisms are poorly standardised. The AICA National Advisory Board (formerly the AICA Expert Working Group) proposed a surveillance system for multiresistant organisms.^[21]

The surveillance indicator definitions for multiresistant organisms were updated and revised in 2004 by the Healthcare Infection Surveillance Subcommittee of the National Quality and Safety Council (now replaced by the Australian Commission on Safety and Quality in Health Care). These indicators include multiresistant organism morbidity, acquisition and burden, as shown in Table 6.1.

Table 6.1 Standardised multiresistant organism indicators recommended by the Australian Infection Control Association and the National Quality and Safety Council

Indicator	Measure	Optional stratifications
MRO morbidity	MRO infections per 10,000 patient days	ICU versus non-ICU Non-sterile site versus sterile site
MRO acquisition (estimated incidence)	MRO acquisitions per 10,000 patient days	ICU versus non-ICU
MRO burden (estimated prevalence)	MRO positive separations (ie patients discharged with MRO) per 10,000 patient days	ICU versus non-ICU

ICU = intensive care unit; MRO = multiresistant organism
Source: National Quality and Safety Council (2004)^[22]

Multiresistant organism morbidity only measures cases of infection and not colonisation, and therefore is not subject to variations caused by differences in screening practices in different institutions. Multiresistant organism acquisition and burden also measure cases of colonisation, and therefore are subject to variation due to differing hospital screening practices.

The Australian Group on Antimicrobial Resistance (AGAR) has complemented the recommendations shown above with standard microbiological definitions for multiresistant organisms.^[23] See Section 6.2.3 for a more extensive discussion of the laboratory surveillance of antibiotic resistance.

6.2.2 Detection

The adoption of a standardised sampling approach is the crucial first step in a robust surveillance system. A minimum standard patient sampling approach was recommended by the AICA for MRSA, VRE and MRGN screening and endorsed by the Australian Council for Healthcare Quality,^[24] though these recommendations have not been systematically applied in Australia. The United Kingdom has also established a standard approach.^[25]

The use of best practice detection methods in laboratories is important. Problems can arise with phenotypic (ie direct demonstration of antibiotic resistance expression using culture methods) and molecular methods (eg nucleic acid amplification assays) of multiresistant organism detection. An example is the detection of MRSA, where some screening methods may fail to detect community strains with relatively low minimal inhibitory concentrations against methicillin or oxacillin.

6.2.3 Laboratory-based surveillance of antimicrobial resistance

National laboratory-based surveillance was recommended by JETACAR in 1999^[26] and is a key part of all antimicrobial resistance management plans and of the World Health Organization's (WHO) Global Strategy for Containment of Antimicrobial Resistance.^[27] Because surveillance systems in Australia are far from comprehensive, the Expert Advisory Group on Antimicrobial Resistance of the National Health and Medical Research Council recently proposed a comprehensive surveillance program.^[28]

In the microbiology laboratory, two basic types of surveillance are possible:

- *passive* surveillance, in which data on susceptibilities and resistances are collated from routine susceptibility testing of clinical isolates
- *targeted* surveillance, in which specific species or groups of species are examined in greater detail (eg broader range of antimicrobials, minimum inhibitory concentration, distribution data, subset of patient or disease types, molecular tests for mechanisms and molecular clone typing) to answer important questions that cannot be addressed by passive surveillance.

These definitions of surveillance are the ones most widely accepted in Australia, although they are not identical to those used by WHO.^[29] They were in common use in Australian laboratories for at least a decade before the WHO definitions were published.

Passive surveillance

Passive surveillance effectively exists in any microbiology laboratory that has computerised records, formally called a laboratory information system (LIS). Individual laboratories often collate and analyse routine susceptibility testing data to create 'antibiograms' for their clients. An antibiogram is the cumulative proportion (percentage) of resistant strains. At least one international standard has been developed describing methods for doing this effectively.^[30] Routine data can be pooled and analysed at a regional, state or national level using the same techniques.

Outputs of passive surveillance

Outputs of passive surveillance include antibiograms and multiresistant organism reporting and identification. Other possible outputs are:

- percentage susceptible by species over time (trending), used to identify targets for antimicrobial prescribing intervention and to detect the effects of such interventions
- analysis of susceptibility profiles by species, patient demographics, specimen source, etc
- correlation of percentage of organisms susceptible with antimicrobial use.

Antibiograms

The most common form of output from passive surveillance is the cumulative proportion (percentage) of resistant strains, sometimes referred to as an antibiogram. This form is considered the most appropriate for guiding antimicrobial choice, but may or may not be suitable to monitor trends, depending on how the data are collated and presented (eg by genus, species or specimen type).^[31]

Antibiograms are often presented as tables of susceptibility of common pathogens to selected antimicrobials. These can be produced and used at a local level (eg for a hospital on an annual basis) to guide clinicians in the selection of empiric antibiotic therapy. However, produced in isolation from education and other antibiotic stewardship initiatives,^[30, 32] antibiograms are just as likely to drive inappropriate prescribing as control it because clinicians often choose to change their prescribing when even modest levels of resistance are reached.

Cumulative antibiograms have greater value when examined at a regional or national level where they can guide the development and updating of prescribing guidelines. In Australia, passive surveillance data are used in the revision of the *Therapeutic Guidelines (Antibiotic)*, the de facto national antimicrobial prescribing standard.^[16]

In generating antibiograms, passive surveillance systems should, where possible, include some type of algorithm to remove duplicate results from the same patient, same infection and same episode. Infection control screening results should also be excluded. Failure to exclude duplicates can lead to overestimating the prevalence of resistance, although in general this is not a major problem.^[33] The most widely-accepted method is that proposed by the Clinical and Laboratory Standards Institute.^[30]

Multiresistant organism reporting and notification

An advantage of the passive LIS-based system is that it can automate the detection of multiresistant organisms of interest. This can work at the local (eg ICU or hospital) or state level. Automated print-outs or more sophisticated software systems can automatically inform infection control staff that multiresistant organisms have been isolated and additional infection control measures need to be implemented. Some states have formal systems for central reporting of multiresistant organisms of interest and have made them reportable or even notifiable to state communicable diseases units. Notification may be associated with the collection of epidemiological data and molecular typing of isolates (eg MRSA in Western Australia) to detect the entry of imported clones or the evolution of resistances locally.

Passive systems are also well placed to detect rare multiresistant organisms that may require urgent and more aggressive infection control measures. Examples include vancomycin-resistant *Staphylococcus aureus* (vanA containing), which has only been reported in the United States but would be of critical importance if detected in Australia.

Previous and current systems of passive surveillance

The first national scheme for collating resistance data was the National Antimicrobial Resistance Surveillance Program. This was funded by the Commonwealth Department of Health and ran from 1992 to 1997. The funds were used to collect annual data, both hard copy and electronic, from up to 30 large laboratories around Australia and collate them into annual reports. The scheme ceased due to lack of funding.

In 1998, a United States-based commercial firm, The Surveillance Network (TSN), set up an electronic network of larger laboratories around Australia collecting identification and susceptibility data.^[34, 35] Data collection involved a nightly download of the laboratory's data via the internet to a holding database in Virginia. Every month the data were examined for anomalies, 'cleaned' and collated. Participating laboratories could view and analyse their own data. Formal national reports were never issued because the system was withdrawn due to lack of a sponsor for the company. Twenty-six laboratories were contributing data at the time of closure. The TSN database (the total amount of data collected 1997–2004) was purchased by the Australian Society for Antimicrobials.

The creation of a single state-wide pathology service in Queensland in 1996 resulted in the implementation of a single LIS for the state. This created an opportunity to build a passive surveillance system for the state public hospital system called 'Antibiogram'.¹⁴ This program has all of the features listed earlier.

Proposed systems of passive surveillance

There is strong laboratory and clinical support for the extension of the Antibiogram program from Queensland to the whole of Australia.^[28] The establishment of the TSN system proved that such technology can be rolled out effectively via the internet. The Antibiogram software is in a relatively mature form and would lend itself to adaptation to a national system. The importation of data from an external LIS has been achieved and a secure web-based application is available. Correctly implemented, the system could meet all of Australia's current passive surveillance needs. A source of funding has not been identified.

Targeted surveillance

Targeted surveillance is designed to provide a more detailed picture of evolving resistances than can be provided by passive surveillance systems. It involves gathering data not normally stored in a laboratory's LIS and laboratory testing additional to that done routinely. An example of targeted surveillance is the monitoring of trends in resistance and their relationship to serotypes in *Streptococcus pneumoniae*. Additional laboratory work is required to subculture invasive isolates at the initial laboratory and send to a referral laboratory for serotyping. Ideally, more antimicrobials would be tested.^[36]

An important example of targeted surveillance in Australia is that conducted by AGAR.^[37] Active for more than 20 years, this group was initially supported by the pharmaceutical industry and focused on *S. aureus*. Later, it moved on to other common pathogens and in recent years has been partly funded by the Australian Government Department of Health and Ageing.

Previous and current systems of targeted surveillance

The targeted surveillance programs listed in Table 6.2 have been supported by the Australian Government Department of Health and Ageing and its predecessors (and by AGAR in recent years). Funding is on an annual, renewable basis. Data from these programs appear regularly in

¹⁴ <http://www.health.qld.gov.au/qhcss/antibiogram.asp>

Communicable Diseases Intelligence and, in the case of AGAR, are posted on their website¹⁵ for open access nationally and internationally.

Table 6.2 Targeted surveillance programs conducted in Australia for more than 15 years

Program	Pathogens monitored
Australian Group on Antimicrobial Resistance ¹⁶	<ul style="list-style-type: none"> • <i>Staphylococcus aureus</i> • Enterobacteriaceae — <i>Escherichia coli</i>, <i>Klebsiella</i>, <i>Enterobacter</i> and <i>Acinetobacter</i> species • <i>Enterococcus</i> species • <i>Streptococcus pneumoniae</i> • <i>Haemophilus influenzae</i>
National Neisseria Network ^[38]	<ul style="list-style-type: none"> • <i>Neisseria gonorrhoeae</i> • <i>Neisseria meningitidis</i>
Australian Mycobacterium Reference Laboratory Network ^[39]	<ul style="list-style-type: none"> • Monitoring of resistance in <i>Mycobacterium tuberculosis</i> • <i>Salmonella</i> reference laboratories • Monitoring of resistance in <i>Salmonella</i> species

Proposed systems of targeted surveillance

The only current proposal for targeted surveillance is from the National Health and Medical Research Council (NHMRC),^[28] which endorses continued support for AGAR but does not mention the National Neisseria Network or the Australian Mycobacterium Reference Laboratory Network. It is assumed these programs will be ongoing. The NHMRC proposal does mention associated surveillance, such as that currently conducted under the auspices of OzFoodNet.¹⁷

Targeted surveillance should be a coordinated national activity based on national priorities. At present there is no overarching group with the authority to set these priorities. The NHMRC proposal for comprehensive surveillance supports the development of such a group by the Office of Health Protection.

Surveillance of key phenotypes might reasonably be done by testing of routine specimens (eg perineal and endotracheal samples) from patients in ICU for the presence of:

- carbapenem-resistant *Acinetobacter baumannii*
- carbapenem-resistant *Pseudomonas aeruginosa*
- metallo-betalactamase-positive Enterobacteriaceae
- extended spectrum betalactamase-positive Enterobacteriaceae
- extended aminoglycoside-resistant Enterobacteriaceae.

This could be achieved by a yearly point prevalence study submitted to a central network such as AGAR, and used to determine the need for and nature of local targeted screening. Information should also be collected on the source of the specimens (ie community or health care associated) and whether these represent infection or colonisation.

¹⁵ <http://www.antimicrobial-resistance.com/>

¹⁶ <http://www.antimicrobial-resistance.com/>

¹⁷ <http://www.ozfoodnet.org.au/>

6.2.4 Validation

Multiresistant organism surveillance systems require validation at several levels to ensure that data are robust. Most current systems and published reports have not given adequate attention to the validation process. The following parameters require regular audit.

- Have standardised multiresistant organism screening processes been implemented in high-risk populations?
- Is there compliance with multiresistant organism screening protocols?
- Are the laboratory methods used to detect multiresistant organisms in screening and clinical samples sensitive, specific and compliant with best practice?
- Is laboratory interpretation and reporting consistent with best practice?
- Is health care association correctly assigned and are all incident cases detected?

6.2.5 Reporting

Various measures have been used to describe levels of bacterial resistance, including the proportion of a particular bacterial species resistant to an antimicrobial (eg percentage of health care associated *S. aureus* bloodstream infections (BSIs) that are MRSA, incidence against admissions, patient days or population).

The Australian Infection Control Association has worked together with the former National Quality and Safety Council to develop standardised multiresistant organism surveillance indicators (see Table 6.2). Hospitals in several states have already adopted these definitions as part of their local and, in some cases, state-wide surveillance systems.

Options for MRSA, VRE and MRGN surveillance are described within the individual sections following.

The Centers for Disease Control and Prevention (CDC) Division of Healthcare Quality Promotion recommends surveillance cultures for targeted multiresistant organisms and the local collection and dissemination of antimicrobial resistance data in order to detect local changes in resistance patterns and the emergence of a new resistance genotype in a particular setting.^[40]

The Australian Council on Healthcare Standards (ACHS) has developed several clinical indicators based on the AICA definitions and many hospitals in several states contribute data on various indicators on a regular basis. The National Clinical Indicator set¹⁸ currently includes indicators for MRSA infection (morbidity) in sterile and non-sterile sites, stratified by intensive care status. These are currently the only clinical indicators directed at health care associated infection (HAI) with multiresistant organisms.

6.3 Methicillin-resistant *Staphylococcus aureus*, vancomycin-intermediate *S. aureus* and vancomycin-resistant *S. aureus*

6.3.1 Background

S. aureus is responsible for the largest proportion of health care associated bacterial infection. It causes 25–33% of hospital-acquired BSI and, according to the 2006 Victorian Hospital-Acquired Infection Surveillance (VICNISS) report, is the most common cause of SSI following coronary artery bypass graft surgery and knee and hip arthroplasty. Up to 50% of health care associated

¹⁸ ACHS (Australian Council on Healthcare Standards) (2005). *Infection control indicator manual*, Version 3. Document is unpublished, but available through the ACHS.

S. aureus BSIs are associated with the presence of an intravascular line. Methicillin resistance in *S. aureus* has become endemic in most parts of the world, occurring in over 60% of isolates in some ICUs in the United States. Isolates with intermediate sensitivity to vancomycin (vancomycin-intermediate *S. aureus* (VISA)) have become more common, with high-level vancomycin resistance (vancomycin-resistant *S. aureus* (VRSA)) being reported in isolated instances.^[41]

The use of methicillin to treat penicillin-resistant *S. aureus* was first described in 1960. Within one year, isolates resistant to methicillin were reported from the United Kingdom. The first reported MRSA outbreak occurred in 1961–62,^[42] with further reports internationally during the mid-to-late 1960s. The first Australian multiresistant MRSA was isolated in 1965 in a Sydney teaching hospital.^[43] By 1967, 5.7% of *S. aureus* strains at this facility were methicillin resistant.

In the early 1970s, there was a general decline in the incidence of ‘classic’ MRSA infection internationally. The year 1976 saw the emergence of a gentamicin-resistant ‘endemic’ MRSA (EMRSA) strain, first in Australia and then in the United Kingdom.^[44, 45, 46] By 1979, this strain had become a significant health care associated pathogen in Australia, with 40% of acute hospitals in Victoria affected.^[47] Since then, multiresistant strains of EMRSA have spread across the world. Some strains (eg UK EMRSA15 and 16) are responsible for the spread of epidemics that have caused large increases in hospital cases of MRSA infection in the United Kingdom since 1994 and more recently in Australia. MRSA is now the most commonly reported antibiotic-resistant organism in most parts of the world.

Since the mid-1990s, the emergence of non-multiresistant strains of MRSA has been increasingly reported in patients who have none of the traditional risk factors for MRSA acquisition, such as association with an acute-care facility. These so-called ‘community-acquired’ MRSA (CA-MRSA) are characterised by lack of resistance to non-beta-lactam antibiotics and the presence of the Panton-Valentine leukocidin (PVL), which mediates leukocyte and tissue destruction. They are particularly associated with severe skin and soft-tissue infection and necrotising pneumonitis, but have been reported to cause many different types of infection, including BSI. In the United States, a particular strain of community-acquired MRSA, the US 300, is the most common cause of skin and soft-tissue infections in some emergency departments. It has also been increasingly reported as a cause of hospital-acquired infections.

Since 1995, non-multiresistant CA-MRSA strains have been reported in Australia, initially in Western Australia and eastern seaboard communities before spreading more widely. At least three subtypes have been identified: the Western Australian, the Oceania and the Eastern Australian clones.^[48] Some of these CA-MRSA strains have shown a capacity for increased virulence and epidemic spread similar to those shown by strains in other countries.^[49] Data from a retrospective study of non-multiresistant MRSA bacteraemias in a New South Wales hospital indicate that these infections are associated with a significantly higher morbidity and mortality compared to infections with methicillin-sensitive *S. aureus* (MSSA).^[50] In a study performed by the AGAR group, the number of CA-MRSA isolates rose from 4.7% of *S. aureus* isolates surveyed in 2000 to 7.3% in 2004 ($P = 0.001$) (see Table 6.3).^[22]

Table 6.3 Number of isolates of health care associated and community-associated methicillin-resistant *Staphylococcus aureus* and percentage of all *S. aureus* isolates in participating Australian cities in 2000, 2002 and 2004

City	Total <i>S. aureus</i> isolates			Health care associated isolates (HA-MRSA) % of total				Community-associated isolates (CA-MRSA) % of total			
	2000	2002	2004	2000	2002	2004	<i>P</i>	2000	2002	2004	<i>P</i>
Perth	400	398	400	1	3	2	0.45	10	11	11	0.65
Darwin	99	100	59	1	11	9	0.03	5	10	20	0.003
Brisbane	300	300	300	2	4	4	0.16	5	7	13	< 0.001
Sydney	700	689	699	12	17	14	0.25	5	7	8	0.04
Newcastle	na	na	96	na	na	8	na	na	na	5	na
Canberra	100	100	100	0	5	3	0.09	4	3	2	0.41
Adelaide	399	400	399	3	3	4	0.69	3	6	7	0.03
Hobart	100	100	99	0	1	1	0.38	2	5	2	0.38
Melbourne	400	299	500	8	11	10	0.23	1	2	2	0.99
Total	2498	2386	2652	5.6	8.7	7.6	0.006	4.7	6.5	7.3	0.001

HA-MRSA = health care associated methicillin-resistant *Staphylococcus aureus*; CA-MRSA = community-acquired MRSA; na = not available

Source: Nimmo et al (2006)^[51]

Endemic strains of both MRSA and MSSA circulate within most facilities and can cause significant cross-infection. In most Australian hospitals, MSSA remains a more common cause of HAI than MRSA. Much research has focused on MRSA in view of its capacity for epidemic spread and high economic impact on individual patients. Collectively, however, it is likely that MSSA infection has a greater overall financial and morbid impact. A recent study at Austin Health showed that, of the 114 patients with *S. aureus* bacteraemia in 2006, 60% of infections were health care associated. Of these, 68% were due to MSSA, 31% to multiresistant MRSA and 1% to non-multiresistant MRSA.^[52]

There are now a number of reports of vancomycin treatment failure due to vancomycin-intermediate strains of *S. aureus* (VISA) in Japan, the United States, Europe and Australia.^[53, 54] These strains have a thickened cell wall that is thought to reduce penetration of glycopeptides. A far greater proportion of MRSA strains than previously realised are able to generate subpopulations with low-level intermediate resistance (heteroresistant-VISA) on subculture in the presence of vancomycin and other agents. Such strains may then convert to stable VISA after exposure to glycopeptides for prolonged periods. These strains have been detected in many centres, including the eastern states of Australia, and appear to contribute to treatment failure in some patients.^[55, 56]

In July 2002, in the United States, the first report of an infection due to high-level vancomycin-resistant *S. aureus* (VRSA) in a renal dialysis patient appeared. This strain was shown to contain the *vanA* complex of genes responsible for high-level vancomycin resistance in enterococci.^[57] Seven cases of VRSA have now been reported from the United States.^[58]

6.3.2 Harm to patients from methicillin-resistant *Staphylococcus aureus*

Infections caused by MRSA in hospital cause significant morbidity, with mortality from BSI ranging from 10% to 50% according to the setting.^[59] Another consequence of a high rate of MRSA is increased vancomycin usage, not only for proven MRSA sepsis but also as the standard empirical treatment for suspected hospital-acquired sepsis. This in turn is a significant risk factor

for the selection and amplification of VRE. There is some evidence that treatment of MRSA BSI is associated with a poorer outcome than infection with MSSA strains.^[60, 61]

6.3.3 Impact of methicillin-resistant *Staphylococcus aureus* on the health-care system

Many facilities have accepted MRSA colonisation as an inevitable event because the cost and difficulty of control is seen as being too high^[62, 63, 64] However, there are many valid reasons for actively attempting to control MRSA. It occurs in addition to MSSA^[65] rather than simply replacing it and is a virulent organism with limited treatment options. There is also increasing evidence that MRSA control is cost-effective even in an endemic setting.^[66]

The financial costs of infection with MRSA have been examined in many studies, the methods used for calculating these costs being highly variable. The costs depend on the site of the MRSA infection and whether MRSA infection is compared with MSSA infection or with no infection. The major cost is attributable to extended length of stay.^[67] Most studies examining the costs of MRSA infection and its control are analysed from a hospital perspective, and most are conducted overseas, often using methodology that is flawed (see Chapter 17 on the costs of HAI). There are no studies specifically examining the cost–benefit of a national or centralised surveillance system.

A New York study estimated the incidence, deaths and direct medical costs of *S. aureus* infections in hospitalised patients.^[68] It also examined the relative impact of MRSA versus MSSA, and community-acquired versus hospital-acquired infection. Methicillin-resistant infections had more than twice the mortality (21% versus 8%) and incurred higher costs than methicillin-sensitive infections (US\$31,400 vs US\$27,700). A sensitivity analysis still found a difference in costs; its main impact was to reveal the high costs of staphylococcal infection to the community.

A study at the Duke University Medical Center compared the costs of MSSA and MRSA BSIs and found the attributable median costs were US\$9661 and US\$27,083, respectively, a three-fold difference.^[69] Methicillin resistance was independently associated with increased mortality and hospital charges among patients with *S. aureus* SSI at the same hospital.^[70]

A recent study examined the economic impact of MRSA in Canadian hospitals.^[71] The mean number of additional hospital days attributable to MRSA infection was 14, with most admissions having at least one attributable day. At a tertiary facility in Toronto, the total attributable cost of treating MRSA infections was CA\$287,200, or CA\$14,360 per patient. The cost of isolation and management of colonised patients was CA\$128,095, or CA\$1363 per admission. Costs of MRSA screening in the hospital were CA\$109,813. Assuming an infection rate of 10–20%, the investigators determined the costs associated with MRSA in Canadian hospitals to be CA\$42 million to CA\$59 million annually.

There have been no studies published fully examining costs of controlling MRSA in the Australian setting. A study from a Brisbane hospital examined the effectiveness of hand washing with triclosan in eliminating MRSA from a neonatal ICU and a saving of \$17,000 was estimated based on the consequent reduction in vancomycin use.^[72] In 1993, the cost of MRSA control at a Perth hospital was estimated to be at least \$50,000 per year in a setting where endemic infection had not yet been established. It was also estimated that the cost to the hospital of established endemic infection was more than \$500,000 per year.

A conservative estimate of the cost to a hospital can be derived by combining the data from a large hospital in New South Wales^[73] with the attributable cost of an *S. aureus* bloodstream event from South Australian data of \$12,430 per event.^[74] An average of 28 hospital-acquired MRSA

BSIs per year occurred over the study period, resulting in an estimated annual cost of \$348,040. Since BSIs accounted for only 7% of MRSA acquisitions in that study, a large number of other infections would have added significant additional costs.

A preliminary study was undertaken in a South Australian hospital to determine the costs of caring for patients colonised or infected with MRSA compared to those colonised or infected with MSSA (P Hakendorf, Flinders Medical Centre, pers comm, 2000). MRSA patients cost the hospital 56% more than the notional case-mix funding and, on average, a patient with MRSA colonisation or infection cost the hospital five times more than a patient with MSSA colonisation or infection.

Many studies have shown that various infection control strategies based on combinations of active surveillance, isolation, contact precautions, decolonisation and improved hand hygiene are cost-effective.^[67] This cost-effectiveness has been shown for both outbreak control and control of endemic disease.

In the United States, a cost-effectiveness analysis of a policy of routine screening of all transfers from nursing homes and hospitals with appropriate isolation estimated that such a policy would decrease total MRSA isolation days by 42%. This would have prevented an estimated 8–41 MRSA infections, saving an estimated US\$20,062 to US\$462,067.^[75]

A Canadian study compared the costs of a screening program designed to detect MRSA on admission in patients transferred from, or recently exposed to, other health-care facilities with costs for subsequent isolation of positive cases. The study found that if such a program prevented hospital-acquired transmission in as few as six patients, it was cost-effective.^[76]

In one hospital in the United Kingdom, it was estimated that an MRSA control program over three years had saved more than £629,000 in costs that would have been incurred in treating more than 300 excess hospital-acquired infections.^[77]

A cost–benefit analysis in a French ICU estimated the mean cost attributable to MRSA infection as US\$9275. It was estimated that the total costs of the control program ranged from US\$340 to US\$1480 per patient, with a 14% reduction in the MRSA infection rate justifying these costs.^[78]

A detailed cost analysis of the stringent approach to MRSA taken in the Netherlands was recently published.^[79] The authors analysed the detailed costs of the ‘search and destroy’ MRSA policy at Utrecht University Hospital over a 10-year period. Hypothetical costs were at least twice as much in the absence of such a policy.

No Australian studies have been published on cost–benefit analysis of screening, surveillance or control programs for MRSA, although there is at least one such study in progress.

6.3.4 Current surveillance systems and data

A number of options are available for collection of MRSA data. Most countries collect this information and there is no evidence to suggest that one collection system is superior to another; nor is there any validation of any particular system. The system chosen depends on the specific aims of the program and the capacity to implement it. Other considerations include the ability of each system to:

- differentiate between colonising isolates and true pathogens (not relevant for bloodstream isolates)
- avoid duplicate isolates from the same patient

- differentiate between health care- and community-associated isolates.

Table 6.4 outlines the four main options for collection of MRSA data.

Table 6.4 Options for collection of methicillin-resistant *Staphylococcus aureus* data

Comments	Benefits	Barriers/disadvantages
Option 1 — Reporting all <i>S. aureus</i> BSI cases, including rates of methicillin resistance		
Including extra information such as whether the infection is health care or community associated, and the likely source of infection, will add significantly to the usefulness of the data. This option has been proposed as a clinical indicator for all hospitals in a recent Australian publication. ^[80]	<ul style="list-style-type: none"> • Straightforward case definition • Laboratory-based system: data can be easily retrieved from computerised records unless extra epidemiological information is required • Data already collected by most hospitals • Virtually all <i>S. aureus</i> bloodstream isolates are significant; thus, no clinical input is required • Provides an estimate of the relative proportion of MRSA to MSSA in both hospital and community settings, which will assist in monitoring changing epidemiology. 	<ul style="list-style-type: none"> • Will require extra clinical and epidemiological data collection to determine likely place of acquisition • Will include isolates that are community acquired from endogenous sources and thus not amenable to hospital-based prevention strategies.
Option 2 — Reporting all MRSA BSIs, with additional information about type of acquisition as in option 1		
	As for option 1	As for option 1 In addition: <ul style="list-style-type: none"> • The relative proportion of MRSA to MSSA is not available
Option 3 — Reporting of hospital-acquired MRSA bloodstream isolates only		
	As for option 1 In addition: <ul style="list-style-type: none"> • In many hospitals the number of isolates would be very small; thus, the burden of data collection would be correspondingly small 	As for option 1 In addition: <ul style="list-style-type: none"> • Does not provide any measure of the burden of serious MRSA infection in the community setting
Option 4 — Reporting all MRSA cases using AICA multiresistant organism indicator definitions		
The AICA multiresistant organism indicators may be stratified according to sterile or non-sterile site and likely place of acquisition (eg ICU, non-ICU). For national surveillance, reporting MRSA morbidity only is recommended because acquisition and burden are subject to differences in screening practices.	<ul style="list-style-type: none"> • Provides a more accurate picture of the burden of MRSA, as infections at many sites (not just BSIs) cause significant morbidity and mortality and increased costs of care • Some information may be extractable electronically from laboratory databases • Can be used to monitor the effectiveness of infection control procedures at an institutional or regional level. 	<ul style="list-style-type: none"> • Requires additional clinical input to determine if infection is present and whether health care associated or not. • Only measures infection, not colonisation

AICA = Australian Infection Control Association; BSI = bloodstream infection; ICU = intensive care unit; MRSA = methicillin-resistant *Staphylococcus aureus*; MSSA = methicillin-sensitive *S. aureus*

International

United Kingdom

Mandatory reporting of *S. aureus* bacteraemia (methicillin-sensitive and methicillin-resistant) was introduced in the United Kingdom in 2001. In 2004, a performance target of 50% reduction by 2008 was set. All 172 acute National Health Service (NHS) trusts (comprising 394 hospitals) are required to participate. There were significant annual increases in MRSA bacteraemia up to 2003–04, rates then stabilised at about 7000 cases per year. This corresponds to an estimated total annual MRSA bacteraemia rate per 10,000 bed days of 1.70 in 2001–02, 1.78 in 2002–03, 1.83 in 2003–04, 1.76 in 2004–05, 1.77 in 2005–06 and 1.67 in 2006–07, representing a 10% reduction in reported cases in the last reported year. The number of trusts submitting voluntary data increased from 42 in 1990 to 139 in 2005, peaking at 153 in 2001.^[81] The MRSA Enhanced Surveillance Scheme has been mandatory since 2005. Data entry is web-based and includes hospital, date of birth, sex, patient location, date of admission, consultant specialty and care details at the time the blood specimen was taken. Aggregated data are reported for six-monthly and annual periods. Quarterly counts of MRSA bacteraemias per trust are published on the Health Protection Agency website.¹⁹

The Health Protection Agency also operates a mandatory quarterly reporting system whereby all NHS acute trusts in England are required to report all *S. aureus*-positive blood cultures, including MRSA and MSSA. Antibiotic resistance is monitored by voluntary reporting of bacteraemias with antibiotic susceptibility patterns of the causative organism.

The British Society for Antimicrobial Chemotherapy has a laboratory-based bacteraemia resistance surveillance program that monitors antimicrobial resistance in bloodstream and respiratory isolates. This project was implemented in the United Kingdom and Ireland in 2001–02, with 25 laboratories contributing isolates to a centralised laboratory. Testing is carried out by the Antibiotic Resistance Monitoring and Reference Laboratory of the Health Protection Agency in London. The program monitors the rates of oxacillin resistance in health care associated and community-acquired staphylococcal isolates.

New Zealand

In New Zealand, the Crown Company Monitoring Advisory Unit collects data on hospital-onset infections. Results are published quarterly in the Hospital Benchmark Information Report. Reporting of health care associated *S. aureus* BSIs is mandatory. Antibiotic resistance is monitored by the Institute of Environmental Science and Research.²⁰ The proportion of all *S. aureus* resistant to methicillin is monitored. This resistance surveillance is not linked to the monitoring of BSI data.

United States

Surveillance of HAIs in the United States is carried out under a number of programs coordinated by the Centers for Disease Control and Prevention (CDC) Division of Healthcare Quality Promotion. The National Healthcare Safety Network (NHSN) has recently replaced the National Nosocomial Infections Surveillance System (NNIS), which commenced operations in 1970. Approximately 300 hospitals voluntarily participate in the network, which monitors a variety of HAIs and the organisms causing them. The proportion of *S. aureus* isolates causing infections that were resistant to methicillin in participating ICUs increased by about 3% per year, from 35.9% in 1992 to 64.4% in 2003.^[82] The Active Bacterial Core Surveillance of the Emerging Infection Program is another CDC program that performs MRSA surveillance via a network of participating microbiology laboratories.

¹⁹ Reports available at http://www.hpa.org.uk/infections/topics_az/hai/Mandatory_Results.htm

²⁰ Reports available at http://www.surv.esr.cri.nz/antimicrobial/antimicrobial_resistance.php

Canada

The Canadian Nosocomial Infection Surveillance Program (CNISP) involves collaboration between the Canadian Hospital Epidemiology Committee and the Centre for Infectious Disease Prevention and Control of the Public Health Agency of Canada.²¹ Forty-nine hospitals from nine provinces participate in the CNISP network, which currently conducts surveillance on a number of hospital-acquired infections, including MRSA, VRE, and central line associated BSI. MRSA surveillance involves laboratory-based review of isolates from any anatomical site in hospitalised patients. Chart review is required to obtain demographic and clinical data, such as whether the isolate was health care associated or community acquired, whether the patient is epidemiologically linked to another patient, and the site of infection. Data entry is web-based and regional and national rates are published.

Denmark and Scandinavia

The Danish Integrated Antimicrobial Resistance Monitoring and Research Program (DANMAP) was established in 1995 to monitor antimicrobial consumption and antimicrobial resistance in bacteria from animals, food and humans.^[83] All *S. aureus* blood isolates from 15 of 16 Danish counties and all MRSA isolates nationwide are sent to Statens Serum Institut.²² Blood isolates are typed using several different methodologies, including phage typing and pulsed-field gel electrophoresis (PFGE). Discharge summaries for each of the patients are collected from general practitioners and hospitals to obtain clinical and epidemiological information. Reporting MRSA cases has been mandatory since 2006.

In 2006, a total of 1351 *S. aureus* bacteraemia cases were reported. This corresponds to an incidence of 23.5 per 100,000 inhabitants, a slight decrease from 2004 and 2005. Nineteen (1.4%) of the bloodstream isolates were methicillin-resistant, similar to 2005, in which there were 23 cases (1.5%). Reporting MRSA cases has been mandatory since 2006. In 2006, a total of 706 new MRSA-positive cases from any site were reported (13 per 100,000 inhabitants); this is a decrease from the 851 new cases detected in 2005, but a marked increase from 1994 when only 46 cases were reported. The number of cases began to rise sharply from 2003, when 229 cases were reported compared with 100 in the previous year. Community-acquired infections accounted for 82% of the MRSA infections in Denmark in 2006.²³

Five Scandinavian countries report MRSA rates to the Scandinavian Society for Antimicrobial Chemotherapy Working Party on MRSA. Results from the first report in 2004 are shown in Figure 6.1. All MRSA cases are registered (in some countries as a notifiable disease), although definitions vary between countries.²⁴

²¹ http://www.phac-aspc.gc.ca/nois-sinp/survprog_e.html

²² <http://www.ssi.dk/sw3425.asp>

²³ http://www.danmap.org/pdfFiles/Danmap_2006.pdf

²⁴ <http://www.strama.se/dyn//,119,44,20.html?q = MRSA>

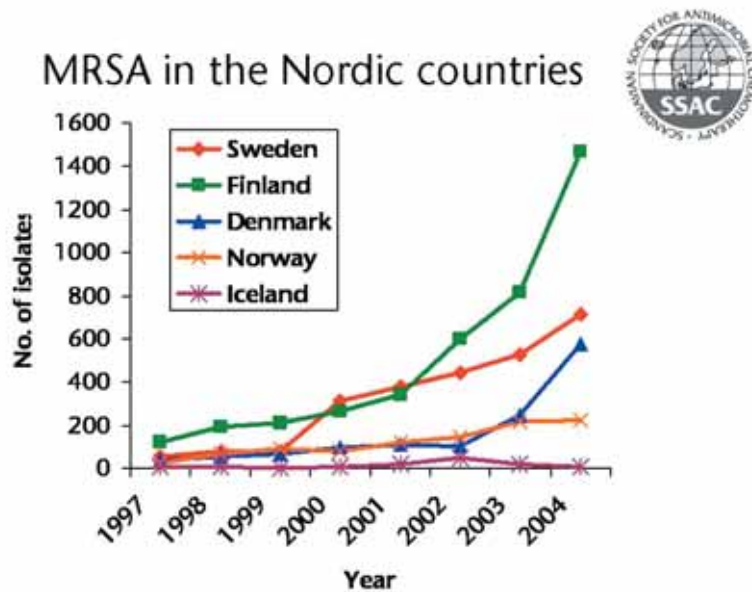


Figure 6.1 Methicillin-resistant *Staphylococcus aureus* (MRSA) in the Nordic countries

Australia

AGAR periodically surveys antimicrobial resistance in selected organisms, including *S. aureus*. The most recent published survey on the prevalence of resistance in unique clinical isolates of *S. aureus* from 32 laboratories from all states and territories was performed in 2005.^[48] Only isolates from patients who had been hospital inpatients for at least 48 hours were included. Nationally, 31.9% of *S. aureus* isolates were methicillin-resistant, with rates varying between states (see Table 6.5).

Table 6.5 Proportion of methicillin-resistant *Staphylococcus aureus* for all isolates, invasive isolates and non-invasive isolates by region

	All isolates	Proportion MRSA (%)	Invasive isolates	Proportion MRSA (%)	Non-invasive isolates	Proportion MRSA (%)
New South Wales/Australian Capital Territory	825	43	85	41	739	44
Queensland/Northern Territory	664	27	36	36	628	26
South Australia	340	25	34	29	304	24
Victoria/Tasmania	724	32	59	39	664	31
Western Australia	355	23	30	20	325	23
Australia	2908	3	244	36	2660	32
Difference across regions (Chi ²)		81.01		5.20		78.81
<i>P</i> value		<0.0001		0.267		<0.0001

MRSA = methicillin-resistant *Staphylococcus aureus*
 Source: Nimmo et al (2007)^[48]

Victoria

The Victorian Hospital-Acquired Infection Surveillance (VICNISS) program collects data from Victorian public hospitals for a range of hospital-acquired infections. Programs monitoring the rates of surgical site infection, ventilator-associated pneumonia and BSIs include causative organisms only. MRSA data are collected only by the smaller (type 2) hospitals and are reported in the VICNISS Annual Report, available on the website.²⁵ MRSA isolates are stratified into those identified within 48 hours of admission and those that occur after that time.

The Microbiological Diagnostic Unit at The University of Melbourne has coordinated the Victorian Hospital Pathogen Surveillance System (VHPSS), a voluntary laboratory-based scheme, since 1988. All significant bloodstream and cerebrospinal fluid (CSF) isolates together with sensitivity results are reported by participating laboratories and hospitals. Nineteen laboratories (including four private) participated in the 2006–07 period, reporting bacteraemias from 111 hospitals (75 public and 36 private, 52 metropolitan and 59 regional). An estimated 50–70% of all bacteraemias are reported via this scheme. Results are reported quarterly to participating laboratories and published in the Victorian Infectious Diseases Bulletin.

The Hand Hygiene Project has been supported by the Victorian Quality Council since 2004. As part of the project-outcome monitoring, all patient episodes of MRSA bacteraemia and all clinical isolates of MRSA are recorded. No clinical or epidemiological data are collected. Data are available for 75 hospitals in Victoria. This project has been extended as part of the Department of Human Services Start Clean Victorian Infection Control Strategy 2007–11.

Queensland

The Centre for Healthcare Related Infection Surveillance and Prevention (CHRISP) collects data from Queensland hospitals for a range of hospital-acquired infections. Data collected include health care associated BSIs and epidemiologically significant indicator organisms including MRSA. AICA definitions are used and only MRSA morbidity data are collected.²⁶ Data are not centrally aggregated or reported publicly.

New South Wales

In 1998, the Hospital Infection Standardised Surveillance Programme (HISS) was implemented as a strategy for monitoring HAI. Until 2007, HAI data on modified AICA surveillance indicators were collected collaboratively between the ACHS and New South Wales Health. From 2008, all public hospitals report MRSA and multi-resistant *Acinetobacter baumannii* (MRAB) acquisitions associated with intensive care admission and all health care associated *S. aureus* BSIs, including MRSA events. Reports are made directly to New South Wales Health.

Western Australia

MRSA is a laboratory notifiable disease in Western Australia. The Healthcare Associated Infection Surveillance Unit of the Communicable Diseases Control Directorate runs the state-wide hospital-acquired infection surveillance program. The program includes a module for monitoring MRSA morbidity using AICA definitions. Infection rates are stratified by specimen site (sterile or non-sterile) and patient location (ICU or non-ICU). Individual hospitals receive reports and aggregate reports are available on the website.²⁷ MRSA morbidity has been a mandatory key performance indicator for all public hospitals since 2006. The rates of all *S. aureus* BSI have been collected since the beginning of 2008.

²⁵ <http://www.vicniss.org.au/AnnualReport.aspx>

²⁶ <http://www.health.qld.gov.au/chrisp/default.asp>

²⁷ <http://www.public.health.wa.gov.au/3/277/3/surveillance.pm>

South Australia

The Communicable Disease Control Branch Infection Control Service of the South Australian Department of Health collects state-wide data on BSIs, multiresistant organisms (including MRSA), *Clostridium difficile* diarrhoea, and antibiotic use. AICA definitions for multiresistant organism surveillance indicators are used (MRSA burden, acquisition and morbidity). Participation in the system is not mandatory, but all metropolitan acute-care hospitals (including private hospitals) participate in most of the surveillance activities. Each contributor receives monthly reports for MRSA and antibiotic use, with their own rates and the state aggregate rate as comparators. Annual reports with more in-depth analysis of aggregated data are prepared for multiresistant organism infections and BSI. These reports are publicly available on the website.²⁸ There are plans to make *S. aureus* BSI a mandatory clinical indicator for all public hospitals in the near future. Figure 6.2 illustrates the results of state-wide efforts to control health care associated MRSA infections in ICUs.

Other states and territories

There is currently no state-wide collection of HAI data in Tasmania, the Northern Territory or the Australian Capital Territory.

6.4 Vancomycin-resistant enterococci

6.4.1 Background

Enterococci are intrinsically resistant to many antimicrobials, but in recent decades they have developed high-level resistance to aminoglycosides and penicillins, leaving vancomycin as the only effective antibiotic for treatment.

Infections caused by VRE were first noted in France and the United Kingdom in 1986.^[84, 85] Over the subsequent two decades, the incidence of hospital-acquired infection with VRE rose sharply, particularly in the United States and parts of Europe.^[86] The lack of a consistent approach to VRE infection surveillance makes comparison difficult, but the incidence of VRE infections appears to be rising worldwide according to data from England, Europe, the United States and AGAR.

Six glycopeptide-resistant enterococcal phenotypes — vanA, vanB, vanC, vanD, vanE, and vanG — have been described, distinguished on the basis of the level, inducibility, and transferability of resistance to vancomycin and teicoplanin. Van A and van B are the most clinically relevant. Vancomycin resistance is more common in *Enterococcus faecium* than in *Enterococcus faecalis*. Some experts believe that hospital outbreaks are almost exclusively caused by a specific genogroup of vancomycin-resistant *E. faecium* characterised by co-resistance to ampicillin and the presence of the variant *esp* gene, and that control programs should therefore be restricted to these strains.^[87]

²⁸ <http://www.health.sa.gov.au/infectioncontrol>

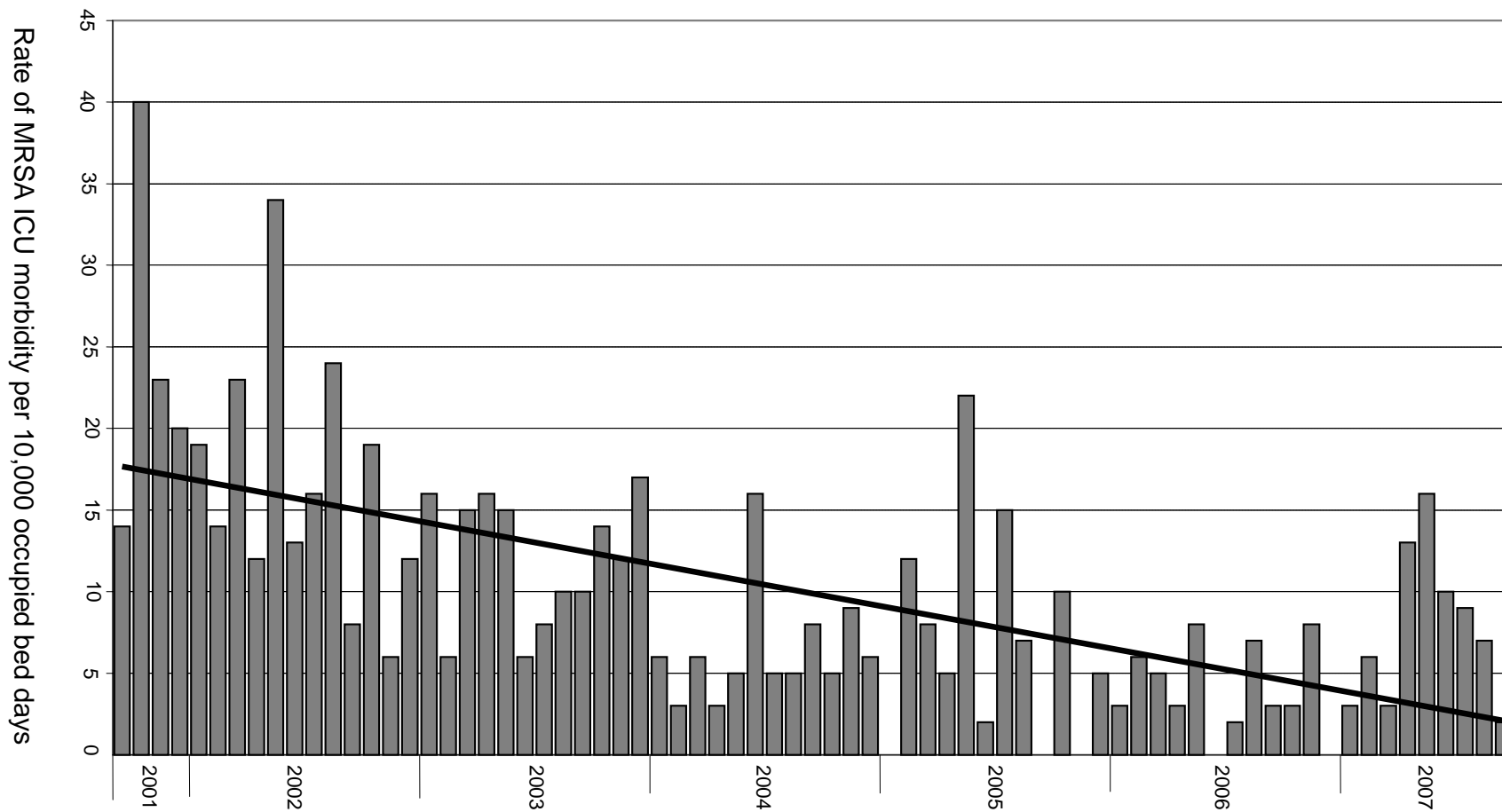


Figure 6.2 Changing methicillin-resistant *Staphylococcus aureus* intensive care unit morbidity across eight contributing hospitals (South Australia)

ICU = intensive care unit; MRSA = methicillin-resistant *Staphylococcus aureus*

The proportion of resistant *E. faecium* isolates in Europe in 2005 ranged from 0% to 46%. In the 2005 AGAR survey, 7.3% of *E. faecium* isolates were resistant, with a wide variation of 0–25% in the small number of isolates from different states. In contrast to European Antimicrobial Resistance Surveillance System (EARSS) surveys, only 10% of isolates in the AGAR survey were from sterile sites.

In Australia, the number of cases of VRE infections reported to state-wide surveillance programs is low. For example:

- in Victoria, 90 smaller hospitals (<100 beds) reported a total of seven infections (five in blood) over three years
- in Western Australia, 11 infections (seven in blood) were recorded on the Gram Positive Bacteria Typing Unit (GPBTU) database between 1998 and 2007
- in New South Wales, less than 15 sterile site infections were reported each year in 2003, 2004 and 2005
- in South Australia, only one new health care associated VRE infection has been detected in a sterile site since 2003.

The incidence of invasive infections with VRE appears to be relatively small in Australian hospitals, probably partly due to management of VRE-colonised patients to prevent cross-infection, particularly in high-risk areas such as ICU, haematology and oncology units, and dialysis centres.

VRE colonisation is much more common than infection and is an important risk factor for VRE infection. Colonised patients are the main reservoir for ongoing transmission of VRE in a health-care setting. Identification of VRE-colonised patients and implementation of contact isolation have been shown to be cost-effective and may reduce morbidity and mortality in populations at high risk for VRE acquisition.^[88, 89]

Routine surveillance markedly increases the detection of VRE compared to reliance on clinical specimens.^[90] Using mathematical models, passive surveillance without screening has been predicted to prevent few cases in high-risk settings.^[91]

6.4.2 Harm to patients from vancomycin-resistant enterococci

The consequences of infection with VRE are serious; for example, the mortality from VRE BSI is generally higher than that for infection with vancomycin-sensitive strains. Although some results are inconclusive, two meta-analyses concluded that vancomycin resistance is associated with greater rates of clinical treatment failure and recurrence, and higher all-cause mortality than infections with susceptible enterococci.^[92, 93] The 2005 study by DiazGranados and colleagues concluded that patients with bacteraemia caused by VRE were more likely to die than those with vancomycin-sensitive enterococcal bacteraemia, with a summary odds ratio of 2.52 (95%CI, 1.9 to 3.4).^[93]

6.4.3 Impact of vancomycin-resistant enterococci on the health-care system

Estimates of attributable excess costs (over and above costs of infections by susceptible enterococci) to treat VRE bacteraemia have ranged from US\$12,766 to \$81,208, with an associated excess length of stay of approximately 17 days.^[94, 95] Data comparable to those from the United States are not available from Australia.

The costs of controlling an established outbreak of cross-infection with VRE can be substantial. In South Australia, the cost of controlling a small outbreak involving nine patients in a

haematology unit was calculated at \$173,500. These costs included the additional cost of one-on-one nursing, additional cleaning, laboratory screening, the development of policies and information sheets, and education of staff.^[96] A much larger outbreak of a single strain of vanB vancomycin-resistant *E. faecium* in a Western Australian teaching hospital in 2003 involved 169 patients in 23 wards and cost \$2.7 million to control over a three-month period.^[97]

6.4.4 Current vancomycin-resistant enterococcus surveillance systems

Detection

Vancomycin resistance in enterococci is detected by either phenotypic or molecular testing. Broth enrichment followed by subculture on selective solid media has been recommended for patient screening swabs, although the concentration of vancomycin influences specificity and sensitivity.^[87] Several screening methods have been developed using stool specimens, rectal swabs or perirectal swabs. Isolation rates from stool are generally higher.^[87]

Molecular (polymerase chain reaction (PCR)) tests that detect the presence of vanA and vanB genes are more sensitive than direct plating and can lead to more rapid identification and earlier isolation of patients. However, the cost-effectiveness of molecular testing in comparison to direct plating is currently unknown.^[98] Systems to detect VRE are prone to false positives (due to the presence of vanB resistance genes in other bowel bacteria) and false negatives (due to insensitive direct culture screen methods or failure to use PCR detection of vanB in important enterococcal isolates such as those cultured from blood or sterile sites²⁹).

For every patient with VRE detected in clinical cultures, at least 10 others will be colonised. Asymptomatic carriers who remain undetected facilitate dissemination of VRE.^[87] Active surveillance cultures in specific high-risk patient groups, such as renal dialysis, intensive care and haematology–oncology, are therefore generally recommended in order to identify silent carriage.^[40]

International

A variety of systems have been used to monitor the impact and incidence of VRE infections in Australia and internationally, primarily based either on laboratory data or the rates of infections and colonisations in health-care institutions (ie patient-based surveillance). Patient-based surveillance generally requires clinical assessment and classification.

European Antimicrobial Resistance Surveillance System

EARSS is a network of laboratories in Europe that collaborate to monitor rates of key bacterial resistance patterns in isolates from blood and CSF cultures. The proportions of *E. faecium* and *E. faecalis* resistant to vancomycin and aminoglycosides are reported annually by country. Participating countries nominate laboratories that cover at least 20% of that country's population and a variety of demographic and health-care institutions.^[99]

England

Acute NHS trusts in England have been required to report all 'clinically-significant' bacteraemias caused by glycopeptide-resistant enterococci to the Health Protection Agency of the Department of Health since September 2003. Results are reported annually as the number of bacteraemia episodes per trust. Recommendations and findings from experts and participating trusts have been reported.^[100]

²⁹ <http://www.antimicrobial-resistance.com/> (Accessed 4 March 2008)

United States

A collaborative prospective study involving microbiology laboratories in Atlanta was carried out as part of the Georgia Emerging Infections Program between 1997 and 2000. All isolates of VRE identified from blood, CSF, pleural fluid, pericardial fluid, synovial fluid and sterile surgical sites were typed and clinical information was collected.^[101]

Australia

Many individual hospitals and facilities monitor detections and cases of VRE infection and colonisation internally. Only South Australia and New South Wales conduct comprehensive state-wide surveillance for VRE infection and colonisation.

Monitoring VRE infection rates without promoting and supporting the use of active surveillance is unlikely to reduce VRE incidence but may provide an indicator of the effectiveness of infection prevention and control programs in the high-risk areas where these infections occur. It may also inform empiric treatment and antibiotic usage policies.

Australian Group on Antimicrobial Resistance

AGAR periodically performs laboratory-based surveillance of resistance in enterococci in 22 Australian laboratories (based primarily at tertiary hospitals). In 2005, laboratory and clinical data were collected for 100 consecutive 'clinical' (non-screening) enterococcal isolates from each laboratory and used to estimate enterococcal resistance in states and nationally.^[102]

Western Australia

All new VRE isolates from Western Australian laboratories are sent to the Gram Positive Bacteria Typing Unit reference laboratory at the Royal Perth Hospital for confirmation and molecular typing. Results are reported every six months to referring laboratories. Standardised definitions of health-care acquisition, infection or colonisation are not applied.

Victoria

Only type 2 (<100 beds, non-metropolitan) hospitals in Victoria monitor episodes of health care associated VRE infection, which are then reported to the VICNISS coordinating centre using standardised definitions and methodology comparable to the AICA definitions. Results are available to participating hospitals and are published in the VICNISS annual report.³⁰ Larger hospitals report infecting organisms as part of SSI, central line associated BSI and ventilator-associated pneumonia (VAP) surveillance, but vancomycin resistance is not specified for enterococci.

South Australia

A voluntary collaborative of hospitals in South Australia reports all new health care associated acquisitions of VRE according to AICA definitions to the South Australia Infection Control Service. Information on the anatomical site of isolation and place of acquisition (ie ICU or non-ICU) is also collected. Incidence rates are reported annually using overnight occupied bed days as the denominator. Information on VRE is included in the annual multiresistant organism surveillance reports, which are available on the Infection Control Service website.³¹

New South Wales

New South Wales hospitals are required to report all new health care associated VRE detections. Definitions used are comparable to those used in South Australia and episodes are subclassified to fit ACHS indicator criteria (ie sterile or non-sterile site, acquired in ICU or non-ICU). Results

³⁰ <http://www.vicniss.org.au>

³¹ <http://www.health.sa.gov.au/infectioncontrol/>

are reported as the number of infections per 10,000 patient days to participating hospitals and as aggregate data in annual reports.³²

Table 6.6 summarises jurisdictional surveillance programs monitoring the occurrence of VRE infections.

Table 6.6 Jurisdictional surveillance programs monitoring the occurrence of vancomycin-resistant enterococci infections

Location	Type of surveillance program
National	Voluntary participation of 22 laboratories in AGAR periodic survey
Australian Capital Territory	No jurisdictional reporting but facilities investigate new VRE episodes using AICA definitions
New South Wales	Mandatory reporting of all new VRE infections or colonisations to New South Wales Health, classification comparable to AICA definitions
Northern Territory	No jurisdictional reporting
Queensland	No jurisdictional reporting, but all Queensland Health facilities include VRE episodes as indicator organisms specified in the Queensland Health Infection Prevention and Control Standard and use AICA definitions to classify episodes
South Australia	Voluntary reporting of all new health care associated VRE infections or colonisations to SA Infection Control Service using AICA definitions
Tasmania	Laboratory-based surveillance
Victoria	Type 2 (small, non-metropolitan) hospitals report via VICNISS, nil for other hospitals
Western Australia	Laboratory-based typing of new isolates at reference laboratory; hospitals investigate individual cases

AGAR = Australian Group on Antimicrobial Resistance; AICA = Australian Infection Control Association; VICNISS = Victorian Hospital-Acquired Infection Surveillance; VRE = vancomycin-resistant enterococci

6.5 Multiresistant gram-negative bacteria

6.5.1 Background

Highly transmissible resistance is a particular feature of antibiotic resistance among the gram-negative bacteria, especially the Enterobacteriaceae. Antibiotic resistance among enteric gram-negative hospital pathogens such as *Escherichia coli*, *Klebsiella pneumoniae*, *Proteus* and *Enterobacter* species has been a recognised problem for over 30 years.

Initially, resistance to aminoglycoside antibiotics was seen as the main marker of the type of organism likely to spread among highly compromised patients in health-care settings. More recently, the appearance of plasmid-mediated extended spectrum beta-lactamases (ESBLs) in gram-negative organisms has heralded the arrival of multidrug resistance in these hospital pathogens.^[103] Typically, these organisms are resistant to gentamicin and variably resistant to other key gram-negative antibiotics such as quinolones and carbapenems. Emergence of ESBL strains coincided with the introduction of third-generation cephalosporin antibiotics in the early 1980s.^[104]

More than 150 types of ESBL have now been described, and their rapid development following the introduction of any new beta-lactam antibiotic poses particular problems for treatment of

³² http://www.health.nsw.gov.au/health_pr/infection/prof/

infections caused by these strains. The detection of these enzymes in the laboratory is highly problematic, requiring a high degree of technical skill and the need for laboratory personnel to be alert to the development of new resistances and familiar with the methods for their detection.

The epidemiology and dynamics of spread of these organisms is complex. They are carried in the bowel and frequently contaminate the environments of colonised patients. Hands of staff and inanimate objects are thought to be the main vehicles of spread. Infections with ESBL *Klebsiella pneumoniae* occur particularly in patients managed in intensive care, neonatal intensive care, transplant services and other high-intensity units. Transfer of the resistance determinants (plasmids and transposons) into other gram-negative organisms has been observed.

According to a recent study by Bell and colleagues, the frequency of occurrence of ESBL-producing clinical strains varied widely across the Asia-Pacific and South African regions in 1998–99 (SENTRY Antimicrobial Surveillance Program).^[105] The frequency of occurrence of confirmed ESBL-producing *E. coli* varied from 0–1% for medical centres located in Australia to 13–35% for mainland China. The highest prevalence rates (>20%) of ESBL *K. pneumoniae* phenotypes were observed in all mainland Chinese centres, one Japanese and one Taiwanese centre, and in the Philippine, South African, and Singaporean centres.

Nonfermenting gram-negative bacteria represent the most serious problem of multidrug resistance. Important members of the group include *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, *Stenotrophomonas maltophilia*, and *Burkholderia cepacia*. These organisms are niche pathogens that primarily cause opportunistic HAIs in patients who are critically ill or immunocompromised. Multidrug resistance is common and increasing among this group of organisms, and a number of strains have now been identified that exhibit resistance to essentially all commonly used antibiotics, including aminoglycosides, antipseudomonal penicillins and cephalosporins, fluoroquinolones, and carbapenems.^[106]

The emergence and spread of multidrug-resistant *P. aeruginosa* and *A. baumannii* and their genetic potential to carry and transfer diverse antibiotic resistance determinants pose a major threat in hospitals. Some reports indicate that nearly 30% of imipenem-resistant *P. aeruginosa* strains possess a metallo-beta-lactamase.^[107] Their clinical significance is enhanced by their ability to hydrolyse all beta-lactams, including the carbapenems, and by the lack of any current or foreseeable clinically active inhibitor of these enzymes. The genes encoding metallo-beta-lactamases are often carried by integrons embedded in transposons, resulting in a highly transmissible genetic apparatus. Moreover, other gene cassettes within the integrons often confer resistance to aminoglycosides, precluding their use as an alternative treatment. The incidence of resistance to non-beta-lactam antimicrobial classes has escalated since 2000, particularly in Asia, Europe and Latin America, and less so in the United States and Canada.^[108]

Infection with antibiotic-resistant *Acinetobacter* species illustrates the growing number of challenges posed by antibiotic-resistant organisms. *Acinetobacter* species are widely distributed in nature and in the hospital environment.^[109] Most *Acinetobacter* infections are opportunistic in nature and develop in patients compromised by invasive diagnostic or therapeutic procedures.^[110] *A. baumannii* is recognised as the species associated with the majority of human infections, including HAIs. This organism's propensity to develop resistance to multiple antibiotics and its potential role as a reservoir of aminoglycoside resistance genes is a cause for concern.^[111, 112]

HAIs due to resistant *Acinetobacter* species are increasingly being reported, with many outbreaks of infection, particularly in ICUs.^[110, 113, 114, 115, 116, 117, 118, 119, 120, 121] In Australia, transmissible carbapenem resistance in *A. baumannii*^[122] and the Enterobacteriaceae^[123] and of high-level pan-aminoglycoside resistance in the Enterobacteriaceae^[124] has been reported. These resistances severely limit treatment options.

Emerging multidrug resistance in *Pseudomonas aeruginosa* is of particular concern for hospitals, especially in burns units and ICUs, where the risk factors for acquisition are highest. The Meropenem Yearly Susceptibility Test Information Collection (MYSTIC) program monitors worldwide in vitro susceptibilities of clinical bacterial isolates from centres that prescribe meropenem. A recent report focused on 107 isolates of multidrug resistant *P. aeruginosa*, which commonly causes infections that are difficult to treat in hospitalised patients. Samples were from patients from 33 European ICUs. There was considerable variation between countries in the proportion of *P. aeruginosa* that was multidrug resistant, ranging from 50% in Turkey to $\leq 3\%$ in Spain, the United Kingdom, Germany, Bulgaria and Malta.^[125]

Metallo-beta-lactamase (MBL)-producing *P. aeruginosa* has also been reported in Australia, with at least one report from a Melbourne hospital of transmission of a MBL-carrying strain involving 16 patients, most of whom had spent time in the ICU, between January and July 2004.^[126]

The key to reducing the selection and spread of MRGN is to restrict the use of certain classes of antibiotics, in particular third-generation cephalosporins. A 44% reduction in nosocomial multiresistant *Klebsiella* isolates was seen following an 80% reduction in the hospital-wide use of cephalosporins in an American hospital.^[20] In a Queensland teaching hospital, an 80% fall in isolates was seen following the introduction of cephalosporin restrictions in 1992.^[127] There is a strong mathematical relationship between the level of third-generation cephalosporins prescribed and the number of ESBL-producing *K. pneumoniae*.^[128] Dancer provides an extensive review of the impact of cephalosporins and the emergence of resistant gram-negative bacteria.^[129] Once the resistant organisms are present, control focuses on precautions to prevent transmission from patient to patient, including hand hygiene, isolation procedures, and environmental cleaning.

Difficulty with detection of MRGN is likely to be responsible for the lack of information regarding the burden of MRGN infections at a hospital level. Nevertheless, surveillance for infections caused by selected MRGN in high-risk patient populations such as intensive care and haematology–oncology units, where use of antibacterial agents is high, will provide a measure of the disease burden in these patient populations and may be used to alert clinicians to the necessity for antibiotic stewardship as a method of controlling the emergence and spread of resistance genes.

6.5.2 Harm to patients from multiresistant gram-negative organisms

The main harm to patients from infection with MRGN, as with other multidrug-resistant organisms, results from treatment failure, with associated increased risk of mortality and morbidity. For example, ESBL-producing *K. pneumoniae* causes a number of serious infections, including urinary tract infection, BSI and health care associated pneumonia.^[130] Risk factors for infection include admission to a teaching hospital, ICU stay, nursing home residence, comorbidity, central IV line, urinary catheter, longer duration of stay and previous antibiotic exposure.^[131, 132] Mortality from infection is high, ranging from less than 10% for those appropriately treated to 100% for those not treated with an antibiotic active against the organism.^[133]

The range of infections caused by *Acinetobacter* species includes intravascular line associated BSI, pneumonia (most usually ventilator-associated), post-neurosurgical infection, skin and wound sepsis, and urinary tract infection.^[109] Each of these is associated with a significant risk of mortality or complications such as disseminated infection. This risk is greatly increased in the case of infection with multidrug-resistant strains.

6.5.3 Impact of multiresistant gram-negative organisms on the health-care system

Schwaber and colleagues studied the clinical and economic impact of BSI with ESBL-producing Enterobacteriaceae using a case–control methodology.^[134] Thirty-five per cent of cases died versus 18% of controls (odds ratio (OR), 2.3; 95%CI, 1.1 to 4.5) and the median excess length of stay was six days. Cases were also more likely to be discharged to long-term care. The mean attributable cost was US\$9620 per case.

Serious infections due to carbapenem-resistant *P. aeruginosa* and *Acinetobacter* spp and ESBL-producing Enterobacteriaceae are associated with increased mortality and costs,^[135, 136, 137] especially in ICU,^[138] and are associated with a two to three-fold excess mortality.^[11, 139]

6.5.4 Current surveillance systems for multiresistant gram-negative organisms

Detection

Laboratory-based surveillance is the primary source of information about the epidemiology of resistant gram-negative bacteria. Phenotypic detection of some types of MRGN is prone to error — well-known examples of this are ESBLs and inducible third-generation cephalosporin (3GC) resistance (AmpC in ESCHAPPM organisms³³).^[123, 140, 141] Automated identification systems are in widespread use. However, these systems often fail to correctly identify transmissible carbapenem resistance in the Enterobacteriaceae. Instead, these organisms are often mistaken for ESBLs,^[142] for which meropenem is generally recommended; such treatment may in turn select for a carbapenem-resistant phenotype.

These limitations of gram-negative organism phenotypic testing mean that detection of resistance genes by molecular methods in gram-negative bacteria is sometimes more useful than identification of the infecting species. This poses challenges for the routine diagnostic laboratory and for surveillance of infection due to these organisms.

A number of resistance surveillance programs in various countries detect MRGNs as part of their overall surveillance.

International

International programs include the SENTRY Antimicrobial Surveillance Program and MYSTIC. Both are funded by the pharmaceutical industry. SENTRY is co-ordinated by JMI Laboratories in Iowa,³⁴ with the Asia-Pacific component being run from the Antimicrobial Research Laboratory at the Women's and Children's Hospital in Adelaide. MYSTIC focuses on meropenem resistance along with comparator agents in a broad range of gram-negative organisms.³⁵

The Intensive Care Antimicrobial Resistance Epidemiology (ICARE) project is a CDC collaboration that focuses on monitoring resistant organisms in ICUs; it collects data from a number of participating countries.³⁶

³³ *Enterobacter*, *Serratia*, *Citrobacter*, *Hafnia*, *Aeromonas*, *Proteus*, *Providentia*, and *Morganella* spp typically possess AmpC-type inducible cephalosporinases and typically have a ceftazidime-resistant (FOX^R) phenotype, which is also evident in non-ESCHAPPM bacteria such as *E. coli* and *Klebsiella* spp, with plasmid-encoded AmpC enzymes.

³⁴ <http://www.jmilabs.com/surveillance/default.cfm>

³⁵ <http://www.infectionacademy.org/surveillance/>

³⁶ <http://www.sph.emory.edu/ICARE/index.php>

Scandinavia

Comprehensive national surveillance programs are well established in Denmark (Danish Integrated Antimicrobial Resistance Monitoring and Research Program³⁷), Sweden (Swedish Antibiotic Utilisation and Resistance in Human Medicine Report³⁸) and Norway (NORM/NORMVET³⁹), each covering MRGNs in both the human and veterinary fields.

Europe

EARSS,⁴⁰ funded by the European CDC, monitors resistance in human isolates of sentinel gram-negative organisms *E. coli*, *K. pneumoniae* and *P. aeruginosa*.

United States

The United States runs the Active Bacterial Core Surveillance program⁴¹ through the CDC, but this monitors only one gram-negative species, *Haemophilus influenzae*. The United States Food and Drug Administration also funds the National Antimicrobial Resistance Monitoring System (NARMS).⁴² Bacterial isolates are collected from human and animal clinical specimens, from healthy farm animals and from raw product from food animals. The human component monitors only enteric pathogens (*Salmonella*, *Campylobacter* and *E. coli* O157).

Japan

A program similar to NARMS for veterinary and food animal isolates, called the Japanese Veterinary Antimicrobial Resistance Monitoring Program, is run in Japan.⁴³

New Zealand

The Institute of Environmental Science and Research collects data on ESBL-producing *E. coli* and *Klebsiella* species on a periodic basis and publishes summary reports annually on its website.⁴⁴ The 2006 report indicates a significant increase in the prevalence of ESBL producers from urinary isolates of *E. coli* and *Klebsiella* compared to previous surveys in 2000 and 1993. Data were not collected on whether isolates were hospital or community acquired.

Australia

The only system of active national surveillance for resistance in gram-negative organisms is laboratory-based and conducted by AGAR. A new survey is scheduled for 2008.

In 2004, AGAR prospectively collected unselected unique clinical isolates of *E. coli*, *Klebsiella* and *Enterobacter* species from 25 institutions in Australian capital cities and tested them for sensitivity to 15 key antibiotics.⁴⁵ The survey revealed that 6.5% of *E. coli* and 8.3% of *K. pneumoniae* clinical isolates cultured in participating Australian laboratories were resistant to three or more classes of antibiotics. ESBL enzymes are still uncommon in Sydney but are well established in community strains of *E. coli* and *K. pneumoniae*, highly transmissible on R plasmids and strongly associated with aminoglycoside resistance, much of it co-transmissible.^[124]

³⁷ <http://www.danmap.org>

³⁸ <http://en.strama.se/dyn/84,,.html>

³⁹ <http://www.vetinst.no/eng/>

⁴⁰ <http://www.rivm.nl/earss/>

⁴¹ <http://www.cdc.gov/ncidod/dbmd/abcs/index.htm>

⁴² http://www.fda.gov/cvm/narms_pg.html

⁴³ [http://www.nval.go.jp/taisei/etaisei/JVARM\(text%20and%20Fig\)%20Final.htm](http://www.nval.go.jp/taisei/etaisei/JVARM(text%20and%20Fig)%20Final.htm)

⁴⁴ <http://www.esr.cri.nz/competencies/communicabledisease/CD+Surveillance+Reports.htm>

⁴⁵ <http://www.agargroup.org/surveys>

Monitoring the emergence and evolution of resistance in gram-negative organisms requires a two-pronged approach based on local surveillance of infection in key high-risk patient populations, such as intensive care and haematology–oncology units with high antibiotic usage, coupled with a nationally coordinated system of targeted laboratory-based surveillance.

The ICU environment is an excellent barometer of resistance development and is an important clinical situation to survey regularly, providing insights into decisions on hospital-wide or regional screening, infection control and antibiotic use strategies.

In order to determine the burden of infection with MRGN, additional clinical information will be required, such as the type of infection and whether the infection is community or health care associated. This is especially important in the case of ESBL producers, since a large proportion of community-onset urinary tract infections have been shown to be caused by these organisms.

South Australia

South Australia is the only Australian state that conducts state-wide surveillance on infections with MRGN. The program targets four priority resistances in gram-negatives and uses the AICA definitions for multiresistant organism surveillance. All new acquisitions are recorded and information is collected on infection status and whether the infection is ICU or non-ICU-acquired. The organisms targeted for surveillance are:

- *P. aeruginosa* resistant to at least one antibiotic from two or more of the following antibiotic classes (isolates from cystic fibrosis patients are not included):
 - beta-lactams (eg piperacillin, ticarcillin, ceftazidime, cefipime, imipenem)
 - aminoglycosides (gentamicin, tobramycin)
 - fluoroquinolones (ciprofloxacin, norfloxacin)
- ESBL-producing Enterobacteriaceae
- metallo-beta-lactamase producers
- carbapenem-resistant *Acinetobacter* species and Enterobacteriaceae.

Results are reported annually and are available from the Infection Control Service website.⁴⁶ The aggregate rate of new acquisitions of MRGN remains low in participating South Australian hospitals: <1 per 10,000 occupied bed days. For the larger (>300 beds) tertiary referral hospitals, the aggregate rate is approximately 2 per 10,000 occupied bed days. The majority of these are associated with ICUs.

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7 *Clostridium difficile* associated disease

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Key points

- *Clostridium difficile* is a common health care associated infection that causes significant patient morbidity and mortality, as well as adds to health-care costs. Almost all cases follow the use of antibiotics, and the major reservoir of infection is infected patients in hospitals or long-term care facilities.
- The emergence of a novel strain of *C. difficile* (NAP1/027(B1/NAP1)) in North America and Europe has been associated with increased frequency, severity and relapse of *C. difficile* disease.
- Principles of *C. difficile* prevention include antibiotic stewardship, monitoring of incidence and outbreaks, appropriate use of contact precautions, accurate identification of infected patients, consistent hand hygiene and improved environmental cleaning.
- A variety of surveillance systems and definitions have been used to monitor infection rates. Recently published international recommendations and definitions support implementation of an appropriate surveillance program in Australia.

Recommendations on *Clostridium difficile* associated disease

1. Early warning and response capabilities for *C. difficile* associated disease (CDAD) should be developed to include:
 - reporting of severe cases to jurisdictions and nationally
 - ensuring culture for *C. difficile* occurs across a wider spectrum of laboratories.
2. Strain typing and surveillance for *C. difficile* is required nationally, including testing for the presence of the emerging, highly virulent NAP1/027 strain.
3. *C. difficile* surveillance results should be linked with antibiotic use data from each facility to highlight specific drivers of local *C. difficile* incidence.
4. National guidelines for prevention, control and outbreak management of CDAD (including isolation) should be accessible and current.

7.1 Background

Clostridium difficile is the most common cause of infectious hospital-acquired diarrhoea in developed countries. It is found in the stool of 15–25% of patients with antibiotic-associated diarrhoea and more than 95% of patients with pseudomembranous colitis (PMC).^[1] *C. difficile* associated disease (CDAD) has a significant impact on modern health care. International studies show that infected patients spend an extra 1–3 weeks in hospital, costing €5000–15,000 per case.^[2] Age is a risk factor for the development of CDAD; thus, the impact of CDAD is expected to rise as the population ages. A thorough understanding of the epidemiology of CDAD at a local, national and international level is necessary to minimise this impact. This epidemiological knowledge is not currently available in Australia. The absence of surveillance also means it is difficult to detect any alteration of the status quo; for example, an upsurge in cases similar to that reported in the United States and Europe. It seems prudent to consider options for future CDAD surveillance at a jurisdictional level.

The emergence of a new, highly virulent strain of *C. difficile* in North America and Europe since 2003 has caused extensive morbidity and mortality, leading to heightened awareness of this pathogen and rapid advances in surveillance methods internationally. There have been no reports of this strain in Australia as yet, but local capacity to detect and respond to such an occurrence is limited.^[3] Additionally, levels of antibiotic use in Australia are likely to further the spread of such a strain among community and hospital populations once it is introduced.

This chapter outlines:

- the harm to patients from CDAD (Section 7.2)
- the impact of CDAD on health-care systems (Section 7.3)
- methods for surveillance of *C. difficile* (Section 7.4)
- surveillance systems and data for *C. difficile* (Section 7.5)
- CDAD prevention and control (Section 7.6).

7.2 Harm to patients

CDAD remains the single most frequently occurring health care associated infection (HAI) in hospitals in developed countries. In the United Kingdom in 2003, twice as many deaths were attributed to *C. difficile* as to methicillin-resistant *Staphylococcus aureus* (MRSA). While MRSA rates are falling in the United Kingdom, CDAD rates continue to rise.^[4] England, Wales and Northern Ireland reported 44,403 cases of *C. difficile* disease in persons aged 65 years and over in 2004, 50,912 in 2005 and 55,213 in 2006. This represents a 24% increase in reported incidence in just two years.^[4]

C. difficile is transmitted via the faecal–oral route when either vegetative bacteria or, more likely, spores are ingested. Exposure occurs during contact with infected patients or their environment.

In general terms, recognised risk factors for CDAD can be grouped as those that:

- disrupt normal colonic flora (eg antibiotics, some antineoplastic agents)
- increase the likelihood of exposure of an individual to *C. difficile* (eg hospitalisation or residence in a long-term care facility)
- increase susceptibility to colonisation once an individual is exposed (eg gastric acid suppression, nasogastric feeding and old age).

The incidence of community-acquired cases may be underestimated and increasing; however, most cases continue to occur in hospitals or long-term care facilities. In a recent detailed hospital study from the United States, 91% of patients had been exposed to a health-care service within the previous 90 days.^[5] Even in the ambulatory care setting, most cases are associated with recent inpatient health care. In one study, 78% of cases had been discharged from an acute-care facility within 100 days of the diagnosis of CDAD.^[6]

Hospitals and residential aged-care facilities provide a high concentration of intrinsically susceptible individuals, high rates of antibiotic usage and, if CDAD cases are present, multiple opportunities for transmission of toxigenic *C. difficile* strains. Shared equipment, a contaminated environment or the hands of health-care workers (HCWs) are the most common means of transmission. *C. difficile* can be readily cultured from inanimate environmental sources such as beds, cupboards, floors and walls, as well as from the hands of HCWs caring for patients with CDAD.^[7] Lapses in infection control in such environments then expose highly susceptible patients to the risk of colonisation.

Independent risk factors for CDAD in hospitalised patients relate to the risk of an individual being exposed to, and then colonised with, toxigenic *C. difficile* strains. These factors include:

- physical proximity to a symptomatic case (attributable risk 12%)^[8]
- transfer of patients between wards or between institutions^[9]
- CDAD pressure — the number of patients in the facility who are infected or colonised with *C. difficile*^[10]
- environmental contamination and, as a corollary, poor standards of environmental cleaning
- duration of hospitalisation^[11]
- medical patients as opposed to surgical patients^[1, 12, 13]
- having a nasogastric tube in place
- receiving specific antibiotics
- increased duration of antibiotic therapy
- older age
- other comorbidities or debilitation
- immunodeficiency and chemotherapy.^[1, 14]

In most series, more than 90% of patients with symptomatic CDAD have a history of receiving antibiotics. One recent study found that 99% of patients with a first episode of CDAD had received antibiotics within 90 days before diagnosis.^[6] Although CDAD has been described following exposure to all antibiotics except aminoglycosides, some agents appear to have a higher chance of disruption of normal colonic flora and pose a higher risk.

The first antibiotic to be associated with CDAD was clindamycin; however, in recent years, infection has been linked to the use of third generation cephalosporins and fluoroquinolones.^[15] In general, treatment with broad spectrum antibiotics is more likely to lead to CDAD than treatment with narrow spectrum antibiotics.^[14] However, measuring complex patterns of antibiotic usage is challenging and many studies have a suboptimal study design with no or poorly selected controls.^[16]

The effects of specific antibiotic usage rates on CDAD rates have been demonstrated in outbreak situations, and in a non-outbreak situation in Western Australia (where reduced third generation cephalosporin use was associated with reduced CDAD incidence).^[17] *C. difficile* colonisation or disease can occur after only a single antibiotic dose but it is more common with longer durations of therapy and multiple different antibiotics.^[1, 12, 14, 18]

Because of changes in faecal flora, host defences and increased medical comorbidities, advanced age has been associated with both a higher risk of CDAD and worse outcomes in multiple studies.^[17, 19, 20, 21, 22] In one study from the United States, the rate of CDAD discharge diagnosis from 1996 to 2003 in those over 65 years was 228 per 100,000; more than 5 times that of 45–64 year olds and 20 times the rate for 15–45 year olds.^[20] In one of the few studies done in Western Australia detailing CDAD epidemiology, more than 60% of patients in an adult teaching hospital who had *C. difficile* were aged over 60 years and the incidence was significantly higher than in patients less than 60 years of age.^[17]

The rate of CDAD also appears to be rising disproportionately in older age groups in the United States, Canada and France.^[20, 23, 24] This may reflect the inherent virulence of a novel strain emerging in those countries, but a similar increase has been noted even in the absence of a novel

strain. Host factors such as increasing age, debility and antibiotic treatment of hospital inpatients are also likely to be important.^[14]

Case-control and cohort studies in the United Kingdom, United States and Canada in both hospital and community settings have found gastric acid suppressants, particularly proton pump inhibitors, to be independent risk factors for CDAD, with an odds ratio consistently around 2.^[12, 25, 26, 27, 28] However, in a Canadian intensive care unit (ICU), this association was not found.^[25]

Reported incidence rates of CDAD in hospitals and long-term care facilities vary significantly due to differing antibiotic usage patterns, case mix, endemic strains, infection control practices and case definitions. Incidence rates ranging from 0.5 to 30 cases per 1000 discharges have been reported.^[29]

7.2.1 New epidemic *Clostridium difficile* associated disease

An increase in the frequency, severity and rates of relapse of CDAD was reported in a number of hospitals in Quebec, Canada, in the early 2000s.^[24, 30] Incidence rates increased from 3–12 per 1000 admissions between 1991 and 2002 to 25 per 1000 admissions in 2003 and 43 per 1000 admissions in 2004. While incidence increased 4-fold in total, the increase was 10-fold in persons older than 65 years of age, and attributable mortality was 16.7%.^[22]

The suspicion that a new, more virulent strain of *C. difficile* was responsible for these common epidemiological findings was confirmed by analysis of isolates from North American sites.^[18, 31] In Europe, outbreaks of the same strain have subsequently occurred in England, Wales, Ireland, the Netherlands, Belgium, Luxembourg and France, and epidemic strains have been detected in Austria, Scotland, Switzerland, Poland and Denmark.^[32] In each case, more frequent and severe CDAD was noted and the same strain was subsequently isolated.

This novel epidemic strain is variously known as North American PFGE type 1, restriction enzyme analysis type BI, and polymerase chain reaction (PCR) ribotype 027 (NAP1/BI/027 strain). Analysis of the strain has revealed three factors that may be responsible for the observed increased virulence and frequency:^[31]

- production of *C. difficile* toxins A and B in greater quantities in vitro (due to a mutation in a regulatory gene *tcdC*, resulting in upregulation of toxin production)
- production of an additional (binary) toxin (although its role in disease pathogenesis is currently unclear)
- resistance in vitro to fluoroquinolone antibiotics.

Case-control studies designed to assess risk factors for patients developing CDAD with this novel strain suggest an association with fluoroquinolone use.^[31] The recent acquisition of resistance to the newer fluoroquinolones may have facilitated the wide dissemination of this new, hypervirulent clone as previous strains that were identical, except for this resistance, were only involved in sporadic cases.^[18, 32] An alternative hypothesis is that the increased virulence and diarrhoeal symptoms promote cross-infection and spread.^[32]

Detection of the novel strain relies on culturing the organism and referring the isolate to a specialised reference laboratory for identification. Many Australian laboratories do not routinely attempt to culture *C. difficile*, instead relying on toxin detection assays for diagnosis. In the absence of such culture and identification, the early detection of a new and more virulent strain of *C. difficile* in Australia would be difficult, relying primarily on the recognition of changes in the clinical pattern or incidence of disease.

The consensus view is that the management of individual CDAD cases resulting from this novel strain should follow standard guidelines.^[31] As the course of disease is likely to be severe, there may be a role for early empirical treatment of suspected cases in a hospital or facility where this pathogen has been detected. The view of oral vancomycin as the preferred agent has been challenged recently by Canadian researchers who found that the emergence of NAP1/BI/027 coincided with a loss of superior effectiveness of vancomycin compared to metronidazole.^[19, 31, 33] Prevention measures are similar to routine measures for CDAD. Outbreaks of this epidemic strain have been successfully controlled in numerous hospitals and jurisdictions.^[34, 35]

7.3 Impact on health-care systems

The impact of CDAD on the health-care system is considerable. Patients with CDAD require additional infection control precautions, ongoing supportive and specific treatment, and improved hygiene measures; also, they spend 1–3 additional weeks in hospital. The costs of treatment have been estimated at €5000 to €15,000 per case, or £340 million a year in the United Kingdom and US\$1.1 billion a year in the United States.^[2] In a single state in the United States comparable in population to New South Wales, the total direct cost of health care for CDAD was estimated to be US\$51.2 million over two years.^[36]

7.4 Surveillance methods for *Clostridium difficile* associated disease

CDAD surveillance programs and results are rapidly evolving internationally.

The appearance and rapid global spread of a new, more virulent strain of *C. difficile* has led to calls for increased monitoring of CDAD in Australia.^[3] Surveillance has been an effective tool to document incidence and evaluate infection control interventions elsewhere.^[18, 35, 37] A critical review of the surveillance systems in place in other countries and local experience with CDAD surveillance will help to determine optimal methods.

An international consensus on CDAD case definitions is emerging that will support future CDAD surveillance. This consensus is an important step, allowing the evolution of accepted benchmarks and measures to evaluate prevention programs. Broadly, there are two proposed approaches for monitoring CDAD rates: the first is based on laboratory detection of CDAD cases (see Section 7.4.1), while the second is based on monitoring clinical events in patients (eg severe disease or outbreaks). Both of these approaches have advantages and have been used in various countries to monitor CDAD incidence and impact.

The main areas of difference between definitions currently in use relate to the definition of a health care associated case — specifically the use of either 48 or 72 hours after admission — and incorporation of past hospitalisation into criteria (see Table 7.1). The draft European surveillance definitions used 72 hours as a cut-off period; however, the final published version used 48 hours.^[2] This change reflects the reality of an emerging and evolving area of health-care epidemiology.

Incorporating recent hospitalisation into definitions involves a balance between what is pragmatic and possible, and what is epidemiologically accurate. In the absence of a universal electronic health record, incorporating these data requires review of the medical record or patient interview for each case, adding to complexity and resource requirements. In addition, the increasing provision of health care on an outpatient basis blurs the boundaries of what constitutes a health care associated case.

Does this variation in definition have an impact on calculated disease rates? Using a fixed dataset, a group of United States researchers estimated the impact varying case definitions have on the calculated incidence rates of health care associated CDAD.^[38] The strictest definition of health care associated CDAD (positive toxin test collected three or more days after admission) resulted in a 30% lower estimate of health care associated CDAD risk than did the most inclusive definition (positive test result more than two days after admission or hospitalised within 30 days of test result). This study provides useful insights into analysing various published incidence rates.

Patient-based and laboratory-based surveillance systems provide complementary information. True patient-based surveillance systems can allow monitoring of key clinical outcomes not easily captured in a laboratory-based system, such as outbreaks of disease or severe episodes of disease. Collecting data from selected individual cases means that incidence cannot be calculated. However, these individual data are useful to inform future refinement of case definitions, answer important research questions, and suggest the underlying risk of CDAD in different patient populations in order to better compare rates.

7.4.1 Detection: laboratory diagnosis — methods and impact

CDAD should be suspected in any adult with diarrhoea during or following antibiotic treatment, because *C. difficile* is the most common infective cause of diarrhoea in this population.^[39] However, because CDAD will be implicated in only 30% of hospitalised patients with diarrhoea, specific testing for CDAD should be performed if the diagnosis is suspected. Only watery or loose stools should be tested for *C. difficile* because the rate of asymptomatic colonisation in hospitalised patients without diarrhoea is high. A positive test in an asymptomatic patient proves colonisation but not infection, and treatment is ineffective in clearing the organism in the absence of diarrhoea.^[1]

C. difficile can be cultured on specific media from stool specimens. It can also be detected by molecular methods such as the PCR. However, as 10–30% of hospitalised patients are colonised with *C. difficile*, the diagnosis of CDAD requires the demonstration of *C. difficile* toxins or toxin-producing genes either in diarrhoeal stool specimens or in an isolated organism.^[31] The exception to this is pseudomembranous colitis, a severe and pathognomonic presentation of CDAD, which can be diagnosed with confidence by characteristic endoscopy or histopathology.

A number of different methods are used to detect *C. difficile* toxins. Each has advantages and disadvantages, and which test is used depends on local laboratory expertise and resource availability, as well as on diagnostic accuracy. While the optimal strategy is likely to depend on local factors and be influenced by regulatory and economic constraints, it is clear that variation in testing strategy will affect reported incidence rates. Laboratory methods therefore need to be considered in any analysis of published incidence figures or in deciding what kind of local surveillance program to adopt.

7.5 Current surveillance systems and data

7.5.1 International studies

United Kingdom

The United Kingdom uses both laboratory-based and patient-based surveillance, supported by typing of isolates at a reference laboratory. Various elements of the surveillance program are mandatory, as indicated in the following text.

Laboratory-based CDAD surveillance coordinated by the Department of Health has been mandatory in England since January 2004 and in Scotland since 2006. Cases included are patients with diarrhoeal stools that test positive for *C. difficile* toxin (where the patient has not been diagnosed with CDAD within the preceding four weeks). Until April 2007, only patients over 65 years of age were included, but since that date the age limit has been revised downward to two years of age. As of April 2007, data on whether the case is a hospital inpatient or not must be submitted every month. Incidence rates are publicly reported monthly for each health-care trust using overnight bed days (adjusted for the appropriate age range) obtained from a central data repository.^[40]

To augment this existing laboratory-based surveillance, an 'enhanced' surveillance program is planned, for use on a voluntary basis. The program will require submission of additional clinical information, including severity and outcome of CDAD for each case. In addition, outbreaks of CDAD (using a standard definition) must be notified to the local health authorities by all acute trusts in a complementary patient-based surveillance system.

The availability of a reference laboratory to characterise *C. difficile* isolates provides additional information. There is a mandatory sampling scheme to obtain isolates from all English laboratories. Laboratories can also voluntarily submit *C. difficile* isolates to this service for typing.

A survey of the United Kingdom CDAD surveillance program in 2005 evaluated laboratory practices and compliance with patient-based surveillance requirements. A significant number of trusts did not comply with requirements for the laboratory-based system because of inappropriate exclusions and inclusions. There was also inconsistency in implementation of the patient-based program. Less than half of trusts used the standard definition of an outbreak and 40% did not inform appropriate authorities when an outbreak occurred.^[41]

Although CDAD incidence in the United Kingdom has increased while monitoring has been in place in the country, the increase may have been greater had monitoring not been taking place. However, a monitoring system does not reduce infections unless effective preventive actions and clinical accountability and investment follow. These appear to have been lacking.

France

Following concern about the increasing severity of CDAD and the emergence of NAP1/BI/027 in Europe, national CDAD monitoring began in France in February 2006 through a national patient-based surveillance system. Final recommendations for diagnosis, surveillance and notification of CDAD were issued in May of that year.^[32]

The patient-based surveillance scheme requires French hospitals and nursing homes to notify severe CDAD cases or clusters of cases to local public health authorities, who then coordinate investigation supported by a network of reference laboratories. When data were analysed in 2007, it was concluded that this system was efficient in detecting, controlling and tracing NAP1/BI/027 as long as infection control units and professionals in the health-care facilities supported it. The drawback, however, was that it does not easily produce incidence data. As a result, a voluntary prospective surveillance scheme is currently being implemented to allow calculation of incidence rates. Health-care facilities will collect the number of cases each month in total, by origin (health care or community associated) and by severity. Incidence rates will be reported using the number of patient days as a denominator. For one month each year, all culture isolates will be sent to the reference laboratory for typing. The definitions proposed by the European Centers for Disease Control and Prevention (CDC) will be used.^[23]

Belgium

Laboratory-based prospective surveillance of CDAD incidence is conducted in Belgian acute-care hospitals. CDAD clusters are notified to local authorities. National guidelines were disseminated in June 2006 but evaluation or results have not yet been published.^[32]

Netherlands

CDAD guidelines for infection control and treatment were issued in October 2005 and resources directed to diagnostic laboratories. A national patient-based surveillance program monitors for severe cases or case clusters and refers isolates from these events to a national reference laboratory for investigation and characterisation.^[32] In addition, periodic laboratory-based prospective incidence studies have been undertaken since 2005.^[42] Recently published results from a two-month period involving 13 laboratories and 17 hospitals found a median incidence rate of 16 per 10,000 admissions or 2.2 per 10,000 patient days with wide variations.^[43] This study used molecular typing and led to the discovery of an outbreak of NAP1/BI/027, which had not been detected via patient-based surveillance methods.

Germany

A voluntary national prospective surveillance program for CDAD was initiated in Germany in 2007 (titled 'CDAD-KISS', where KISS is the Krankenhaus Infektions Surveillance System — Germany's Nosocomial Infection Surveillance System). The program is similar to the French model, using standardised definitions to estimate the incidence of health care associated cases, but the definitions differ slightly from those proposed by the Euro CDC.^[44]

United States

Although CDAD surveillance by hospitals is recommended by the national CDC, there is as yet no national surveillance program in the United States.^[18] A consensus recommendation for standardised definitions has recently been proposed.^[45] Surveillance methods reported in published studies from the United States vary.

In 2006, the state of Ohio mandated reporting of health care associated CDAD cases by acute-care hospitals and nursing homes using a laboratory-based surveillance system.^[36, 46] The rate of initial cases in Ohio hospitals was 7–8 per 10,000 patient days and that of recurrent cases was 1–2 per 10,000 patient days. The system is reported to have facilitated the recognition and management of two outbreaks at health-care facilities. Personnel costs were US\$2,486,000 for the year.^[46]

Canada

Canada has been carrying out periodic laboratory-based CDAD surveillance in hospitals since 1997. Selected tertiary teaching hospitals (Canadian Nosocomial Infection Surveillance Program (CNISP) hospitals) participated in a voluntary prospective laboratory-based CDAD surveillance program in 1997 and 2004–05. Since 2007, participation has been mandatory for all major teaching hospitals. Nationally agreed case definitions are used and CDAD cases are classified as hospital acquired or not. The total number of monthly CDAD cases and denominator data are submitted every three months to a central health authority. During a two-month increased surveillance period each year, additional detailed patient information including age, gender, admission date, symptom onset, source of infection and clinical outcome is collected and cultured isolates are submitted for laboratory characterisation at a central reference laboratory.^[47]

Individual Canadian provinces have been carrying out their own prospective laboratory-based CDAD surveillance, most notably in Quebec, where the impact of NAP1/BI/027 has been

greatest. This surveillance documented a 40% decrease in incidence compared with the model's forecast between 2004 and 2005.^[35]

The 2005 national CNISP survey showed a wide variation between hospitals. The mean incidence of CDAD ranged from 6 per 1000 admissions to 78 per 100,000 patient days, an overall decrease since 1997; however, there was a significantly elevated death rate in the two provinces with the highest incidence of NAP1/BI/027.^[37]

7.5.2 Australia

Draft definitions for laboratory-based CDAD surveillance were proposed in 2002 but have not yet been widely adopted. The proposed case definition includes detection of the organism or toxin by any method and does not require symptoms, diarrhoea or a positive toxin test (see Table 7.1).^[48]

Estimates of incidence using this definition are likely to be higher than those using more detailed definitions. However, they are more easily derived from routine laboratory data. *C. difficile* is not notifiable to public health authorities in any jurisdiction in Australia. There are no known formal patient-based surveillance systems for notification of severe cases of CDAD or of CDAD outbreaks, and no recognised reference laboratory for *C. difficile* typing. Very little information has been published about the clinical or molecular epidemiology of *C. difficile* in Australia.

Western Australian researchers used laboratory and administrative data to retrospectively estimate CDAD incidence in a single adult teaching hospital from 1993 to 2000.^[17] A positive culture or toxin test fulfilled the case definition. The incidence rate calculated using this case definition and the number of total discharges was 1.88 cases per 1000 discharges (95%CI, 1.94 to 2.34), with women and patients over 60 years having a significantly higher overall incidence.^[17] The case definition used and high frequency of *C. difficile* testing (88–96% of all stools received each year tested) is likely to have resulted in a higher incidence rate than studies requiring symptoms, toxin positivity or a more selective approach to testing.

Results of a prospective multicentre CDAD laboratory-based surveillance program undertaken in Western Australia in 2006 have not yet been published. CDAD cases were defined as cases of diarrhoeal stool with *C. difficile* toxin detected by the facility's microbiology laboratory. Health care associated cases were those with onset more than 72 hours after admission or within 30 days of discharge. The incidence of health care associated CDAD in this group of nine Western Australian hospitals was 1.2 per 10,000 overnight occupied bed days (95%CI, 0.9 to 1.6). Incidence rates ranged from 0 to 3.3 at the hospitals (H Van Gessel, Coordinator, Office of Safety and Quality in Healthcare, Department of Health, Western Australia, pers comm, 2008).

The South Australian Department of Health established a pilot prospective hospital laboratory-based CDAD surveillance system in 2006 and is yet to fully evaluate its findings. Data were collected by the infection control professionals at 14 metropolitan hospitals and submitted monthly to the Department of Health Infection Control Service. Cases were defined as any patient with laboratory-confirmed CDAD by toxin assay and/or culture and were designated as either hospital onset (if diarrhoea commenced more than 24 hours after admission) or community onset. No attempt was made to trace prior hospital contact in those patients admitted with diarrhoea. Preliminary findings indicate an incidence of hospital-onset CDAD of 0.9 per 10,000 overnight occupied bed days (range 0 to 1.9). This is likely to be an underestimate of the true rate, because a proportion of the admitted cases may well have had prior hospital contact (I Wilkinson, Manager, Infection Control Service, Department of Health, South Australia, pers comm, 2008).

A summary of surveillance definitions is shown in Table 7.1.

Table 7.1 Comparison of *Clostridium difficile* associated disease surveillance definitions

	UK ^[40]	Canada CNISP ^[47]	Germany CDAD- KISS ^[44]	Australia AICA ^[48]	Euro CDC ^[2]	US CDC ^[45]
Laboratory criteria	Toxin + diarrhoea	Diarrhoea / other symptoms PLUS toxin-positive stool OR PMC	Diarrhoea PLUS toxin or evidence of toxin-producing strain OR PMC	Any positive culture / toxin test, no symptoms necessary	Diarrhoea without other cause or toxic megacolon PLUS toxin-positive stool or toxin-producing strain OR PMC	Diarrhoea or toxic megacolon without other cause PLUS toxin positive stool or toxin-producing strain OR PMC
Age group	2004–06 >65 years 2007 >2 years	2004–05 >1 year 2007 >1 month old	Neonates excluded	>2 years	Neonates excluded	Not defined
Exclusions					Other aetiological agent isolated Asymptomatic patients	
Time between cases	4 weeks		4 weeks	4 weeks	8 weeks	2 weeks (2–8 weeks classify as recurrent, >8 weeks classify as new case)
Recurrence defined	No	No	No	No	Episode occurring within 8 weeks of onset of previous episode	Onset 2–8 weeks after previous episode
Severe CDAD defined	No	No	No	No	Admission for community-acquired case Admission to ICU for treatment Surgical treatment Death within 30 days of diagnosis	Within 30 days of onset / lab test, one of: <ul style="list-style-type: none"> • admission to ICU • surgery • death caused by CDAD

	UK ^[40]	Canada CNISP ^[47]	Germany CDAD- KISS ^[44]	Australia AICA ^[48]	Euro CDC ^[2]	US CDC ^[45]
Recurrent cases counted as incidents	Yes	Yes	Yes	Yes	Not clear in final version	No (optional)
Include community-acquired cases	Yes	Yes, if hospitalised	Yes	Yes	Yes (optional)	Yes (optional)
Criteria for health care associated origin	2007 — specimen obtained in hospitalised patient				Subcategorised into community-onset or health-care facility onset	Subcategorised into community-onset or health-care facility onset
Hours after admission		≥72 hours	≥72 hours	>48 hours	>48 hours (>72 hours in draft)	>48 hours
Days from prior discharge		60	28	2	28 (discharge 4–12 weeks before onset classify as 'unknown')	28 (discharge 4–12 weeks before onset classify as 'unknown')

AICA = Australian Infection Control Association; CDAD = *Clostridium difficile* associated disease; CNISP = Canadian Nosocomial Infection Surveillance Program; CDC = Centers for Disease Control and Prevention; ICU = intensive care unit; KISS = Krankenhaus Infektions Surveillance System (Nosocomial Infection Surveillance System — Germany); PMC = pseudomembranous colitis

7.6 *Clostridium difficile* associated disease prevention and control

Principles underpinning the prevention of CDAD transmission in a hospital setting have been reviewed and there is ongoing debate about which particular interventions are most valuable.^[18] Accepted principles include:^[49]

- antibiotic stewardship (particularly limiting agents associated with CDAD)
- monitoring of cases to detect clusters or outbreaks
- compliance with syndromic infection control recommendations for contact precautions for patients with diarrhoea
- accurate identification of infected patients
- consistent hand hygiene
- improved environmental cleaning.

Where there is ongoing transmission within a health-care facility, it may be valuable to use soap and water rather than alcohol hand rub for hand hygiene and bleach-containing disinfectant for environmental cleaning.^[49]

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8 Respiratory syncytial virus infection

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Key points

- Respiratory syncytial virus (RSV) is the leading cause of paediatric lower respiratory tract infections and related hospitalisations and of health care associated infections in infants and young children.
- The burden of severe RSV disease falls particularly on premature infants, immunosuppressed patients, and children and adults with chronic respiratory and cardiac disease.
- Mortality rates are low in developed countries but infections have a significant impact on the health-care system.
- Targeted infection control programs that control the spread of RSV within paediatric hospitals are highly cost-effective.
- Effective surveillance systems are required to detect the onset of the annual community-acquired RSV season and to measure the effectiveness of facility infection control programs for health-care acquired cases.

Recommendation on respiratory syncytial virus

1. Monitoring and prevention of hospital-acquired paediatric cases of RSV should be based on laboratory-confirmed RSV results.

8.1 Background

Wherever surveillance data has been collected, reported and published, respiratory syncytial virus (RSV) has been identified as the leading cause of community-acquired lower respiratory tract infections (LRTIs) in infants and young children. RSV is also the most frequent cause of nosocomial infection in this age group.^[1, 2] In the literature on RSV infection, the term ‘nosocomial’ almost always refers to infections that are hospital acquired; however, for consistency with the rest of this document, the term ‘health care associated’ is used from this point on.

Health care associated RSV infection rates are higher in children who have additional risk factors such as prematurity, chronic lung disease, mechanical ventilation, congenital heart disease and neuromuscular impairment.^[2]

Health care associated RSV infections particularly affect the elderly; for example, RSV has recently been recognised as the viral pathogen most frequently associated with respiratory illness in institutionalised elderly people.^[1] Adult patients with underlying cardiopulmonary and immunosuppressive conditions are also affected.^[1]

Health-care workers (HCWs) are an important potential source of health care associated RSV infections. More than 50% of paediatric ward staff have become infected with RSV during periods of RSV prevalence in the community.^[1]

The incidence of RSV shows a marked seasonal variation, with an increase occurring each winter.^[1] All age groups are susceptible to RSV infection and, because immunity to RSV is

incomplete, repeated infections occur throughout life, often within intervals of only weeks to months.

Surveillance is a key component of an effective RSV infection control program. Detecting the onset of the annual increase in community-acquired cases should trigger the introduction of additional measures that prevent RSV transmission within hospitals. Monitoring health care associated RSV infections allows evaluation of the effectiveness of hospital infection control practices.

The cost-effectiveness of a targeted RSV infection control program was evaluated in an eight-year study in a general paediatric hospital.^[3] Health care associated RSV infection rates were measured for four years before and after the introduction of a quality-improvement program aimed at decreasing the incidence of health care associated RSV infection. A median of 10 health care associated RSV cases were prevented per year, resulting in a cost benefit ratio of 1:6. The authors concluded that the intervention was cost-effective.

8.2 Harm to patients

In young infants and children, RSV accounts for 20–25% of hospital admissions for pneumonia and up to 75% for bronchiolitis.^[4] About 1–2% of all RSV-infected children require hospitalisation.^[2] In Germany, RSV-related annual hospitalisation rates in 1999–2001 were 1400 per 100,000^[5] and accounted for about 35% of all LRTI-related hospitalisations.^[6]

The rates of health care associated RSV infection in the Australian paediatric population (2.9 cases per 1000 at-risk days) are comparable with international rates.^[7] For example, the rate was 4.4 cases per 1000 bed days in Houston, United States^[8] and 2.9 cases per 1000 patient days in Germany.^[4]

Health care associated RSV infection may result in severe complications, particularly when it is associated with severe chronic lung disease, mechanical ventilation, congenital heart disease or surgery. Health care associated RSV is more likely to require mechanical ventilation.^[2] The attributable mortality of RSV infections is low (1.1%).^[2]

8.3 Impact on health-care system

The additional length of stay attributable to health care associated RSV infection is estimated to be 7.8 days, with a median cost of US\$9419.^[3] A German study identified the excess costs as €3433, with 53% of costs due to treatment in an intensive care unit (ICU); the additional median length of stay was seven days.^[4] The length of stay is influenced by factors such as youth, prematurity, underlying disease and previous hospitalisation.

8.4 Surveillance methods

8.4.1 Detection

In paediatric populations, clinical signs of viral respiratory tract infection prompt the collection of nasopharyngeal aspirates. RSV infection is then virologically confirmed by detection methods such as antigen detection, direct immunofluorescence, viral culture or polymerase chain reaction (PCR). Viral culture of the pathogen is considered the gold standard but false negatives can result from sampling difficulties, or from transport or processing of fresh specimens. Although antigen detection and direct immunofluorescence provide rapid results, they lack the sensitivity and specificity of PCR-based methods. Therefore, PCR-based standardised protocols should be used.^[2]

8.4.2 Definitions

The incubation period of RSV infection is three to five days. The infection is therefore classified as health care associated if the patient becomes symptomatic on or after the fifth day of admission or if symptoms occur within five days of discharge after admission due to an unrelated illness.^[2]

8.4.3 Reporting

Measures of incidence of health care associated RSV have been reported in various ways, including:

- proportion of admitted patients who develop the infection
- proportion of diagnosed symptomatic RSV infections that are healthcare associated
- incidence density hospitalisation rates of health care associated RSV compared to total patient days or RSV-free patient days.

8.5 Current surveillance systems

8.5.1 International

There are no formal structures or procedures to monitor and report health care associated RSV cases.

Germany has operated a standardised surveillance system and database for paediatric RSV infections since 1999, with 14 paediatric hospitals contributing data.^[2]

8.5.2 Australia

Australia has no jurisdictional RSV surveillance systems.

In the 2007 surveillance survey (see Appendix 1), 33 respondents indicated that they perform surveillance of paediatric health care associated RSV, although the methods of surveillance were not specified. No recent reports have been published.

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9 Rotavirus infection

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Key points

- Rotavirus is the major agent of paediatric hospital-acquired diarrhoea across the world; it particularly affects younger infants, including neonates.
- Mortality rates are low in developed countries; however, the impact on the health-care system is significant.
- Controlling the spread of rotavirus within paediatric hospitals through targeted infection control programs is cost-effective.
- Effective surveillance systems are required for community-acquired cases (to identify the onset of the annual rotavirus season) and for hospital-acquired cases (to measure the effectiveness of facility infection control).
- The recent availability of a rotavirus vaccination makes more effective prevention a prospect.

Recommendation on rotavirus infection

1. Monitoring and prevention of hospital-acquired paediatric cases of rotavirus should be based on laboratory-confirmed rotavirus results.

9.1 Background

Rotavirus infects nearly all children by the age of five years. Worldwide, an estimated 111 million rotavirus-associated illnesses occur each year, with approximately 440,000 deaths.^[1] Rotavirus is an important cause of hospital cross-infection, particularly in very young children.

Two effective rotavirus vaccines have now been licensed in Australia. They have been available free of charge on the National Immunisation Program to all young infants in Australia since July 2007. The Northern Territory introduced one of these vaccines (Rotarix — a live attenuated human G1P[8] rotavirus) into the immunisation schedule in August 2006.^[2] Davidson and colleagues have reviewed the vaccines and their likely impact.^[3]

The explicit cost-effectiveness of hospital-acquired rotavirus surveillance has not been examined. However, given the substantial burden of hospital-acquired rotavirus disease and the minimum estimates of financial burden, hospital-acquired rotavirus surveillance (which can be predominantly laboratory based) and associated measures to improve prevention of disease are likely to be cost-effective.

The availability of effective rotavirus vaccines now makes prevention of both community- and hospital-acquired rotavirus more achievable. It is apparent that good surveillance data from both community and health-care settings will be required to monitor the impact of vaccination and other measures. No data are available on the impact of vaccination on hospital-acquired rotavirus infections.

9.2 Harm to patients

Rotavirus is the major agent of paediatric hospital-acquired diarrhoea in most studies, causing 31–87% of cases, although the number of cases due to other virus infections is increasing.

Hospital-acquired rotavirus infections are mainly associated with infants of less than 6 months of age, whereas community-associated disease is more prevalent in children 6–23 months of age. Hospital-acquired rotavirus is generally introduced to paediatric wards after hospitalisation of children with community-onset rotavirus infection. Hospital-acquired rotavirus infection usually becomes apparent 2–6 days after hospitalisation. Rotavirus excretion can begin shortly before the start of clinical symptoms and may continue well after the resolution of diarrhoea (up to 57 days), although the period of transmissibility is limited to two weeks.^[4]

Hospital-acquired rotavirus infections are seasonal in temperate countries. They occur in winter, starting from the appearance of community rotavirus activity. In infants younger than four months of age, the winter seasonality is less pronounced, as shown by data from Germany.^[5] In the United States, rotavirus activity follows a progressive wave from the southwestern states towards the northeastern states from winter to spring. Over the past two decades, peak rotavirus activity in Japan has shifted from winter to early spring.

A significant proportion (18–39%) of infections are asymptomatic, especially in neonates and infants under three months of age. This situation contributes to the spread of the virus and might reduce the efficiency of prevention measures because the lack of symptoms means that measures may be implemented too late.^[4] In a systematic review, the percentage of hospital-acquired rotavirus among total rotavirus cases ranged from 14.3% to 50.8%.^[1] The observed or calculated incidence rates of hospital-acquired rotavirus infection varied from 0.97 to 27.7 per 100 hospital admissions.

The epidemiology of hospital-acquired rotavirus was reviewed in six large European countries.^[4] The review showed a significant burden of disease, although there were wide variations. Different studies described incidence rates from 1.6 to 15.8 per 1000 patient days; however, the studies differed in the age ranges studied and the criteria for hospital-acquired rotavirus diagnosis. It is currently not possible to obtain a complete and accurate overview of hospital-acquired rotavirus disease at country level because of the limited robustness and comparability of studies, and national changes in health-care systems, which create a changing baseline.^[4]

9.2.1 Australia

In Australia, the National Rotavirus Reference Centre publishes annual data on the strains of rotavirus circulating in the country.^[2] The most recent report concerns 2006–07. Serotypes G1 (36.7% of isolates), G3 and G9 represent the most prevalent strains. Nearly all of these strains contain the P[8] type of VP4 protein. In 2007, the G9P[8] strain caused a second large outbreak from March to May in the Northern Territory. G9 strains have also spread across Australia.

Health care associated rotavirus infections were investigated in Adelaide. A total of 220 patients under three years of age who were admitted without gastroenteritis to two paediatric general medical wards during a 10-month period were studied.^[6] Faecal specimens were collected within 48 hours of admission and then daily until the patients were discharged. Samples were also collected after discharge if patients developed enteric symptoms within two days of discharge. Of the 220 patients, 31 (14%) acquired rotavirus infections while in hospital, with 71% of these being symptomatic. Acquisition of rotavirus infection was most prevalent during the months May to August, with a prevalence of 34% (12 of 35 patients) in May.

A study at the Children's Hospital in Westmead, Sydney reported on hospital-acquired rotavirus surveillance data from children under two years of age admitted during the winter rotavirus seasons 1999 to 2004.^[7] The incidence density of proven hospital-acquired rotavirus (rotavirus diarrhoea with onset >72 hours after admission and within 24 hours of discharge) varied between 6.7 and 14.8 cases per 10,000 rotavirus-free patient days. Over the study period, 14.5% of all

rotavirus infections confirmed by enzyme immunoassay were proven to be hospital acquired. Stools from hospitalised patients were not tested systematically and post-discharge follow-up was not maintained; therefore, it is likely that the true rates of symptomatic and asymptomatic hospital-acquired rotavirus infection were much higher. Subsequently, routine rotavirus testing of diarrhoeal stools from hospitalised patients was instituted. This led to a significant increase in detections of HAIs (D Dalton, Westmead Children's Hospital, pers comm).

9.2.2 International

A review found that mortality associated with rotavirus is low in developed countries.^[4] The review found that hospital-acquired rotavirus leads to increased duration of hospitalisation, with estimates ranging from 1.7 to 5.9 additional days. However, most studies did not match cases with controls and had other deficiencies. The two studies that provided appropriate controls found increases of four days (from a study in the United Kingdom)^[8] and 4.9 days (from a study in France).^[9]

In a systematic study of rotavirus infections in Europe, hospital-acquired rotavirus infections led to a median estimated increase of length of stay of 1.5 days (Germany), 3 days (Austria) and 4.5 days (Switzerland).^[10] In Switzerland, only 5 of 17 hospital-acquired rotavirus infections led to increased length of stay. Most hospital-acquired rotavirus infections were moderate. The percentage of hospital-acquired rotavirus infections that occurred in premature infants was 10% (Germany), 12% (Austria) and 24% (Switzerland). Illness may be particularly severe in this age group, causing necrotising enterocolitis and intestinal perforation.

9.3 Impact on health-care system

A recent review of hospital-acquired rotavirus infection found that additional direct hospital costs (using the increased length of stay and direct costs of hospitalisation per hospital-acquired rotavirus episode) were up to €2500.^[4] The studies reviewed significantly underestimate the true cost of hospital-acquired rotavirus infection. Only two studies matched cases with controls and these documented additional costs per case of €1070 (in a study from the United Kingdom)^[8] and €1930 (in a study from France).^[9] It is not possible to make reliable calculations of total country hospital-acquired rotavirus costs due to variability of methodologies used and the absence of comparable country-wide surveillance data on hospital-acquired rotavirus.^[4]

An Australian study assessed the impact of community rotavirus gastroenteritis on young children attending a Sydney paediatric hospital.^[11] The estimated mean total cost per episode of rotavirus gastroenteritis was A\$1744 for children admitted to hospital and \$441 for children not admitted, with an additional mean cost of \$493 to families of children admitted to hospital. In this study, hospital-acquired rotavirus was not defined or costed separately.

In the Adelaide study described (see Section 9.2.1), hospitalisation was prolonged in those patients who acquired rotavirus (11.1 days compared with 8.0 days in rotavirus negative patient admissions, $P < 0.05$) but there was no matching of cases and controls and no quantification of financial impact.^[6]

9.4 Surveillance methods

9.4.1 Detection

Clinical signs of viral infection of the gastrointestinal tract prompt the collection of faecal samples in paediatric populations. Virological confirmation of rotavirus infection is then made through various detection methods, including antigen detection, which is generally through enzyme immunoassay or a polymerase chain reaction (PCR)-based technique. Antigen detection

by enzyme immunoassay provides rapid results but lacks the sensitivity and specificity of PCR-based methods.

Surveillance systems for hospital-acquired rotavirus detection have either been passive (only children with symptomatic hospital-acquired diarrhoea are tested) or active (stools of all admitted children are tested at intervals and post-discharge). The most effective ongoing method is to ensure that hospitalised children who develop diarrhoea are routinely tested for rotavirus.

9.4.2 Definitions

The definitions and methods used in studies of hospital-acquired rotavirus infection vary.^[4] The incubation period of rotavirus infection is three to five days; therefore, technically, the infection should be classified as hospital acquired if either of the following apply:

- the patient becomes symptomatic on day five or later after admission
- symptoms occur within five days of discharge if the patient is admitted with an unrelated illness.

However, most studies have used a >72 hours post-admission criterion, with variable post-discharge criteria. There are no international standards for surveillance.

9.4.3 Validation

No reported studies have attempted to validate surveillance data for rotavirus for accuracy, sensitivity or specificity.

9.4.4 Reporting

Hospital-acquired rotavirus incidence measures have been reported in various ways, including:

- proportion of admissions who develop hospital-acquired rotavirus
- number of hospital-acquired rotavirus cases per 100,000 children
- proportion of diagnosed symptomatic rotavirus infection that is hospital acquired
- number of hospital-acquired rotavirus cases per number of community-acquired rotavirus infections that require hospitalisation
- incidence density (against total patient days or rotavirus-free patient days) of proven and/or possible hospital-acquired rotavirus, as defined.

9.5 Current surveillance systems and data

9.5.1 International

No countries have formal structures and procedures in place for monitoring and reporting on hospital-acquired rotavirus cases.

9.5.2 Australia

Australia has no jurisdictional surveillance systems for hospital-acquired rotavirus. The National Rotavirus Reference Centre links nine Australian laboratories and analyses rotavirus strains that derive predominantly from community rotavirus infections.^[2] The centre does not collect data on hospital-acquired rotavirus.

In the 2007 surveillance survey (see Appendix 1), 38 respondents indicated that they perform surveillance for paediatric hospital-acquired rotavirus. Methods of surveillance were not specified and no recent reports have been published.

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**Part D — Specific locations in hospital or
community**

10 Adult intensive care unit acquired infection

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Key points

- Patients in intensive care units (ICUs) are at high risk of health care associated infections (HAIs) that often have severe adverse outcomes.
- The most important HAI types are central line associated blood stream infections (BSIs) and ventilator-associated pneumonia.
- Many international ICU-acquired HAI surveillance programs base their methods on the United States National Healthcare Safety Network (NHSN) (formerly the National Nosocomial Infections Surveillance System (NNIS)) program.
- Several Australian states undertake ICU surveillance — particularly of BSIs — using either NHSN/NNIS definitions or those of the Australian Infection Control Association.
- The NHSN/NNIS definitions for BSIs have recently changed and this should prompt a review of the Australian definitions.
- In the United States, recent comprehensive prevention programs that ‘bundle’ a group of three to five evidence-based HAI strategies have significantly reduced ICU-acquired infections.
- ICUs provide an ideal environment for the development and spread of antimicrobial-resistant pathogens and are the setting for considerable broad-spectrum antimicrobial use. Antimicrobial resistance is expected to increase.
- Optimal antibiotic use, guided by a local knowledge of likely pathogens and their antibiotic resistance, is a key factor in controlling the development of antibiotic resistance.
- No integrated national surveillance system exists to monitor ICU infections, antimicrobial resistance or antibiotic use. Standardised monitoring of antibiotic use has recently been established in some Australian ICUs.

Recommendations on adult intensive care unit acquired infection

1. A mandatory continuous national surveillance system to collect and report on an agreed minimum dataset for central line associated BSIs in all ICUs is required.
2. Australian expert consensus is required to agree on national definitions for central line associated BSIs and ventilator-associated pneumonia, and methods for calculation of infection rates.
3. Evidence-based strategies for HAIs should be used to target central line associated BSIs and ventilator-associated pneumonia. These will include standardised application and auditing of compliance.
4. Monitoring of national antibiotic usage and resistance surveillance data, resistance management and intervention strategies requires a comprehensive integrated surveillance program.
5. Expansion of the national antibiotic utilisation data obtained from hospital pharmacies to include data from all ICUs.

10.1 Background

Patients in intensive care units (ICUs) are at high risk of health care associated infections (HAIs). Of all HAIs, 20–30% occur in ICUs.^[1, 2] The risk of contracting an HAI increases by 6% for each day spent in hospital.^[1]

Patients in ICUs are at increased risk of infection because they often:

- are admitted with severe life-threatening illness or injuries, with major organ damage
- have multiple defects in their normal defence barriers, especially due to use of invasive devices such as vascular access catheters, urinary catheters, and respiratory and gastrointestinal devices
- have multiple comorbidities.

Outcomes in ICU patients may be affected by:

- severity of the underlying illness, degree of immunosuppression and use of vascular access devices^[3]
- mechanical ventilation and endotracheal intubation^[4]
- length of ICU stay and the increasing occurrence of multiresistant organisms^[5, 6, 7]
- understaffing^[8, 9]
- higher ratios of pool or agency nurses to ICU patients^[10, 11]
- nursing workload.^[12]

In 2006, Australia had 104 ICUs in the public sector and 52 ICUs in the private sector; New Zealand had 24 ICUs in the public sector and two in the private sector.^[13] Approximately 68% of the public sector's ICUs were located in a capital city or metropolitan centre.

Per 100,000 population, the Australian public sector has 6.3 ICU beds and 4.66 ventilator beds. Internationally, the total number of adult ICU beds per 100,000 population ranges from 3.3 in the United Kingdom to 20.3 in the United States (excluding neonates, paediatric and critical care unit (CCU) ICU beds) and 24.6 in Germany.^[14] ICU admissions (excluding same day separations) account for 3.89% of all admissions to Australian public hospitals.

HAI rates vary by ICU type (eg medical, surgical and burns). The different types of ICU are considered separately by the National Healthcare Safety Network (NHSN) (formerly the National Nosocomial Infections Surveillance System (NNIS)) of the United States Centers of Disease Control and Prevention (CDC). The NHSN/NNIS continues to use and modify existing definitions and methods.^[15, 16]

Australian and New Zealand ICUs are categorised in a number of ways, including:

- general ICUs, in which most ICU beds are located (medical or surgical care; may incorporate high-dependency unit (HDU) facilities or beds)
- ICUs/CCUs/HDUs (ie combined ICUs)
- specialty ICUs (ie neurology, oncology or cardiothoracic ICU patients)
- paediatric ICUs (PICUs) (medical or surgical care for paediatric purposes)
- HDUs (intermediate care between intensive and general ward care).

10.1.1 Antibiotic use and antibiotic resistance in intensive care units

The ICU is an ideal environment for the development and spread of pathogens resistant to antimicrobials. Severe infections (eg severe sepsis and septic shock) are common indications for ICU admission. ICU patients often receive multiple, escalating courses of broad-spectrum antimicrobials to treat possible or proven infections caused by a wide range of pathogens. High use of antimicrobials increases selection pressure for resistant organisms, particularly in long-stay patients. Organisms may spread laterally to other patients within the ICU and then out to the wards. Also, elective postoperative patients may be in close proximity to patients with severe infections caused by resistant organisms. Conversely, patients on the wards with multiresistant organisms may be transferred to the ICU and act as a point source for an ICU outbreak. Patients transferred between hospitals may then transmit the organisms elsewhere. There is a lag period between acquisition of a multiresistant organism and its detection; during this period, the infection may spread between patients if risk factors for acquisition are not considered carefully.^[17]

There is increasing evidence that multiresistant organism infection leads to greater morbidity and mortality^[18] and that a delay in treatment or a failure to adequately treat the microbiological cause of severe sepsis is associated with a substantially worse outcome.^[19] The *Sepsis Bundles* and *Surviving Sepsis Campaign*⁴⁷ include this viewpoint as part of their expert-guided, evidence-based recommendations for the treatment of infections in ICUs. ICU clinicians are therefore under pressure to prescribe broad-spectrum agents against likely pathogens in an environment where multiresistant organisms are common, further increasing the development of resistant organisms. Isolates with resistance to broad-spectrum antibiotics are increasingly being recognised in Australia^[20, 21] and multiresistant organisms are increasingly being imported into the hospital from the community.

While methods to optimise antibiotic use in the ICU setting have been published,^[17, 22, 23, 24] disciplined and rigorous systems are required for such optimisation and the protocols are not widely adopted. Individual institutions have initiatives that warrant further encouragement and development (eg John Hunter, Royal Melbourne and Austin hospitals). Some measures, such as cycling classes of antibiotics through an ICU, have not garnered general support.^[17]

The Australian and New Zealand Intensive Care Multicentre Studies Group studied antimicrobial use in 10 Australian and New Zealand ICUs.^[25] The study involved 481 consecutive critically ill patients receiving antibiotics for any reason while in an ICU. Of 292 patients admitted after surgery, 80% received antibiotics for ‘surgical prophylaxis’: this represented 48% of the ICU patients. Antibiotics were prescribed for treatment of clinically diagnosed infection in 56% of patients, and for systemic inflammatory response syndrome and clinical suspicion of infection in 38%.

10.2 Harm to patients

ICU-acquired HAIs have a significant effect on patients in ICUs, causing, for example, increased morbidity, mortality, antibiotic use, laboratory tests and length of stay.^[26, 27, 28, 29, 30]

Most ICU-acquired infections are associated with the use of invasive medical devices. A high proportion of ICU HAIs involve three major sites: lungs, urinary tract and bloodstream. In a report of North American combined medical–surgical ICUs, these sites accounted for 68% of infections: 31% due to pneumonia, 23% to urinary tract infection (UTI) and 14% to bloodstream infection (BSI).^[31] A similar study of medical-only ICUs reported figures for these sites as 31% due to pneumonia, 27% to UTIs and 19% to BSIs.^[32]

⁴⁷ <http://www.ihl.org/IHI/Topics/CriticalCare/Sepsis>

In a French study of 12 ICUs, BSIs associated with high-risk microorganisms — for example, methicillin-resistant *Staphylococcus aureus* (MRSA), *Pseudomonas aeruginosa*, *Acinetobacter* spp, *Enterobacteriaceae* spp with extended-spectrum β -lactamase and yeasts — were associated with a nearly three-fold increase in mortality risk.^[33] The study also associated gram-negative organisms with a higher mortality rate than gram-positive organisms.

Reports from developing countries often document much higher infection rates than those seen in developed countries. The higher rate in developing countries may be due to factors such as limited funding, low nurse-to-patient ratios, outdated technology and variable hand hygiene.^[34]

10.2.1 Mortality

A number of international studies have documented the mortality attributable to HAIs in ICUs. The attributable mortality for ICU patients with central line associated BSIs is 4–20% (calculated from data from industrialised countries). Patients with ventilator-associated pneumonia (VAP) have an attributable mortality of up to 30% and those with late onset VAP caused by more virulent organisms have an attributable mortality of up to 50%.^[35]

Mortality from hospital-acquired infection is more frequent in ICUs than in other hospital departments.^[36, 37, 38, 39, 40, 41] However, assessment of mortality is not straightforward and may be confounded by a number of factors. For example, a case–control study found that the risk of dying was 2.5 times higher in patients with an HAI than in uninfected patients.^[42] Paradoxically, the relative risk was greatest in patients under 45 years of age and in less severely ill patients.

Two similar studies reported a relative risk of death in younger ICU patients of 3.5 and 2.3.^[37, 38] Another study suggested that bloodstream HAI-associated mortality might previously have been overestimated and emphasised the need for these studies to carefully match case patients with their controls.^[43]

More recently, crude excess mortality rates reported in developing countries were 18% for ICU central line associated BSIs, 27.8% for VAP and 21.3% for catheter-related UTIs.^[34]

10.2.2 Ventilator-associated pneumonia

Up to 86% of ICU-acquired pneumonia cases are associated with mechanical ventilation.^[31, 32, 34] Data on VAP rates per 1000 ventilator days are listed in Table 10.1.

Medical ICU VAP patients were commonly infected with gram-negative bacteria (64%); common individual organisms were *P. aeruginosa* (21%) and *S. aureus* (20%). *Enterobacter* species and *Klebsiella pneumoniae* were the most commonly reported enteric bacteria.^[32] A recent report from eight developing countries found that Enterobacteriaceae were isolated in 26% of VAP cases; other infections were *P. aeruginosa* (26%), *S. aureus* (22%) and *Acinetobacter* species (20%).^[34]

There are few Australian reports on VAP rates. In 2005, the Victorian Hospital-Acquired Infection Surveillance (VICNISS) aggregated ICU VAP infection rate was 5.0 per 1000 ventilator days for group A1 ICUs and 14.3 per 1000 ventilator days for ‘other’ hospitals.^[44]

Table 10.1 International intensive care unit ventilator-associated pneumonia per 1000 ventilator days

Country	Participating ICUs	Ventilator days	Ventilator utilisation ratio	VAP per 1000 ventilator days (pooled mean)
United States (NHSN/NNIS — 2006)				
Burns ICU	12	10,098	0.42	12.3
Coronary ICU	48	35,727	0.28	2.8
Surgical cardiothoracic ICU	48	46,710	0.41	5.7
Medical ICU	64	109,277	0.45	3.1
Medical–surgical ICU				
Major teaching	58	84,530	0.43	3.6
All others	99	135,546	0.34	2.7
Paediatric medical–surgical ICU	32	32,936	0.42	2.5
Neurosurgical ICU	15	13,799	0.42	7.0
Surgical ICU	61	73,205	0.61	5.2
Trauma ICU	19	32,297	0.57	10.2
Germany (KISS — 1999–2003)				
Medical–surgical	29	119,764	Not reported	8.8
Medical	18	47,362	Not reported	9.7
Surgical	20	42,003	Not reported	10.0
Neurosurgical	2	9,897	Not reported	8.1
Paediatric	2	5,112	Not reported	4.7
Overall	71	224,138	Not reported	9.1
Spain	1	4,426	Not reported	21.1
Japan (2002–04)	28	51,361	0.50	12.6
Greece	8	14,196	0.81	12.5 (95%CI, 10.7 to 14.4)
International Nosocomial Infection Consortium (2002–05): Argentina, Brazil, Colombia, India, Mexico, Morocco, Peru and Turkey	55	52,987	0.38 (Range 0.19–0.64)	24.1 (95%CI, 10.0 to 52.7)
(Overall rate)				

CI = confidence interval; ICU = intensive care unit; KISS = Krankenhaus Infektions Surveillance System (Nosocomial Infection Surveillance System — Germany); NHSN/NNIS = National Healthcare Safety Network (formerly the National Nosocomial Infections Surveillance System (NNIS)); VAP = ventilator-associated pneumonia

10.2.3 Central line associated blood stream infection

Up to 87% of primary BSIs have been associated with central venous catheters.^[31, 32, 34] Data reporting central line associated BSI rates per 1000 device days are listed in Table 10.2.

Table 10.2 International intensive care unit central line associated bloodstream infections per 1000 device days.

Country	Participating ICUs	Device days	Central line utilisation ratio	Central line-associated BSIs per 1000 central line days (pooled mean)
United States (NHSN/NNIS)				
Burns ICU	127	18,812	0.64	6.8
Coronary ICU	181	63,941	0.44	2.8
Surgical cardiothoracic ICU	150	92,484	0.73	1.6
Medical ICU	486	170,719	0.59	2.9
Medical–surgical ICU				
Major teaching	304	128,502	0.58	2.4
All others	431	198,551	0.49	2.2
Paediatric medical–surgical ICU	255	48,144	0.49	5.3
Neurosurgical ICU	75	21,412	0.48	3.5
Surgical ICU	378	21,412	0.62	2.7
Trauma ICU	182	137,484	0.65	4.6
Germany (KISS — 1999–2003)				
Medical/surgical ICU				
<600 beds	49	119,764	Not reported	9.8
≥600 beds	18	47,362	Not reported	7.7
Medical	45	42,003	Not reported	8.8
Surgical	56	9,897	Not reported	11.0
Neurosurgical	9	5,112	Not reported	11.3
Paediatric	5	224,138	Not reported	2.7
Spain	1	5,373	Not reported	30.0
Greece	8	16,652	0.95	12.1 (95%CI, 10.5–13.9)

Country	Participating ICUs	Device days	Central line utilisation ratio	Central line-associated BSIs per 1000 central line days (pooled mean)
International Nosocomial Infection Consortium (2002–05): Argentina, Brazil, Colombia, India, Mexico, Morocco, Peru and Turkey (Overall rate)	55	74,641	0.54 (Range 0.22–0.97)	12.5 (95%CI, 7.7–18.5)

BSI = bloodstream infection; CI = confidence interval; ICU = intensive care unit; KISS = Krankenhaus Infektions Surveillance System (Nosocomial Infection Surveillance System — Germany); NHSN/NNIS = National Healthcare Safety Network (formerly the National Nosocomial Infections Surveillance System (NNIS))

Two reports from North America on combined medical–surgical and medical-only ICUs found that coagulase-negative staphylococci (CNS) were responsible for approximately one-third of central line associated BSIs, and that the incidence of coagulase-negative staphylococci was increasing.^[31, 32] Other organisms responsible for these infections were enterococcus species (16%), *S. aureus* (13%) and fungi (12%). A different spectrum of organisms occur in a report from eight developing countries: Enterobacteriaceae (57%), *S. aureus* (25%), CNS (18%), *Acinetobacter* species (13%) and *P. aeruginosa* (9%).^[34]

There are limited, but increasing, Australian reports on ICU HAIs. A Victorian study using NHSN/NNIS methods reported a central line associated BSI rate of 4.97 per 1000 central line days and a device use ratio of 0.95 in a 10-bed ICU.^[45]

A 2000 study reported on the New South Wales state-wide Hospital Infection Standardised Surveillance (HISS) pilot program, which commenced in 1998 and involved 10 hospitals. Five surveillance modules, including intravascular device-related bacteraemia (IVDRB) in ICU, were included in the pilot. Of the 10 hospitals, 8 contributed data on the IVDRB module using the NHSN/NNIS method. Of 5804 line days monitored in ICU, a central line associated infection rate of 4.7 per 1000 central line days was reported (95%CI, 2.3 to 8.6).^[46]

Six Victorian group A1 hospitals and 12 ‘other’ hospitals submitted surveillance data on ICU central line BSI for the VICNISS 2007 annual report. The 2006 aggregated rate of ICU central line associated BSIs was 5.5 per 1000 central line device days for group A1 hospitals and 1.1 per 1000 central line device days for ‘other’ hospitals.

In 2005, the New South Wales group 1 ICU central line associated BSI rate was 2.73 per 1000 device days, with a device use ratio of 49.4 (16,887 central line days were monitored). The group 2 ICU rate was 2.60 per 1000 device days, with a device use ratio of 52.5 (16,046 central line days were monitored).^[47]

10.2.4 Catheter-associated urinary tract infection

Up to 97% of ICU cases of UTIs have been associated with indwelling catheters.^[31, 32, 34] Data reporting rates of urinary catheter-associated UTIs per 1000 urinary catheter days are listed in Table 10.3.

Table 10.3 International intensive care unit urinary catheter-associated urinary tract infections per 1000 urinary catheter days

Country	Participating ICUs	Device days	Urinary catheter utilisation ratio	UTI per 1000 urinary catheter days (pooled mean)
United States (NHSN/NNIS)				
Burns ICU	12	12,860	0.69	7.5
Coronary ICU	41	65,277	0.62	4.6
Surgical cardiothoracic ICU	41	70,221	0.80	3.7
Medical ICU	55	156,261	0.76	4.4
Medical–surgical ICU				
Major teaching	51	132,096	0.80	3.4
All others	83	221,435	0.67	3.1
Paediatric medical–surgical ICU	27	21,686	0.29	5.2
Neurosurgical ICU	14	26,253	0.83	6.5
Surgical ICU	54	126,887	0.82	4.0
Trauma ICU	19	51,027	0.91	5.5
Germany (KISS — 1999–2003)				
Medical–surgical				
<600 beds	49	119,764	Not reported	9.8
≥600 beds	18	47,362	Not reported	7.7
Medical	45	42,003	Not reported	8.8
Surgical	56	9,897	Not reported	11.0
Neurosurgical	9	5,112	Not reported	11.3
Paediatric	5	22,4138	Not reported	2.7
Spain	1	7,503	Not reported	8.4
Greece	8	17,203	0.98	3.5 (95%CI, 2.7 to 4.5)
International Nosocomial Infection Consortium (2002–2005): Argentina, Brazil, Colombia, India, Mexico, Morocco, Peru and Turkey	55	100,114	0.73 (range 0.48–0.94)	8.9 (95%CI, 1.7 to 12.8)
(Overall rate)				

CI = confidence interval; ICU = intensive care unit; KISS = Krankenhaus Infektions Surveillance System (Nosocomial Infection Surveillance System — Germany); NHSN/NNIS = National Healthcare Safety Network (formerly the National Nosocomial Infections Surveillance System (NNIS)); UTI = urinary tract infection

Fungi — especially *Candida* species — have been isolated in up to 40% of catheter-related UTI cases.^[32, 34, 48] Other common isolates are *Escherichia coli* (up to 29.5% of cases), *P. aeruginosa* (18%) and enterococcus species (14%).^[48]

10.2.5 Antimicrobial resistance of intensive care unit-acquired pathogens

A 2003 cohort study of Australian and New Zealand adults reported the incidence of severe sepsis at 0.77 per 1000 population; ICU mortality was 26.5% and hospital mortality was 37.5%.^[49] *S. aureus* was the most common microbial cause of severe sepsis, comprising 28.1% of isolates (16% methicillin-sensitive *S. aureus* (MSSA) and 12.1% MRSA). Other organisms were *E. coli* (9.3%) and *P. aeruginosa* (8.6%). The authors also reported that 18.2% of infections were ICU-acquired, but did not distinguish further between community- and hospital-acquired sources.

A Victorian study published data on the microbiological causes of sepsis over the period July 1999–June 2003 using the Victorian admitted episodes dataset to identify episodes of sepsis through International Classification of Diseases (ICD) codes.^[50] Of 33,741 recorded cases of sepsis among 3,122,515 patients, a potentially causative organism was identified in 55% of patients. The most commonly isolated organisms were *S. aureus* (13%, with MRSA in 27% of these), *E. coli* (11.5%) and group A and other streptococci (8%).

Problem organisms in ICU include MRSA, vancomycin-resistant enterococcus (VRE), *Acinetobacter* and organisms that produce metallo-beta-lactamases (MBLs).

Methicillin-resistant Staphylococcus aureus

MRSA is endemic in many large Australian tertiary hospitals. ICU patient screening (on admission, twice-weekly and on discharge) found that 6.8% of screened patients had MRSA colonisation on admission, 11.4% of screened patients were newly colonised during their stay, and trauma patients were at increased risk.^[51] A subsequent study of ICU patients found that being admitted for trauma and length of stay were risk factors for MRSA acquisition.^[52]

In a Melbourne ICU (Dandenong Hospital) in 2004, the median monthly ICU MRSA acquisition was reported as 15.2 patients per 1000 occupied bed days (OBD).^[53] Interventions such as increased access to an alcoholic chlorhexidine hand rub dropped this rate to 3.2 patients per 1000 OBD.

The rate of new ICU patients with MRSA has been reported as 9.3 per 100 patient admissions.^[54] Introducing a gel-based hand hygiene product and the use of feedback through statistical process control charts decreased this rate to 6.7 per 100 patient admissions.

A state-wide South Australian study involving public and private hospitals estimated that monthly ICU MRSA acquisition rates ranged from 28.2–69.0 per 10,000 OBD.^[55]

Vancomycin-resistant enterococcus

A 15-month prospective cohort study that included regular (on admission and then weekly) rectal swabs for VRE cultures from ICU patients at three large Melbourne teaching hospitals demonstrated a low incidence of VRE detection. Only 32 positive cultures were obtained from 2312 patient admissions.^[56]

The initial index case of a subsequent hospital-wide outbreak of VRE occurred in an ICU, demonstrating the importance of ICUs as a source of hospital-wide infections.^[57]

Acinetobacter

Two studies have documented outbreaks of multidrug-resistant *Acinetobacter baumannii* (MDR-AB) in ICUs. One study described an outbreak in two ward areas, including the ICU, and its subsequent control.^[6] The other study found 64 cases of ICU patients who acquired carbapenem-resistant *A. baumannii* (CRAB) over a 24-month period and demonstrated that specific risk factors for CRAB acquisition were associated with increased hospital mortality and prolonged ICU stay.^[58]

Organisms producing metallo-beta-lactamases

A large multigenus outbreak of infection and colonisation with gram-negative pathogens has been described.^[7] Most patients acquired the infection in ICUs.

10.3 Impact on health-care systems

A case–control study attributed an extra length of stay of 8 days in ICU and 24 days in hospital overall to bloodstream HAIs compared to matched controls with no bloodstream HAIs.^[59] The median cost for the extra stay was US\$40,000 per survivor. Another report calculated an increased direct cost of US\$34,508 per survivor.^[60] Both studies attributed a crude mortality of 35% to bloodstream HAIs.

In one study, VAP was reported as prolonging hospitalisation by a median of six days and increasing costs by US\$4947.^[61] More recently, VAP was shown to increase ICU stay by 13 days.^[26, 35]

Urinary tract HAIs in surgical patients increased hospitalisation by at least one day, at a median cost of US\$593–700.^[62, 63] In ICU patients, the added costs would probably be considerably greater.

10.4 Methods of surveillance

The surveillance methods for ICU-acquired infections as described by the NHSN/NNIS^[64] are based on unit-level rather than patient-level data. As a result, they have a lower burden of data collection. A specific ICU-acquired infection module has not been developed in Australia. However, elements of the BSI surveillance module of the Australian Infection Control Association National Advisory Board (AICA-NAB),^[65] particularly central line associated BSI using the AICA-NAB definitions, are used in high-risk settings, including ICUs. ICU-acquired infections reported in the NHSN/NNIS system are device-associated infections in recognition of the fact that invasive devices are the major risk factor for the most important infections acquired in ICUs.

10.4.1 Data collection

In the intensive care setting, patients with ICU-acquired infections may be identified either through infection control personnel or ICU nursing staff. Data collection requires education in the use of surveillance definitions, which at times are complex (eg for VAP). When using NHSN/NNIS methods, collection of denominator data (the number of device days) is often through a count, at a set time of day, of the number of patients with each invasive device in place, be it a central line, a mechanical ventilator or a urinary catheter.

10.4.2 Definitions

Central line associated bloodstream infections

The NHSN/NNIS system changed the definition for reporting of commensals from 1 January 2008 because of controversy with this definition.^[66] The positive culture of a commensal is now recognised as significant only if the same commensal is identified from a second blood culture taken separately soon after the first. This approach will undercall the number of BSIs with these organisms, but will allow units with excellent processes in place to achieve, at times, a zero infection rate. This goal, achieved in a large number of international ICUs recently, can be used to strongly motivate prevention programs.

When the AICA-NAB definitions of central line associated BSIs were applied to ICUs, the data collected for that site of infections was identical to that in the United States NHSN/NNIS system as it was up to January 2008. If a recognised pathogen is found in blood cultures and a central line is in place, this is reported as a central line associated BSI if there is no site of infection elsewhere for that pathogen. Australian and NHSN/NNIS definitions have previously taken a similar approach to reporting of commensals (eg CNS) from a single blood culture. That event may reflect a true bacteraemia complicating (usually) an intravenous line infection, or it may be a consequence of contamination of the sampling equipment at the time of venipuncture or other blood culture collection method. If the treating clinician commences directed antibiotic therapy as a consequence of this report and the patient has clinical features suggestive of sepsis, this situation is reported as a central line associated BSI. Use of this definition significantly overcalls the true number of infections by CNS. Contamination is fairly frequent, making it unlikely that an ICU will report no BSIs even if no infections occur.

Ventilator-associated pneumonia

The AICA-NAB has not developed Australian definitions for VAP. In the United States, the NHSN/NNIS definitions were revised in the late 1990s. These revised definitions are used by most Australian hospitals that undertake VAP surveillance. Development of appropriate surveillance definitions has proven difficult but improvements on previous NHSN/NNIS definitions were clearly required because of the nonspecific nature of pulmonary infiltrates reported using the previous definition. The new definitions embrace the concept that serial chest X-rays are more helpful in diagnosis of VAP than a single chest X-ray, in particular in distinguishing VAP from important differential diagnosis of pulmonary infiltrates, including acute respiratory distress syndrome and pulmonary oedema. There are three categories with different criteria in the VAP definition: diagnosis based on clinical criteria, diagnosis based on laboratory investigations (including situations where invasive investigations such as bronchoalveolar lavage are undertaken) and diagnosis of pneumonia in immunocompromised hosts.

A satisfactory surveillance definition for VAP is important because VAP leads to considerable morbidity and drives a large proportion of ICU antibiotic prescribing. Surveillance definitions are needed to allow understanding of infection rates within a given ICU and to evaluate the impact of prevention interventions.

Catheter-related urinary tract infections

The AICA-NAB has not developed Australian definitions for catheter-related UTIs, which are reported in the NHSN/NNIS ICU program but not in Australian state ICU surveillance programs. The reasons for this are:

- the difficulty of determining, in the ICU setting, whether bacteriuria in a catheterised patient is symptomatic

- the relatively low morbidity of UTIs compared to the other ICU-acquired infections for which data are collected
- bacteriuria is a consequence of a long urinary tract catheterisation, which thus does not require antibiotic treatment of its own accord; indeed, many non-catheterised (especially older) patients also have asymptomatic bacteriuria and similarly do not require antibiotic treatment.

Clinical features that suggest a UTI is symptomatic are less clear cut in the ICU setting. ICU patients are often febrile without a clear focus; catheterised patients do not experience symptoms such as frequency or dysuria related to their infection; and antibiotic therapy is often initiated in ICUs even if the site of possible infection has not been identified. Thus, when infections are reported using NHSN/NNIS methods, large numbers of patients with asymptomatic infections are included, with no consequences in terms of either morbidity for those patients or antibiotic use. In cases where infections are reported using other methods, the attribution of the symptoms to the UTI is often subjective.

10.4.3 Reporting of ICU-acquired infections

In NHSN/NNIS reporting, the infection rates reported are central line associated BSIs per central line day, VAP per ventilator day and catheter-associated UTIs per urinary catheter day. Using AICA-NAB definitions and methods, central line associated BSIs per central line day are reported as with NHSN/NNIS.

Risk adjustment

The number of device-associated infections during the surveillance period is expressed as an infection rate per day per use of the relevant device; for example, the VAP per ventilator per day, central line associated BSIs per central line day or catheter-associated UTI per catheter day.

Rates expressed in this way are independent of the length of patient stay in the ICU, the size of the ICU and the size of the hospital. However, in the United States system, there are differences in infection rates between hospitals with a major role as a medical school teaching hospital and other hospitals. These differences probably reflect differences in patient complexity in teaching hospitals. Thus, rates are reported separately for these two groups.

Currently, no Australian ICU HAI surveillance program collects patient level data beyond device use for more detailed risk adjustment.

Device-use ratios

Data are also collected on the extent of use of the relevant devices in the ICU, the number of device days per ICU patient day or the device-use ratio. This is a crude measure of the ‘intensive’ nature of the ICU.

10.5 Current surveillance

10.5.1 International programs

NHSN/NNIS methods are widely used internationally. Industrialised and developing countries using the NHSN/NNIS system and definitions include Germany,^[67, 68] Spain,^[69] Japan (modified NHSN/NNIS),^[70] Greece,^[71] Australia,^[72] Argentina, Brazil, Colombia, India, Mexico, Morocco, Peru and Turkey.^[34]

10.5.2 Australian programs

Most current surveillance in Australia of ICU-acquired infections is of central line associated BSIs, with established programs in New South Wales, Victoria and Western Australia. The Victorian program is the only one that includes paediatric ICUs. The VICNISS program in Victoria is considering moving to the new NHSN/NNIS definitions in 2008. This will lead to substantial differences in definitions and reported infection rates when compared to data collected using the AICA-NAB definitions, unless moves to establish a national consensus on bloodstream definitions are successful.

Catheter-associated UTI surveillance is not widely undertaken: in a recent survey by National Hospital Infections Surveillance, only 4.5% of replies indicated that this type of surveillance was being undertaken.

State programs

The VICNISS project, established in February 2002, has reported aggregate ICU device-related infection rates using NHSN/NNIS methods since 2004.^[72] Only public hospitals contribute data. ICU rates are stratified into two categories in an effort to reflect the differences observed in two categories of United States ICUs (see earlier section on ‘risk adjustment’). In Victoria, differences in arrangements for medical student teaching do not allow the same criteria as in NHSN/NNIS hospitals. The groupings are based on medical school teaching status, hospital size and profile as a major referral centre for complex patients. ICU infection rates are reported by device per 1000 device days. VAP surveillance is undertaken in four large Victorian hospitals, but this component of ICU surveillance has not been widely accepted elsewhere in Australia.

The Queensland Centre for Healthcare Related Infection Surveillance and Prevention (CHRISP) commenced ICU HAI surveillance in February 2001. CHRISP uses the AICA definition of BSI and stratifies rates into health care associated, community-associated or maternally-acquired groupings.^[73] Device day data are not collected; instead, rates are reported per 1000 OBDs.

The South Australian Department of Health Infection Control Service has been collecting BSI data using AICA definitions from 12 hospitals since 2002. Device day data are not collected; instead, only ICU BSIs, and the proportion of these that are intravascular device associated, are reported.^[74]

New South Wales introduced a mandatory system for monitoring HAIs in January 2003. The system collects and reports aggregate data on ICU central line associated BSIs using AICA definitions. Infection rates are stratified by hospital type: group 1 (principal referral hospitals) and group 2 (district groups and community acute with surgery). ICU infection rates are reported by device type per 1000 device days

10.6 Current surveillance of antimicrobial use and resistance

10.6.1 International programs

Surveillance of antimicrobial use and resistance is clearly important, and various surveillance strategies have been employed and published.

In the United States, collaborative projects between the NHSN/NNIS system and academic institutions have resulted in projects such as the Intensive Care Antimicrobial Resistance Epidemiology Project, which has published landmark papers on ICU antimicrobial use and resistance.^[75, 76]

In the United Kingdom, mandatory reporting is overseen by the National Health Service (NHS) through the Health Protection Agency. The agency has been collecting data from NHS trusts on MRSA bacteraemia since 2001, glycopeptide-resistant enterococci since 2003 and *Clostridium difficile* associated diarrhoea since 2004. ICU-relevant information is limited to MRSA bacteraemia rates.⁴⁸

The European Antimicrobial Resistance Surveillance System (EARSS)⁴⁹ — which began in January 1999 — and European laboratories have collected antimicrobial resistance data on more than 350,000 invasive isolates. EARSS performs ongoing antimicrobial susceptibility surveillance of seven indicator bacteria that commonly cause infections in humans:

- *Streptococcus pneumoniae*
- *Staphylococcus aureus*
- *Enterococcus faecalis*
- *Enterococcus faecium*
- *Escherichia coli*
- *Klebsiella pneumoniae*
- *Pseudomonas aeruginosa*.

EARSS information is available on an interactive section of the organisation's website that allows users to display selected results in formats such as tables, figures and maps. Analysed and summarised data are presented in country reports, and annual reports on European trends are available.

10.6.2 Australian programs

Antimicrobial resistance

The promise of large-scale, Australia-wide antimicrobial susceptibility data from the laboratory-based passive surveillance system (The Surveillance Network (TSN) (United States)) has not been realised. The 1997–2004 data from 94 hospital and 9 private laboratories (approximately 15 million test results from more than two million strains and 1.5 million patients) was purchased by the Australian Society for Antimicrobials.

The infrastructure from TSN has been maintained by Queensland Health Pathology and Scientific Services (QHPSS), which has continued to upload antibiotic susceptibility data from 33 QHPSS hospitals into a powerful relational dataset. The dataset can provide timely information about temporal trends in antimicrobial resistance within Queensland hospitals. The facility has the ability to be scaled up; it can also handle remote data entry. For example, in 2005, the Australian Government Department of Health and Ageing uploaded one year's data from a private laboratory in Queensland.

This system clearly has the potential to be expanded into a national dataset, from which ICU-related data could be readily extracted and merged with the existing AORTIC⁵⁰ dataset that captures ICU-related data from most Australian ICUs. A powerful database could then be established to provide vital information on temporal trends in ICU antimicrobial resistance and effects of antimicrobial resistance on key ICU outcome parameters (eg survival, length of stay). It

⁴⁸ The 2006 report is available at http://www.hpa.org.uk/infections/topics_az/hai/MandSurvHCAI2006.pdf

⁴⁹ <http://www.rivm.nl/earss/>

⁵⁰ AORTIC is a dataset maintained by the Australian and New Zealand Intensive Care Society (ANZICS).

would also provide a platform for effectively and efficiently setting benchmarks and evaluating interventions, with less financial input than a clinical research model.

Mandatory reporting of antibiotic-resistant organism colonisation and selected infections has recently been enacted in New South Wales, with recommendations for universal MRSA screening of all patients on ICU entry and exit, and capture of MRSA bacteraemia. The New South Wales Clinical Excellence Commission has also recently established quality-improvement initiatives in the surveillance of central line associated bacteraemia and VAP.

Antimicrobial use

The National Antimicrobial Utilisation Surveillance Program currently collects data from 23 tertiary referral hospitals. ICU data are reported separately from the general hospital data unless the ICUs are small (see Chapter 15). In the recent National Survey of Surveillance Activities, 10.3% of replies indicated that ICU usage of antibiotics was tracked in their hospitals.

10.7 Prevention of health care associated infections in intensive care units

The ICU setting of critically ill patients, multiple invasive devices and procedures, and prevalent antibiotic use makes prevention of HAIs challenging. However, for specific infections, a number of evidence-based interventions are recommended.

Comprehensive prevention programs that ‘bundle’ evidence-based strategies have been demonstrated to significantly reduce infections. The Institute for Healthcare Improvement (IHI), a not-for-profit organisation founded in the United States in 1991, developed the concept of bundles to improve the care process and patient outcomes. The institute also set up a membership network of organisations called IMPACT. This was established in the belief that ‘it is easier to improve together than it is alone’. Health care organisations and individuals improve health-care outcomes cooperatively.^[77, 78]

A bundle is a set of three to five practices that have been shown to improve outcomes when performed collectively and consistently. The fundamental elements in each bundle are based on well-established research. Examples include a ventilator care bundle and a central line bundle.

In December 2004, the IHI and its partner organisations launched the *100,000 Lives Campaign*, a national initiative to reduce unnecessary hospital deaths. Six best-practice interventions, including the ventilator care bundle and central line bundle, were introduced.^[79] An estimated 122,000 lives were saved over 18 months at 3100 participating hospitals. The program has since been expanded into the *5 Million Lives Campaign*, which includes the ventilator and central line bundles, and aims to protect patients from five million incidents of medical harm between December 2006 and December 2008.

The keys to the bundle strategy’s success are the standardised and unvarying application of bundle practices, the use of multidisciplinary rounds, and daily tracking and auditing of compliance. The outcome measures for the ICU infection-related components of the IHI campaign are bundle compliance and device (central line or ventilator) infection rates per 1000 device days. To ensure success, IHI also recommends that central line bundle implementation should commence in ICUs so that practices and strategies can be refined in one area before expanding to other areas of the hospital.

A recent report on initiatives that have incorporated bundles showed a reduction in VAP from 7.4 to 3.2 per 1000 ventilator days and a reduction in central line associated BSI from 5.9 to 3.1 per 1000 central line days in a 28-bed medical-surgical ICU.^[77]

Another collaborative cohort study, which involved 108 ICUs, showed that the mean rate of central line associated BSI decreased from 7.7 to 1.4 per 1000 device days within 16–18 months of implementing a bundle of evidence-based strategies.^[80]

The 2006 NHSN/NNIS report noted that the central line associated BSI rate in medical ICUs decreased from 5.0 to 2.9 per 1000 central line device days. The implementation of central device associated BSI prevention campaigns in many hospitals is thought to be responsible for the reduction in central line associated BSIs.^[16]

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11 Neonatal intensive care acquired infection

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Key points

- Late onset (intensive care associated) sepsis is a major cause of mortality and morbidity in neonates who require intensive care management. Infection is associated with adverse neurodevelopmental outcomes.
- Best practice is likely to protect most neonates from developing intensive care associated infections.
- Systematic surveillance of infection and antibiotic resistance is required to improve quality and provide meaningful benchmarks.

Recommendations on neonatal intensive care units

1. The late onset neonatal sepsis indicators (bloodstream infection and meningitis) developed by the Australian Council on Healthcare Standards and the Australian and New Zealand Neonatal Network in 2003 require revision.
2. Standardised indications and methods for collection of blood and cerebrospinal fluid cultures from neonates are required.
3. Benchmarking of neonatal intensive care surveillance data is required. Neonatal intensive care units should measure and report antibiotic resistance and usage. The development and updating of prescribing guidelines and other aspects of antibiotic stewardship should be based on analysis of antibiotic resistance and usage.

11.1 Background

Late onset sepsis in neonates admitted to intensive care refers to infections that are acquired during their intensive care stay. Late onset sepsis is a serious problem that affects all neonatal intensive care units (ICUs). It is most prevalent in premature neonates, and causes significant mortality and morbidity.^[1,2] A significant proportion of late onset sepsis events can be prevented by the use of optimal clinical practice.^[3,4,5] Neonatal intensive care is therefore considered a priority area for infection surveillance.^[1]

Systemic infections due to bacteria or fungi are the most significant events. The predominant types of infection in order of frequency are:

- primary bloodstream (no apparent focus for infection), 25–60%
- pneumonia, 10–25%
- intravascular device associated infection, 10–20%
- skin and soft tissue, 5–10%
- meningitis, 3–8%.

Bloodstream infections (BSIs) may be associated with any other type of systemic infection.^[1] Viral infections are usually sporadic or outbreak related; thus, they have not been subject to systematic surveillance.

The aetiology of late onset sepsis in neonatal ICUs is a result of the complex interplay of host defence and an adverse environment. In the neonate, host susceptibility may result from both genetic predisposition and maturational factors associated with prematurity. The relatively late maturation of the skin, particularly keratinisation and sebum production, contribute particularly to host susceptibility. The mechanics of neonatal care (eg intubation, ventilation and intravascular cannulation) all breach host defence mechanisms. Further, the neonatal ICU itself is a microcosm of bacterial activity, being a warm, moist environment with a concentrated population of patients and staff.

To handle this complex range of pathophysiological determinants, robust epidemiological information is required. Analysis of the variation of late onset sepsis rates across neonatal ICUs can help to identify harmful or beneficial clinical care factors that can be subject to change. Surveillance is also desirable within units. Temporal monitoring of late onset sepsis facilitates the early detection of statistical variation in rates. This will most likely be triggered by local environmental or health-care factors that will be amenable to change.

11.2 Harm to patients

Late onset sepsis is a major driver of mortality and morbidity in neonates admitted to intensive care. Infection has also been shown to be linked to adverse neurodevelopmental outcomes. It is not possible to compare infection data from published reports because of variations in selected patient groups, investigation practices, definitions used and types of analyses. In addition, general improvements in care over the past 20 years have significantly improved neonatal outcomes. For example, overall mortality for the entire cohort tracked by the National Institute of Child Health and Human Development (NICHD) system, which represents neonates <1500 g birthweight across 12 units, decreased from 23% in 1987–88, to 17% in 1993–94 and 14% in 1999–2000.^[6]

A selected range of multicentre studies is detailed in Table 11.1. Coagulase-negative staphylococci (CNS) account for 48–59% of bloodstream episodes. A range of other, more virulent bacterial and fungal pathogens are responsible for the remaining culture-proven episodes. Mortality rates in neonates with proven late onset sepsis have been examined in detail by the NICHD group. The most recent report concerned 6215 infants of <1500 g birthweight who survived for more than three days; of those who developed late onset sepsis, 18% died against 7% for those who did not develop late onset sepsis ($P < 0.001$).^[7] Gestational age, sex and study centre were significant risk factors for mortality. Late onset sepsis remained a strong predictor for death after adjustment for these factors. Mortality rates for gram-positive organism events (11.2%) were significantly lower than those for gram-negative (36.2%) and fungal organisms (31.8%).

Another significant problem is pneumonia caused by late onset sepsis, especially in ventilated neonates. Measurement of pneumonia rates is problematic due to the nonspecific methods available for diagnosis and the variable application of these methods. Measurement of pneumonia rates is therefore of most use for internal quality-improvement processes rather than for wider benchmarking.

Table 11.1 Selected late onset neonatal intensive care infection studies

Location	Reference	Sepsis definition used, patient selection	Patient stratification and risk adjustment	Bloodstream infection incidence	Comments
Australia and New Zealand Neonatal Network, 26 units	[16]	ANZNN/ACHS selected high-risk neonates <1000 g	Rates adjusted by gestational age and sex	5.0 (95%CI, 4.8 to 5.3) infections per 1000 p-d Infection rate (day 35 of life): 13.9 (95%CI, 13.1 to 14.7)	Considerable variation in infection rates between participating units
Australia, New Zealand, 11 units	[17]	Culture proven sepsis (BSI or meningitis) >48 hours after birth All admissions	5 BW categories (as per NHSN)	220 episodes in 197 babies <1000 g BW, 22.6% (R 15–32) ≥2500 g BW, 0.6% (R 0–2.1) CNS 56% of events	Mortality 7.7% Meningitis in 5.9%
Germany, 24 units reporting data over 3 years	[10]	Modified NHSN, all admissions	5 BW categories (as per NHSN)	Fall from 4.2 (yr 1) to 3.5 (yr 3) /1000 p-d ($P = 0.009$) CNS 51%	Culture negative late onset sepsis also declined significantly over this period
Netherlands, single unit	[13]	Modified NHSN, all admissions	5 BW categories (as per NHSN)	11.8 /1000 p-d, CNS 59%	Low BW and receipt of TPN were risk factors for BSI
United States 1998–2000 data, 12 NICHD Units	[7, 18, 19]	NICHD definition neonates <1500 g, surviving more than 3 days	5 BW categories	Incidence of blood culture proven sepsis 21% ($n = 6215$, neonates surviving >3 days), 5.4/1000 p-d 400–500 g BW) falling to 1.9/1000 p-d (1251–1500 g), 48% CNS	18% overall mortality (see text)

ACHS = Australian Council on Healthcare Standards; ANZNN = Australian and New Zealand Neonatal Network; BSI = bloodstream infection (= proven late onset sepsis); BW = birthweight; CI = confidence interval; CNS= coagulase-negative staphylococci; NICHD = National Institute of Child Health and Human Development; NHSN = National Healthcare Safety Network (formerly the National Nosocomial Infections Surveillance System (NNIS)); p-d = patient days; R = range; TPN = total parenteral nutrition; yr = year.

Several reports now attest to the success of a range of quality-improvement programs to reduce late onset sepsis; these programs rely on systematic infection surveillance and process audit. In one study, applying a closed medication system was associated with virtual elimination of intravenous line associated BSIs in intensive care neonates.^[4] Use of the Vermont Oxford network approaches to surveillance, process audit and sequenced actions on quality improvement has significantly reduced neonatal ICU late onset sepsis and blood culture contamination rates.^[8, 9] Process audits include:

- elements of hand hygiene practice
- intravascular line setup and hub care
- accuracy of sepsis diagnosis (ie number of culture diagnoses with two blood cultures positive, preparation of skin for blood culture, blood culture volume audit, and treatment of suspected sepsis for >48 hours if blood culture and ancillary tests are negative or normal).

Mean incidence of CNS bacteraemia fell from 24.6% to 16.4% (relative risk (RR) 0.67; 95%CI, 0.51 to 0.87) in three of the six centres under surveillance.

A study in Germany reported significant falls in late onset sepsis (both culture proven and culture negative) across 24 units that had participated in a standard surveillance system for sepsis.^[10] No specific changes in practice were measured in this study.

Antibiotic use in neonatal ICU patients is high and there are many reports of outbreaks caused by methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococcus (VRE) and multiresistant gram-negative pathogens, such as extended-spectrum beta-lactamase producing organisms. Infections with resistant organisms may be associated with prolonged lengths of stay and increased morbidity and mortality.^[11]

Surveillance has an important role to play in managing the risks associated with multiresistant organisms. Early identification of microorganisms with unusual antibiotic susceptibility patterns can improve the success of infection control measures. Knowledge of local antibiotic resistance patterns is needed for development of empiric antimicrobial prescribing regimens that ensure that patients receive antibiotics effective against the prevalent pathogens in a particular unit. Conversely, infection surveillance can help restrict antimicrobial use by defining indications for specific antibiotics such as vancomycin, arguably the most overused antibiotic in neonatal ICUs.^[1, 11] Measures to reduce antibiotic resistance through rational prescribing restrictions have been published.^[12]

Few data have been published on antibiotic use in neonatal ICUs. One study found that the proportion of baby days on antibiotics was 49.8%.^[13] Another study found that the proportion of baby days on antibiotics was 12%.^[14] A point prevalence survey of 1580 neonatal ICU patients in 29 neonatal ICUs, with summer and winter survey points, found that 43.3% of neonates were in receipt of antibiotics, with wide variation across the different units (15.2–85.7%).^[15] The median number of agents in use on individual neonates was 2 (range 1–5).

11.3 Impact on health-care system

The most comprehensive and most effectively controlled study to date looked at 2809 selected surviving infants of birthweights between 401 g and 1500 g admitted to one of 34 collaborative centres within the Vermont Oxford Network.^[20] The authors measured the marginal increase in cost and excess length of stay associated with neonatal ICU-associated BSIs (ie BSI late onset sepsis). These occurred in 19.7% of the patients. The average additional costs incurred by neonates with late onset sepsis, adjusted for potential confounders using multiple regression,

varied from US\$5875 (adjusted to 1999 dollar value) for those of birthweights of 401–750 g to US\$12,480 for those of birthweights of 751–1000 g. The adjusted excess length of stay varied from four to seven days across four birthweight cohorts. Differences in cost and length of stay were significant, except for the cost differential in the birthweight 401–750 g cohort. The authors were able to show that their study population resembled that of the wider United States and extrapolated their data to estimate that late onset BSI late onset sepsis added US\$100,000,000 (in 1999 dollar value) to the annual cost of treating surviving infants with birthweights of 500–1499 g.

11.4 Surveillance methods

11.4.1 Detection

The isolation of microorganisms from blood or cerebrospinal fluid (CSF), or both, remains the gold standard for diagnosis of bacterial sepsis in neonates.^[21] Many infants, however, only have clinical or biochemical signs of sepsis and culture positivity represents the tip of an iceberg. Other indirect laboratory parameters (eg IL-8, C-reactive protein or procalcitonin) have been studied in the hope that they may clarify the status of an unwell neonate.^[22]

The use of lumbar puncture in late onset sepsis is variable; it may therefore lead to under-diagnosis of late meningitis if lumbar puncture is not part of the routine process for investigation of sepsis.^[23] Most neonatologists in Australia, however, do perform a lumbar puncture in the presence of proven gram-negative, fungal or streptococcal sepsis to determine the co-presence of meningitis.^[24]

Most reports of neonatal ICU late onset sepsis are confined to culture-confirmed blood or CSF infection. There are variable definitions for ‘possible late onset sepsis’ or ‘probable late onset sepsis’ (culture negative), and these are not easily made amenable to robust surveillance definitions. The minimum requirement, then, is to accurately monitor proven (culture positive) late onset sepsis; that is, BSIs and meningitis.

11.4.2 Definitions

The differentiation of neonatal ICU-acquired late onset sepsis from early onset (maternally-acquired) sepsis is not always straightforward. In general, vertically-acquired bacterial infections will declare themselves within 48 hours of delivery and neonatal ICU-acquired infections will only rarely present in this time. There are undoubtedly some specific examples, particularly viral infections, that will not obey this rule (eg herpes simplex virus (HSV) infections); such infections tend to be subject to specific notification and investigation.

Gray provides a comprehensive review of infection surveillance in the neonatal ICU setting.^[1] Many different surveillance definitions have been developed. The Australian and New Zealand Neonatal Network (ANZNN) and the Australian Council on Healthcare Standards (ACHS) have an agreed indicator set for neonatal ICU surveillance, developed in 2003. ANZNN applies the infection numerator definition in its detection process for late onset events. This surveillance definition is not completely accepted, and needs to be further reviewed and developed (see Figure 11.1). Other definitions in use include:

- those developed by the National Healthcare Safety Network (NHSN) (formerly the National Nosocomial Infections Surveillance System (NNIS)),^[25] currently in use in Victoria
- modified NHSN/NNIS definitions currently in use in Germany^[26] and the Netherlands.^[13]

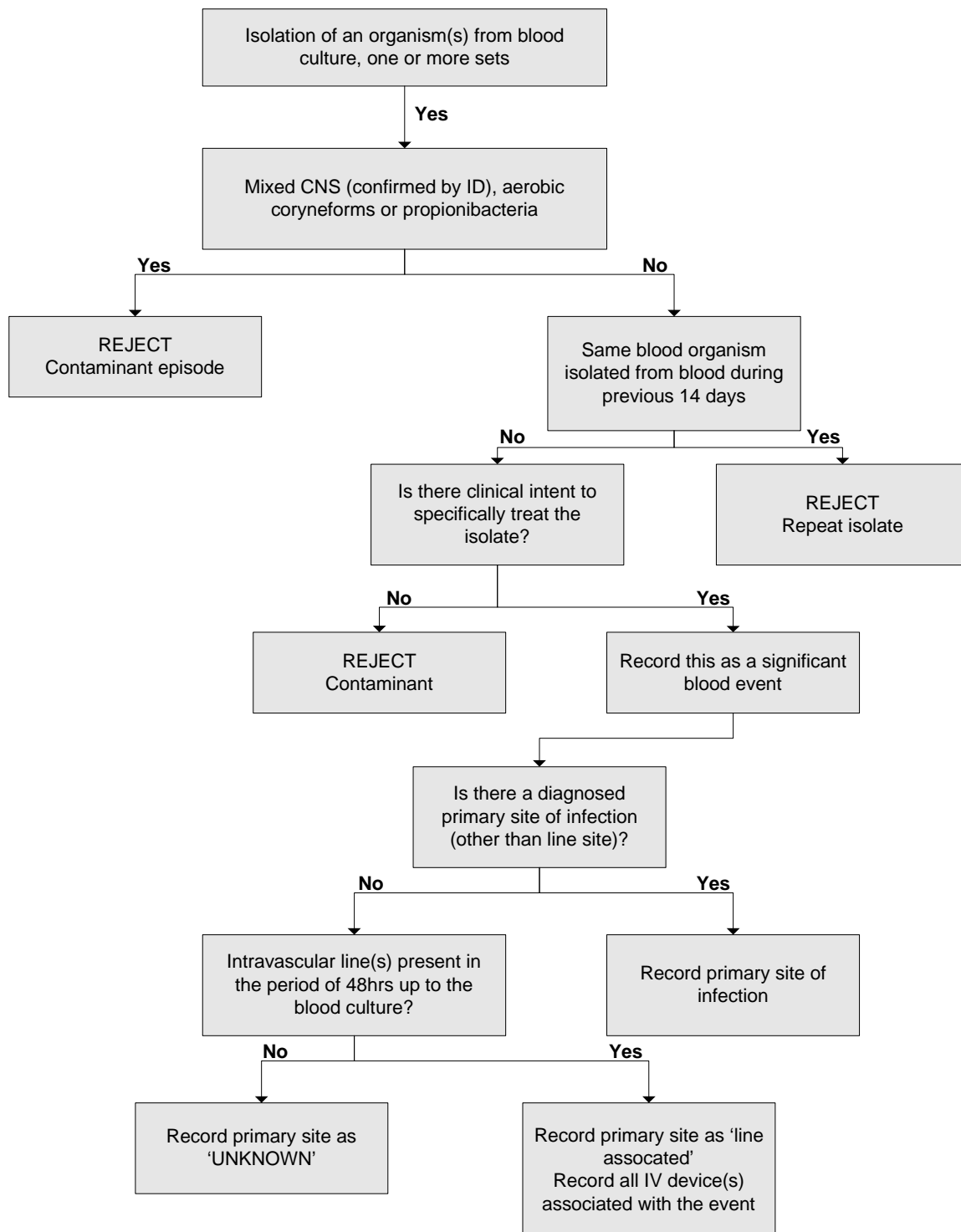


Figure 11.1 Australian Council on Healthcare Standards infection control indicators Version 3 (2005)

CNS = coagulase-negative staphylococci; IV = intravenous

Source: Australian Council on Healthcare Standards Infection Control Indicator Manual (version 3, 2005)^[30]

11.4.3 Validation

Detection of late onset infection by blood or CSF culture is prone to false positives and negatives. False positives occur due to contamination of cultures during collection. False negatives occur due to inadequate volume of sampling or presence of antibiotics that inhibit growth, or both. At least 25% of clinically diagnosed sepsis events are culture negative.^[1]

Most neonates with early or late onset bacterial sepsis develop high colony count bacteraemia. However, quantitative studies indicate that low-density bacteraemia is also recorded for most pathogens. One review looked at the main aspects of blood culture practice that might affect reliability of detection of sepsis (ie volume of blood drawn, dilution factors, number of cultures taken, blood culture technique, timing of culture and choice of blood culture system).^[27] Laboratory-based work indicates that organisms at densities of <4 colony forming units (CFU)/mL, inoculated at volumes of 0.5 mL or less, are not reliably detected.^[28]

A study evaluated 83 pairs of blood cultures (≥ 1 mL per set) taken from 43 neonates for assessment of late sepsis. A total of 21 positive cultures were obtained, with the same organism being cultured from each paired collection.^[29] The study implied that false positives (ie contaminant cultures) were infrequent, provided that great care is taken with asepsis during collection. Further, single-culture collections appeared to have adequate sensitivity, provided the volume of collection was sufficient. This work underlines the importance of standardising blood culture collection practice to improve both surveillance detection and clinical care.

Chapter 4 (Neonatal infection – early onset) discusses blood culture contamination and its avoidance.

11.4.4 Reporting

Early studies reported infection rates against admitted infant numbers. This did not take into account the significant influence of gestational age, birthweight, sex, length of stay and other illness on sepsis rates. More recently, incidence density (neonatal ICU-associated BSI events per 1000 patient days) has found favour. This denominator is a better measure of exposure and more appropriately handles multiple infections. The 2003 ACHS version 3 clinical indicators (ANZNN endorsed) incorporate these denominators in four surveillance indicators (see Table 11.2).

Table 11.2 Numerators and denominators for different indicators

Indicator	Numerator	Denominator
CI. 4.3 Late onset intensive care infection rate — neonates of <1000 g birthweight admitted to intensive care	Number of babies of birthweight <1000 g admitted during the time period under study who have a significant blood infection occurring more than 48 hours after birth at any time during their whole admission	The total number of babies of birthweight <1000 g who survive >48 hours admitted during the time period under study
CI. 4.4 Late onset intensive care infection rate — neonates of ≥1000 g birthweight	Number of babies of ≥1000 g birthweight admitted during the time period under study who have a significant blood infection occurring more than 48 hours after birth at any time during their whole admission	The total number of babies of >1000 g birthweight who survive >48 hours admitted during the time period under study
CI. 4.5 Late onset intensive care infection incidence — neonates of <1000 g birthweight	The number of significant blood infections in admitted babies of <1000 g birthweight occurring more than 48 hours after birth during the time period under study	Number of patient days accrued by babies of <1000 g birthweight during the time period under study (includes level 3 and 2 bed days)
CI 4.6 Late onset intensive care infection incidence — neonates of ≥1000 g birthweight	The number of significant blood infections in admitted babies of ≥1000 g birthweight occurring more than 48 hours after birth during the time period under study	Number of patient days accrued by babies of ≥1000 g birthweight admitted to the ICU during the time period under study

ICU = intensive care unit

Source: Australian Council on Healthcare Standards Infection Control Indicator Manual (version 3, 2005)^[30]

The concept has been further refined by using a census point of 35 days; this recognises the fact that late onset sepsis events are most likely to occur over the first few weeks of life and negates the convalescent period of admission. Using 35 days improves signal-to-noise ratio and corrects for variations in discharge patterns between units.^[16] An analysis of ANZNN unit data concerning infants <1000 g birthweight developed more comparable rates by adjusting for sex and gestational age mixes within each unit.^[16] Adjusting for gestational age is important because infection rates within a birthweight cohort are strongly influenced by this factor.

For the individual unit, changes in neonatal ICU-associated proven late onset sepsis over time are critical. It is statistically challenging to monitor such rare events (typically less than five per month), where a single event can produce a large change in the rate, in a way that can accurately predict true change in a timely manner. Change is currently best measured by Shewart analysis,^[31] where a consistent deviation from a defined point can be related to a set of complex control rules. Again, considerable care is required in the interpretation of such data, and the balance between appropriate concern and overreaction remains delicate. For an individual unit, it is probably unnecessary to correct for gestational age, but such a bias should be considered if control is lost.

The evolution of sophisticated statistical modelling of inter-unit variation will be one of the main drivers of advances in neonatal care over the coming years. Such analysis should be complementary to clinical trials; in many cases, it can inform multicentre randomised control trials. The natural extension of benchmarking is exploration of underlying unit variation, with emphasis on determining why the best performers are achieving such results. There are also clear

advantages in developing this field internationally and the ANZNN would benefit from working closely with both the Vermont Oxford Network and the Canadian Neonatal Network, which are exploring outcome and practice variation internationally.^[32, 33]

11.5 Current surveillance systems

11.5.1 International

In Europe, late onset sepsis surveillance is conducted across all German and Dutch neonatal ICUs, using modified NHSN/NNIS definitions.^[10, 13]

In the United States and Canada, several regional neonatal networks conduct standardised late onset sepsis surveillance, mostly using registry systems that incorporate perinatal and neonatal data on all high-risk infants. Prominent institutes are the NICHD, the Vermont Oxford Network and the Canadian Neonatal Network.

The NHSN/NNIS supports infection surveillance in more than 100 neonatal ICUs in the United States. This system is not based on a neonatal registry; it produces device-associated infection rates stratified by birthweight cohorts.^[34] Recent data are available based on 46 units.^[35]

11.5.2 Australia

In Victoria, the Victorian Hospital-Acquired Infection Surveillance (VICNISS) program conducts a neonatal intensive care surveillance program based on the NHSN/NNIS model. All four public units participate. Central line and peripheral line associated BSIs are detected and reported against line-day denominators, stratified by five birthweight groups.^[36]

Three neonatal ICUs in New South Wales have submitted late onset BSI data using version 3 ACHS indicators, in line with state requirements mandated since January 2005. In 2008, reporting ceases to be recommended. In other states, very few individual facilities have contributed data against the ACHS neonatal indicators across Australia.

The Australasian Study Group for Neonatal Infections collects data from around 16 facilities across Australia and New Zealand. Their surveillance definition for late onset sepsis is slightly different to the ACHS indicator definition. These data are published periodically.^[17, 37, 38, 39]

The ANZNN collects standardised, individual patient data from all neonatal ICUs using a registry system.^[40] The collection includes maternal, perinatal and neonatal data. Sepsis information is collected on a subset of infants admitted to a neonatal ICU during the first 28 days of life who have one or more of the following:

- gestational age less than 32 weeks
- birthweight less than 1500 g
- assisted ventilation (intermittent positive pressure respiration/continuous positive airway pressure) for four hours or more
- major surgery.

The ANZNN has used the ANZNN/ACHS sepsis definition since 2003. Substantial data are available from 26 units and have been analysed recently for publication.^[16]

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12 Smaller hospitals

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Key points

- There is limited published literature on health care associated infections and surveillance programs in smaller hospitals (<100 acute-care beds) because most frequently referenced studies have taken place in larger hospitals.

Recommendations on smaller hospitals

1. A surveillance program for smaller hospitals (<100 acute-care beds) based on the signal event surveillance program and relevant process indicator measures is required.
2. Smaller hospitals require mechanisms to support staff involved in infection prevention and control; for example, through external support networks and alignment of services with infection prevention and control teams from larger hospitals, or with regional, state and territory groups.

12.1 Background

Smaller hospitals may be defined as those with fewer than 100 acute-care beds. The United States National Healthcare Safety Network (NHSN) (formerly the National Nosocomial Infections Surveillance System (NNIS)) included only ‘larger hospitals with greater than 100 acute-care beds’ for statistical reasons.^[1] Alternatively, smaller hospitals may be defined as those that have ‘small datasets’; that is, less than 50 surgical procedures of a similar type per year and/or an average of less than two health care associated bloodstream infections (BSIs) per month.^[2]

In 2003, multiple sources were used to assemble data on the 90 smaller (<100 acute-care beds) hospitals in Victoria.^[3] Most of these hospitals (93%) were located in rural regions. Many had additional subacute or aged-care beds located on the same site. The ratio of acute-care beds to total beds increased with increasing number of acute-care beds. Of the 90 hospitals, 44 (69%) performed surgery, and 11 of these hospitals performed at least 100 procedures per year in one or more of the NHSN/NNIS-associated surgical groups. Only one had an intensive care unit (ICU); 23 had onsite pathology services.

Sixty-two (97%) of the hospitals had designated infection control employment hours (mean 10.6 hours). The average weekly hours worked by the infection control consultants increased with increasing number of acute-care beds. The estimated time spent on surveillance activities per week varied from 0.5 to 8 hours (mean 1.94 hours).

In 2000, responses from a survey sent to Australian Infection Control Association (AICA) members revealed that the smallest facilities (<51 beds) were significantly less likely to conduct surveillance than were the larger facilities ($P = 0.0001$). Larger hospitals spent significantly more time on surveillance than did smaller hospitals ($P = 0.0001$). Larger facilities reported a significantly greater use of computer programs for surveillance than did smaller facilities ($P < 0.0001$).

12.2 Current surveillance systems

Smaller hospitals need to be aware of the limitations of analysing small sample sizes.^[4, 5] Possible alternative approaches include:

- calculating outcome rates less frequently (ie quarterly, semi-annually or annually)
- combining outcome data and generating rates for ‘like’ hospitals^[6, 7]
- monitoring outcomes using non-conventional process control charts such as Bayesian shrinkage plots rather than rate-based analyses (E Tong, statistician, CHRISP, pers comm, 2008)
- using signal infection surveillance
- using process measurement.^[1, 2]

In Australia, hospitals perform outcome, process and signal infection surveillance reporting to a variety of internal and external agencies. Examples of formal jurisdictional surveillance programs for health care associated infection (HAI) specifically developed for smaller hospitals are the Queensland Health Signal Infection Surveillance program, which is also used in South Australia, and the type 2 hospital surveillance in Victoria. In Western Australia and New South Wales, smaller hospitals also participate in jurisdictional HAI surveillance programs.

New South Wales has an incident monitoring system under which all health facility staff are encouraged to report adverse events and near misses. Infection control staff are instructed to report HAI events onto this system. However, relatively few infections that occur are reported. The state’s Quality Monitoring Program (version 2) specifies a range of indicators to be reported from all facilities, including small ones. Under this version, smaller hospitals report:

- occupational exposures (rates of parenteral and non-parenteral injuries against patient-day denominator)
- detailed assessments of all individual exposure events (via EPINET database)
- health care associated methicillin-resistant *Staphylococcus aureus* (MRSA) colonisations and infections in a non-sterile site (against patient-day denominator)
- health care associated MRSA infections in a sterile site
- health care associated BSIs that are not associated with an intravenous line.

New requirements recently published include reporting of *S. aureus* BSI from all facilities.

12.2.1 Centre for Healthcare Related Infection Surveillance and Prevention Signal Infection Surveillance Program

In 2004, the Centre for Healthcare Related Infection Surveillance and Prevention (CHRISP) developed specific methodology to provide small and medium sized inpatient health-care facilities with a framework within which to investigate HAI and identify potential systematic issues requiring improvement.

The following ‘signals’ are included in the surveillance program:

- BSI
- surgical site infection (SSI)
- multiresistant organism infection and colonisation
 - MRSA
 - vancomycin-resistant enterococcus (VRE)
 - *Acinetobacter* spp (carbapenem resistant)

- extended spectrum beta-lactamase (ESBL) producing organisms (eg ESBL-producing *Klebsiella pneumoniae*)
- urinary tract infection (catheter associated)
- gastrointestinal infection (the trigger for this signal will be a request for testing rather than a final result)
 - *Clostridium difficile*
 - norovirus
 - rotavirus
- occupational exposure.

An automated list has been developed in the AUSLAB™ Pathology System (PJA Computer Consultants) that captures results relevant to each signal (eg positive blood culture). Only events that meet criteria for HAI arising in patients who have not been transferred from another facility are investigated further. A structured investigation is then undertaken by the infection control nurse, focusing on policies and practices that are relevant to that particular type of infection. In addition, the results of previous investigations are reviewed to look at whether similar issues have arisen and are recurring, and actions arising from the investigation are formally logged.

The South Australian Infection Control Service^[8] has endorsed the CHRISP Signal Infection Surveillance Program for smaller hospitals in South Australia.

12.2.2 Victorian Hospital-Acquired Infection Surveillance type 2 surveillance program

The Victorian Hospital-Acquired Infection Surveillance (VICNISS) type 2 (or smaller hospital) surveillance program recommends that smaller Victorian hospitals monitor the following process or outcome indicators:

- process indicator modules:
 - surgical antibiotic prophylaxis
 - health-care workers and measles vaccination
 - health-care workers and hepatitis B vaccination
 - peripheral venous catheter use
- outcome indicator modules:
 - multiresistant organism (MRSA and VRE) infections
 - primary laboratory confirmed bloodstream infections (LCBSIs)
 - occupational exposure
 - outpatient haemodialysis events (OPHEs) (positive blood cultures or commencement of intravenous vancomycin)
 - SSI
 - surgical infection reports (‘inherited’ and ‘inhouse’ deep incision and organ space SSIs).

Completed paper data collection forms are faxed to the VICNISS Coordinating Centre by a specified date. Quarterly reports are posted about seven weeks after the data submission deadline

to a password-secure area on the VICNISS website. Hospitals can compare their rates to aggregated rates from other hospitals. Tables 12.1 and 12.2 show examples of VICNISS aggregate rates of one of these outcome indicators.^[9] In general, across the state, process indicators that require improvement were identified and outcome indicators were infrequent.

Table 12.1 Surgical antibiotic prophylaxis (%)

Objective	Number of procedures	Guideline recommendation	Concordant with guidelines	Adequate but not concordant with guidelines	Inadequate	Unknown
Choice	3281	Antibiotics given according to the <i>Therapeutic Guidelines Antibiotics</i> ^a	56.8	17.2	23.7	2.3
Timing	2692	Antibiotics given within two hours before surgical incision	53.2	–	37.8	9.1
Duration	2691	Antibiotics ceased within 24 hours after surgery	78.1	–	16.5	5.4

a <http://etg.tg.com.au/complete/>

In 17% of 2691 procedures, surgical prophylactic antibiotics were administered for a period of more than 24 hours after the procedure.

Table 12.2 Victorian Hospital-Acquired Infection Surveillance outcome indicator module aggregate results

Objective	Surveillance period ^a	No. of hospitals	No. of events	Rate	95% CI
LCBSI >48 hours post-admission per 10,000 OBDs	1	88	31	0.3	0.2 to 0.5
MRSA infection present on admission or within 48 hours post-admission per 10,000 OBDs	1	88	89	1	0.8 to 1.2
MRSA infection >48 hours post-admission per 10,000 OBDs	1	88	46	0.5	0.4 to 0.7
Parenteral occupational exposures per 10,000 OBDs	2	89	276	3.7	3.3 to 4.2
Non-parenteral occupational exposures per 10,000 OBDs	2	89	77	1.0	0.8 to 1.3
OPHEs per 100 patient months	1	20	18	0.76	0.4 to 1.2
Number of surgical infection reports	1	88	151	–	–

CI = confidence interval; LCBSI = laboratory confirmed bloodstream infection; MRSA = methicillin-resistant *Staphylococcus aureus*; OBD = occupied bed day; OPHE = outpatient haemodialysis event

^a Surveillance period 1 = 1/5/04–31/12/06; surveillance period 2 = 1/1/05–31/12/06

12.2.3 Evaluations of smaller hospital health care associated infection surveillance systems

To determine whether ‘novel’ smaller hospital HAI surveillance programs are an effective use of health resources, they should be extensively evaluated. In smaller hospitals, as elsewhere, the most important public health events only should be under surveillance and the surveillance program that monitors these events should meet the surveillance objectives as effectively as possible.^[10]

The definitive measure of an HAI surveillance program is its effectiveness in reducing the incidence of HAIs. The Study on the Efficacy of Nosocomial Infection Control (SENIC) study remains the most important demonstration of effectiveness of an infection control (surveillance) program.^[1] However, the applicability of this study to smaller hospitals is uncertain; hospitals of less than 50 beds were excluded and only a small sample of hospitals of 50–100 beds were included.

In 2003, the VICNISS type 2 surveillance program was piloted in 14 hospitals.^[11] During this pilot stage, a data-quality study was undertaken to assess the accuracy of data collected as part of the MRSA and BSI modules.^[12] The estimates for the reported MRSA infections were 40% for sensitivity, 99.9% for specificity and 33.3% for positive predictive value (PPV). The estimates for the reported BSIs were 42.9% for sensitivity, 99.8% for specificity and 37.5% for PPV. It was concluded that the program needed to be reviewed and changes made to improve these estimates. A detailed data-quality study is yet to be carried out.

In 2006, 45 infection control nurses responded to a survey that assessed a number of key parts of the VICNISS type 2 surveillance program; these were data collection, reports and the educational strategies used to support the program. In general, there was considerable support for the current program. Only a few program elements were identified as needing further development, including the web-based education package and workplace visits.^[13] About half (52.3%) of the respondents agreed that the surveillance reports were easy to understand. The most frequent (72.9%) use of these reports was to present information to accreditation organisations. About half (46.2%) of the respondents did not find the web-based education package useful, and 50% did not find the workplace visits by the 'educators' useful.

In July 2007, CHRISP undertook an evaluation of the Signal Infection Surveillance Program to:

- ascertain the level of implementation in 96 Queensland Health hospitals
- evaluate the usefulness of the manual and online resources
- determine any areas of concern or opportunities for improvement.

A total of 58% of hospitals responded, using a standardised survey form based on the United States Centers for Disease Control and Prevention (CDC) Framework for Public Health Program Evaluation.

The survey found that infection control experience ranged from less than one year to more than seven years. The average number of hours allocated to infection control was eight hours per week; however, 75% of respondents had one or more responsibilities other than infection control. More than 60% of all facilities that responded received less than 5 signals per year for all signal types, 95% received less than 10 signals per year, and 30% received more than 10 signals per year. On average, only one-third of signals required investigation; the most common signals were SSI and multiresistant organisms.

Most respondents were satisfied with the structure and content of the manual, including associated resources. All respondents felt that signal infection surveillance was of benefit to their infection control program and facility; however, 55% indicated that they were not allocated sufficient time to undertake surveillance and 44% indicated that they were provided with insufficient resources, such as access to computers.

Staff attrition in rural and remote health-care facilities has been a significant issue. Subsequent to the evaluation, CHRISP appointed a dedicated project officer to support the signal infection surveillance hospitals.

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13 Residential aged-care facilities

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Key points

- As Australia's population ages, the number of elderly people living in residential aged-care facilities is expected to increase substantially.
- Residents of residential aged-care facilities are at high risk from community infections and health care associated infection. They live in a home-like environment, have close contact with potentially infected or colonised residents and staff, have increased antibiotic exposure and exposure to hospital stays, and are often immunocompromised.
- Residents of residential aged-care facilities may become colonised with multiresistant organisms, which are transmitted to other patients when residents are hospitalised.
- Infection surveillance systems in residential aged-care facilities are needed to detect disease outbreaks. Routine detection of sporadic infections is error prone, given the variability in current infection definitions and surveillance methods, and the lack of trained staff.
- Optimal infectious disease control in residential aged-care facilities focuses on preventive strategies (eg immunisation of staff and residents) and compliance with process measures (eg hand hygiene and other standard infection control requirements).

Recommendations on residential aged-care facilities

1. Long-term facilities require a standardised system of local surveillance focusing on processes such as standard infection control precautions, including hand-hygiene compliance and device-related care.
2. Immunisation status among residents and staff should be monitored, with particular reference to influenza, hepatitis B and hepatitis A.
3. The development of validated Australian definitions for infection surveillance in residential aged-care facilities is required.
4. The development of strategies to evaluate and improve antibiotic prescribing in residential aged-care facilities is required.

13.1 Background

As Australia's population ages, the percentage of older people living in residential aged-care facilities will increase dramatically. The number of people aged 65 and over is projected to increase from 2.3 million in 1998 to 5.1 million by 2031 (from 12% of the total population to 21%). The number of people aged 80 and over, who are most likely to require nursing home or hostel accommodation or other forms of support, is projected to increase from 520,000 to 1.4 million (from 3% of the total population to 6%).^[14]

Residents of care facilities are more susceptible to infections than non-residents for many reasons, including:

- underlying disease
- antibiotic exposure, which affects resistance to infection
- impaired mental and functional status

- invasive devices
- incontinence
- multiple medications
- impaired mobility.

The acuity or dependency of the resident and the type of residential-care facility affects both risk factors for infection and the burden of disease, which thus vary greatly between residents.^[15] The maintenance of a home-like environment, for example, together with staff shortages in the residential aged-care setting can contribute to an environment that promotes transmission of infectious agents.

Residential aged-care settings and resident care practices — for example, extensive use of broad-spectrum antimicrobials, close contact between residents and a poor standard of infection control practice — can also promote the emergence of antimicrobial-resistant organisms and *Clostridium difficile*. Recent reports of outbreaks in residential-care facilities refer to multiresistant *Escherichia coli* (extended spectrum beta-lactamase producers) and *Acinetobacter baumannii*,^[16] and multiresistant *Streptococcus pneumoniae*.^[17] Increasing rates of methicillin-resistant *Staphylococcus aureus* (MRSA) colonisation and infection in residents of care facilities have also been described in many countries, detected by studies that test residents upon admission to hospital and by prevalence studies within residential-care facilities.

Vaccine-preventable diseases, such as hepatitis A, influenza and pertussis, may cause residential-care facility outbreaks resulting in considerable morbidity and mortality. Elderly or immunocompromised residents, who often do not generate protective immune responses following vaccination, remain vulnerable to these infections. In addition, many residents are never offered indicated vaccinations by facility staff.^[18]

Most vaccine-preventable infections are transmitted to susceptible residents by infected health-care staff or facility staff. To protect residents effectively, all facility staff must be vaccinated against key diseases. Universal staff influenza vaccination programs, which have been associated with lowered mortality among residents in two randomised controlled trials, are a recommended standard practice.^[19, 20]

Outbreaks of serious respiratory illness due to other viruses (eg human metapneumovirus, rhinovirus and adenovirus) and bacteria (eg *S. pneumoniae*) have also been recorded. Enteric viruses and bacteria are frequently associated with outbreaks of gastroenteritis in residential-care facilities worldwide, causing significant morbidity and mortality. These outbreaks are usually difficult to control, as are scabies outbreaks.^[21]

13.2 Harm to residents

Infections are common in residential-care facilities, particularly in high-care nursing homes. Elderly people living in these facilities have a substantially increased incidence and severity of infections, which can cause considerable morbidity and mortality.^[22] The risk of residents of aged-care facilities developing infections, compared to elderly persons living at home, has not yet been systematically studied.

Forrest used McGeer definitions^[39] to report on infection surveillance in six Sydney residential-care facilities (total 450 beds) from 2001 to 2005.^[23] Overall infection rates decreased from 4.8/1000 resident days in 2001 to 2.6/1000 resident days in 2005; the mean rate of infection was 3.23/1000 bed days. Respiratory, urinary tract, skin and soft tissue infections were the most

frequent; 134 gastroenteritis and 11 bloodstream infections were also reported. Infections followed a seasonal trend; they mainly occurred from May to September and peaked in July.

Reilly used modified McGeer infection definitions in 2001 in a report on infection surveillance data prospectively collected over one year in 10 private, freestanding, accredited residential-care facilities (total 407 beds) in Perth, Western Australia.^[24] The overall infection incidence was 4.6/1000 resident days; rates in individual facilities ranged from 1.9 to 9.0. The most common infection sites were respiratory tract, urinary tract, skin and soft tissue, including eye and mouth tissue. Gram-negative organisms were the most frequently identified bacterial isolates (72%) and were most commonly isolated from urine cultures. No multiresistant organisms were isolated.

The 1999 Victorian Infection Control Surveillance Project Long-term Care Facilities Point Prevalence Survey (G Harrington, Coordinator, Victorian Infection Control Surveillance Project, pers comm, 2008) examined 19 residential-care facilities (3290 beds in rehabilitation and nursing home settings) in metropolitan Melbourne and country Victoria. McGeer infection definitions were used for wards designated as nursing home type. The overall infection rate for rehabilitation settings was 5.2/1000 beds (95%CI, 3.7 to 7.0), with 2.5% of the infections device related. In nursing home settings, the rate was 6.0/1000 beds (95%CI, 5.1 to 7.0), with 4.0% of infections device related.

Internationally, studies from Germany,^[25] Norway^[26] and Italy^[27] identified rates of 6.0, 5.2 and 11.8 infections per 1000 resident days, respectively. The German study monitored 125 nursing-home residents over almost 35,000 resident days.^[25] Thirty (24.0%) residents died in the nursing home; in 13 (43.3%) of these patients, an infection was regarded as either the direct cause of death or a major contributing factor. In German residential-care facilities, 94% of health care associated infections (HAIs) are caused by gastroenteritis, and skin, soft tissue or urinary and respiratory infections; in this study, residents with pneumonia were more likely to die than those with other HAIs (relative risk (RR) 5.09; 95%CI, 1.87 to 13.89; $P = 0.011$).

In the United States, incidence of infection ranges from 1.8 to 9.4 infections per 1000 resident days; the most reliable study documented an incidence of 7.2 infections per 1000 resident days.^[22] Incidence of infection at all-male veteran affairs facilities ranges from 2.6 to 5.4 infections per 1000 resident days. Urinary tract and lower respiratory infections are the most common, followed by skin and soft tissue infection.

In a Belgian study of 23 nursing homes, MRSA colonisation was an independent risk factor for mortality in residents with impaired cognitive status.^[28]

Outbreak-related mortality (eg from influenza and other respiratory pathogens or from gastrointestinal infections, including *C. difficile*) is a major problem in residential-care facilities.^[29] Ward and colleagues, in 2000, reported three norovirus outbreaks in Brisbane in 1999.^[30] Common findings were rapid spread of the illness within institutions and difficulties in identifying a common source.^[30]

A three-week outbreak of 81 cases of norovirus infection in a South Australian residential-care facility was reported.^[31] Environmental contamination, aerosol transmission and work practices that failed to take account of the natural history of norovirus infection probably contributed to the size and duration of this outbreak among the residents, staff and visitors of the residential-care facility.

A study of the viral aetiology of gastroenteritis outbreaks in Victorian residential-care facilities from 1997 to 2000 found that rotavirus was detected in 18 of 29 individuals who were associated with 7 of 53 outbreaks (13%); these were all due to Group A rotaviruses and had a winter–spring

seasonality.^[32] Norovirus was detected in 22 outbreaks (42%) and astrovirus was detected in one outbreak (2%).

The public health team investigated and managed a cluster of influenza A outbreaks in six residential-care facilities in the Hunter region of New South Wales in 2004 (T Merritt, Hunter Population Health, pers comm, 2004). In this outbreak, 41% of 324 residents became ill and 13 deaths occurred. The investigation's findings included:

- late recognition and notification of outbreaks (18 days in one case)
- variable influenza immunisation rates (56–95%) of residents
- low rates of influenza immunisation among staff (17% in one facility)
- poor immunisation documentation in four of the six facilities.

One study reported a summer outbreak of acute respiratory illness among residents of a Sydney nursing home in 1999.^[33] The authors suggested that surveillance for respiratory infection should continue through the summer months. The case study below gives an example of a norovirus outbreak in a residential-care facility in Melbourne.

Case study —Norovirus outbreak in a residential-care facility

In October 2002, three wards in a 500-bed residential-care facility located in Melbourne, Victoria notified the infection control and epidemiology unit that acute gastroenteritis was occurring among patients and staff. The affected wards were located on different floors of the facility or were in separate blocks of the building.

The outbreak was controlled 32 days after the first report of symptoms of acute gastroenteritis. Fifty-two patients and 11 staff members were affected. Stool specimens were collected from all symptomatic patients and approximately 20% of the symptomatic staff. Bacterial cultures were negative and norovirus was detected in two patients.

Source: Cooper and Blamey (2005)^[34]

13.3 Impact on health-care system

Infection has been identified as the major cause for 27% of hospital admissions among residents of aged-care facilities aged 65 and older.^[35] The authors of the study implied that this estimate was the tip of the iceberg given the absence of standardised residential-care facility surveillance systems. Zimmer and colleagues estimated that if nursing homes provided a higher level of care, they could probably have prevented all hospital admissions or emergency department visits for 75% of the 112 residents in their study.^[36]

MRSA-colonised residents represent an MRSA reservoir and can potentially spread MRSA on admission to hospitals. For example, one study reported MRSA prevalence in South Australian nursing homes.^[37] From the eligible population of 428, 260 residents consented to nasal and wound swabs. Of these residents, 27 (10.4%) were colonised with MRSA and 38% of the MRSA strains shared an antibiogram indicative of the local hospital strain.

A study of New South Wales Central Coast public hospitals evaluated a policy that required screening of all nursing home residents for MRSA upon admission. The screening detected MRSA colonisation in 3% of the final study group of 100; this result influenced policy and nursing home residents are no longer routinely screened on admission.^[38]

13.4 Surveillance

13.4.1 Detection

Following certain process measures is more likely to improve the quality of care in residential-care facilities than implementing surveillance systems that rely on detecting and reacting to relatively infrequent or minor infection outcomes. Process measures that are favoured in residential-care facilities include:

- annual surveys of
 - influenza and pneumococcal vaccination for residents, staff and volunteers
 - tuberculin skin testing status
- audits of
 - hand-hygiene compliance
 - other standard infection control practice (eg selection and use of personal protective equipment such as masks, gloves and protective eyewear)
 - device-related care and utilisation (eg urinary catheters, percutaneous gastrostomies, tracheostomies, subcutaneous infusions)
 - environmental hygiene
 - antibiotic usage (see Chapter 15)
 - prevalence of antibiotic resistance in isolates obtained from residents (see Chapter 6).

The many potential barriers that prevent surveillance from being conducted effectively in residential-care facilities include:

- management staff frequently being unaware of the importance and prevention of infection
- accreditation standards that insufficiently specify surveillance requirements
- trained infection control or other surveillance staff of a residential-care facility often being unavailable, leading to variable surveillance
- variability of medical input and specimen collection, which leads to inappropriate microbiological assessment of residents
- lack of robust standardised infection definitions
- lack of employee health services to facilitate immunisation audits and standard infection control education for staff
- lack of designated time for infection prevention and control activities in residential-care facilities, which leads to failure to adequately address process audits and quality improvements.

13.4.2 Definitions

McGeer and colleagues' definitions for infections in residential-care facility clients are the most widely accepted.^[39] Defined infection types include:

- wound, skin and soft tissue (including scabies, viral and fungal infections)
- respiratory (including upper and lower respiratory tract, and influenza)
- eye, ear, nose and peri-oral

- urinary tract
- gastrointestinal
- systemic.

The McGeer definitions for infection surveillance in long-term care facilities are currently recommended by the infection control guidelines issued by the Australian Government Department of Health and Ageing.^[40, 41]

McGeer definitions have been used successfully in various residential-care facility settings. However, they require a substantial time investment for surveillance, which might detract from measures such as process audits that should have first priority. Reliable application of these definitions away from the research setting is also a problem (see Section 13.4.3).

The McGeer definitions could be made more practical by reducing the number of infection types monitored and revising some of the definitions. Standardised audit measures and methods for key health-care processes in residential-care facilities are also needed for effective implementation of changes required to meet accepted standards.

13.4.3 Validation

Although McGeer surveillance criteria are widely accepted, they have not been rigorously validated and some definitions lack specificity. For example, a resident with a urinary catheter requires only an occurrence of fever (in the absence of another cause) and a macroscopic change in urine character for the diagnostic criteria of urinary infection to be met. Many of the McGeer definitions also cite a temperature of more than 38°C as one criterion for infection, yet residents of aged-care facilities rarely exhibit high temperatures associated with infection; a lowered temperature is more common. Therefore, new-onset hypothermia needs to be considered within the definition of infection; for example, less than 36°C for urinary and respiratory infections.

The McGeer definitions also do not specifically address the detection of influenza or emerging pathogens such as *C. difficile* and MRSA. Infection surveillance systems must focus on reliable detection of certain sentinel events (eg bacteraemic infection, *C. difficile* associated disease) or outbreaks (eg influenza, other respiratory tract infection, gastroenteritis) that are of greater significance and require a faster response than many other minor infections. Systems that detect or document MRSA-colonised clients are also important. These systems ensure that these clients are isolated appropriately in the acute-care setting and also that communication occurs, with the facilities accepting the care of these patients.

13.4.4 Reporting

No reliable system for comparing infection rates is available.^[29] Discussions about expressing residential-care facility infection data as rates per 1000 resident days or device-utilisation days must keep in mind that, even when calculation methods are consistent, infection rates vary widely between facilities. This is due to differences in detection methods, resident risk factors and disease severity.

Existing infection definitions for the acute-care setting do not meet the needs of the diverse range of non-acute residential-care facility environments. The absence of standardised infection surveillance in residential-care facilities makes it difficult to accurately measure infection rates and benchmarking processes that might prevent endemic and epidemic infection in residents. The lack of systems for finding active cases also hinders the detection of infection outbreaks.

Classifying risk in residential-care facilities can be difficult because many factors affect susceptibility to infection. Infection surveillance risk factors could be separated into high- and low-care services, but the care practices for these services and ‘ageing in place’ (whereby low-care hostel residents who progress to needing high care are not moved to another location but supported where they are) in numerous low-care facilities may confound this classification. Alternatively, it may be helpful to risk-stratify residents based on the levels of care specified under the new Aged Care Funding Instrument. However, this option does not take into account that some residents (eg those with dementia) can be classified as having high levels of complex care, yet are at no increased risk of infection or environmental infection risk factors.

13.5 Current surveillance systems

13.5.1 International

No jurisdictional systems of surveillance across residential-care facilities were identified.

13.5.2 Australia

Within Australia, the Aged Care Standards and Accreditation Agency Ltd requires residential-care facilities to have an effective infection control program that includes an infection surveillance system incorporating collection and analysis of resident infection data.^[42] However, the standard does not delineate the specific nature of this surveillance system. Australian literature relating to infection surveillance programs in residential aged care is scarce.^[24]

There are no systematic surveillance systems for infection in residential-care facilities in any Australian state or territory. Annual immunisation audits are performed across residential-care facilities in some regions. Neither the Australian Council on Healthcare Standards nor the Aged Care Accreditation Standards Agency collects indicators associated with residential-care facility infections.

Of the 104 residential-care facility respondents to the National Surveillance Survey (see Appendix 1), only 14% indicated that they do not carry out surveillance. More than 80% indicated that they conduct surveillance for gastrointestinal, respiratory, urinary and other infections, but only 18% indicated that they conduct urinary catheter process audits.

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Part E — Preventive measures

14 Hand hygiene

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Key points

- Transfer of microbial pathogens on the hands of health-care workers (HCWs) is a key driver of health care associated infection (HAI).
- Alcohol-based hand-hygiene programs have been shown to improve hand-hygiene compliance and reduce HAIs in observational studies in Geneva and Melbourne.
- In the United States, the Centers for Disease Control and Prevention now recommends that health-care facilities introduce and maintain alcohol-based hand-hygiene programs for HCWs.
- The World Health Organization (WHO) similarly recommends the worldwide introduction of alcohol-based HCW hand-hygiene programs based on their ‘five moments for hand hygiene’ initiative.

Recommendations on hand hygiene

1. Repeated monitoring of hand-hygiene programs through process measures (eg monitoring compliance with WHO’s ‘five moments for hand hygiene’) and outcome measures (eg rates of nosocomial sepsis, using an indicator organism such as methicillin-resistant *Staphylococcus aureus*) should be conducted in all health-care facilities.
2. Alcohol-based products used for hand hygiene must conform with international testing standard EN 1500.
3. All hand-hygiene clinical competency assessments should be assessed against WHO’s ‘five moments for hand hygiene’ guidelines.

14.1 Background

Large numbers of patients are treated in Australian health-care facilities in confined spaces, where they may undergo invasive procedures, be fitted with prosthetic devices, and require broad-spectrum antibiotics or immunosuppressive therapies. These conditions provide ideal opportunities for the adaptation and spread of pathogenic microorganisms.

In developed countries, 5–15% of all patients admitted to hospital acquire an infection as a consequence of their care.^[1] The most common infections involve the urinary tract, respiratory tract, surgical sites, intravascular catheters and bloodstream. Major illness or complications (eg loss of a newly implanted hip prosthesis) or death occur regularly.

Two categories of microorganism pose a particular threat in the modern health-care environment. In the first category, a pathogen with a novel combination of virulence and antibiotic resistance emerges under antibiotic selective pressure in one patient, is spread to surrounding patients, becomes established in a hospital and sometimes then moves to other hospitals as a result of patient transfers. Examples include methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE) and multiresistant *Acinetobacter* species.

In the second category, a pathogen circulating in the general community enters the hospital and exploits the crowded conditions to spread rapidly within the hospital population. Examples include norovirus and severe acute respiratory syndrome (SARS) virus. In both categories,

microorganisms spread rapidly via the contaminated hands of health-care workers (HCWs) and, to a lesser extent, from exposure to a contaminated environment or aerosols.

14.2 The role of health-care workers in hospital-acquired infection

Up to 70% of hospital-acquired infections could be prevented if infection control procedures were optimised.^[2] The hands of HCWs are the single most important source of preventable hospital-acquired infections.^[3] HCWs inadvertently transfer nosocomial pathogens as they move from patient to patient. Colonised patients become the major reservoir of hospital-adapted pathogens, shedding these organisms into their immediate surroundings. The final transition from colonisation to infection occurs by transfer of a colonising organism to a sterile site during medical care or as a result of the breach of primary defences (injury or medical device).

There are two main methods for hand hygiene in health-care settings:

- handwashing with soap or detergents and water
- hand antisepsis with alcohol-based hand-hygiene agents.

Alcohol-based hand hygiene achieves far greater reduction of microorganisms on hands, requires shorter application times and is gentler to skin than handwashing with soap or detergents and water. Thus, a World Health Organization (WHO) guideline has identified alcohol-based hand hygiene as the new standard of care for health-care facilities.^[4] However, visibly dirty or soiled hands still require the physical removal of foreign material with soap and water.

14.3 Approaches to hand hygiene and the ‘Geneva model’

Semmelweis was the first to show in 1847 that hand antisepsis with chlorinated lime, a substance now known to exert a strong antimicrobial killing action, could break the link between hospital care and the high risk of death from hospital-acquired sepsis. However, chlorinated lime is damaging to hands and sustained use is not possible.

In the modern era, Didier Pittet and his group in Geneva showed that hospital-acquired infections were reduced by providing all HCWs with a hand-hygiene solution of 70% isopropyl alcohol/0.5% chlorhexidine, containing protective skin emollients, for use when moving between patients or from a non-sterile to a sterile site during a single episode of care.^[5] The guiding principles of this program are:

- recognition that transfer of hospital-acquired pathogens on the hands of HCWs is the single most important driver of hospital-acquired sepsis
- provision at the point of care of an effective self-drying alcohol-based hand rub that is able to quickly kill transiently carried pathogens without the necessity for universal access to sinks and towels
- addition of emollients (ie re-fattening, moisturising substances) to the hand rub so the product can be used frequently, even in high-density care settings, without damaging the skin of HCWs
- incorporation of the use of the hand rub into natural workflows through education and promotion.

The authors stated that support by all levels of management was critical to the success of the program.^[5]

The 'Geneva model' has now become part of an advanced standardised model of care as part of WHO's 'Clean Care is Safer Care' program and is summarised in the WHO hand-hygiene guideline.^[4]

Improved hand hygiene in health care has recently been identified as a major goal for improved health care by WHO,^[4] the United States Centers for Disease Control and Prevention (CDC)^[6] and a number of other national campaigns in individual countries.

14.3.1 The concept of 'five moments for hand hygiene'

WHO has developed a standardised conceptual approach to teaching and promoting the new hand-hygiene culture in health-care facilities. The approach is based on 'my five moments for hand hygiene' and involves the following steps:^[7]

- first, define two zones:
 - the patient zone — patient and immediate surrounding (eg linen, equipment, charts and furniture)
 - the health-care zone — all other spaces, surfaces and other patients outside the patient zone
- second, require that an HCW attends to hand hygiene:
 - before patient contact, to prevent cross transmission from another patient
 - before an aseptic task, to prevent introduction of an existing colonising organism to a vulnerable body site (eg when working on a wound dressing), whether or not gloves are used
 - after body fluid exposure (eg after changing a dressing or catheter bag), including after removing gloves
 - after patient contact
 - after patient zone contact, even if the patient has not been touched (eg after checking temperature chart at end of a patient's bed).

14.3.2 The Geneva model in Australia

In 2001, a group at Austin Health in Melbourne introduced a version of the Geneva model and developed their own 70% isopropyl alcohol/0.5% chlorhexidine/emollient formulation.^[8] The focus of the Austin program was to reduce MRSA infections. Over 36 months, the rate of clinical MRSA infection and MRSA bacteraemia per 100 admissions fell by 50%. Seven years later, hospital-acquired MRSA infections are approximately 80% lower than they were in 2001. The Austin Health program was partly funded by the Victorian Government; it later formed the basis for a successful Victorian Quality Council pilot study and a subsequent state-wide roll-out. Similar programs have been introduced in New South Wales, Queensland, South Australia and Western Australia.

14.4 Compliance with hand-hygiene recommendations

Lack of compliance with hand-hygiene recommendations in health-care facilities is a worldwide problem. A study of compliance rates in various hospital settings in different countries found reported rates of 12–81%.^[9] In other words, as many as 9 out of 10 hand-hygiene opportunities are missed by HCWs in situations in which hand hygiene is necessary.

In Australia, adherence to hand-hygiene practice has generally been poor but differs greatly between subspecialty wards and before- and after-patient contacts.^[8, 10, 11] Before commencing a hand-hygiene program, the compliance rate at Austin Health was 21–42%.^[8] Similarly, the compliance in a Queensland teaching hospital averaged around 53% in the hospital overall, with an average of 47% in intensive care units (ICUs) and of 27–70% in four subspecialties associated with after-patient contact.^[10] Compliance rates were similarly low in New South Wales before the *Clean Hands Saves Lives* campaign, with rates averaging 57% across subspecialties.^[11]

The Austin Health program achieved a 21% improvement in compliance rates and a concurrent decrease in MRSA infection rates.^[8] The New South Wales campaign, which introduced alcohol-based hand hygiene across 11 area health services in the state, improved overall compliance by 15%, giving rates of 47% for before-patient contact and 62% for after-patient contact.^[11] Concurrently, a 74% decrease in sterile-site infections (eg bloodstream infections (BSIs)) with MRSA was seen in ICUs, from 5.3 to 3.9 infections per 10,000 occupied bed days.

14.4.1 Behavioural models of compliance

Compliance or non-compliance with hand hygiene has been analysed with the help of behavioural theories.^[12] A behavioural theory is a means of presenting human behaviour in a systematic way. Behavioural models draw on single or multiple behavioural theories to explain and predict behaviour within a specific context.

Two models of hand-hygiene behaviour in HCWs successfully produced a predictive framework — one in Australia and one in Europe.^[13, 14, 15]

The Australian framework was developed from focus discussion groups; it identified hand-hygiene behaviour as being subconsciously considered as two distinct practices:^[14]

- An *inherent* practice, which is performed with little reminding or coaching, such as after going to the toilet or after contact with patients' body fluids or intimate areas. Such contacts are emotionally perceived as 'unclean' based on community-learned perceptions and lead to almost perfect compliance with handwashing.
- An *elective* practice, which requires reminders or coaching. These are contacts not emotionally perceived to be a risk to oneself, such as before-patient contacts, clean-type contacts with patients and contacts with their environment. Based on community-learned behaviour, HCWs often elect not to perform hand hygiene for such contacts and compliance is much lower than for inherent hand-hygiene practice.

Strong predictors of electing not to perform hand hygiene included HCWs' community-based behaviour for similar clean-type hand-hygiene opportunities. Major factors strongly influencing staff to perform hand hygiene were:

- the belief that medical staff and administrators expected hand hygiene after the clean contacts
- the perception that peers practised hand hygiene
- good attitudes towards the benefits of carrying out hand hygiene when related to clean-type hand-hygiene opportunities.

The European behavioural model analysed demographic characteristics and cognitive factors associated with self-reported compliance with hand hygiene, as assessed by a questionnaire.^[15] The investigators found that high self-reported compliance (as defined by hand hygiene performed during 80% or more of hand-hygiene opportunities) was:

- more likely when colleagues expected adherence and when staff had participated in previous campaigns or previous structured hand-hygiene training
- much more likely in female staff than in male staff
- much more likely when colleagues' adherence was perceived as good
- much more likely in staff who perceive hand hygiene as being effortless to perform.

14.4.2 Improving compliance

Although correct hand hygiene can reduce the incidence of health care associated infections, HCWs' compliance with hand-hygiene procedures is suboptimal, putting the safety of many patients at risk.^[4]

The reasons for non-compliance are highly complex and multifactorial. They are influenced by HCWs' characteristics, such as knowledge and educational status, cultural and perhaps religious background, workplace culture and role modelling, gender, rank in the workplace hierarchy and access to hand-hygiene facilities. Other factors affecting compliance include staffing levels and time pressure.^[4]

The best relative results in terms of hand-hygiene promotion have been achieved with multimodal hand-hygiene campaigns that target several of the underlying factors for non-compliance.^[4, 5, 6, 8, 16, 17]

The two main goals in terms of hand-hygiene improvement are:

- initial significant improvement in hand-hygiene compliance
- sustained improvement in the long term, which this is generally much more difficult to achieve than initial improvement.

Successful strategies for hand-hygiene promotion include:^[4, 6, 9]

- education and promotion
- availability of written guidelines
- monitoring of compliance and provision of feedback on performance
- reminders in the workplace (eg hand-hygiene posters)
- easy availability of hand-hygiene facilities
- introduction of alcohol-based hand rubs in settings where handwashing is still the predominant method for hand hygiene
- administrative sanctions and rewarding
- an institutional safety climate with hospital executive support and senior medical staff acting as role models
- avoidance of overcrowding, understaffing and excessive workloads.

Ideally, a combination of these strategies should be employed when implementing a hand-hygiene campaign.^[4] The introduction of alcohol-based hand rubs has clearly been associated with increased compliance in several important studies.^[5, 8, 17, 18, 19] However, it is also clear that simply introducing such hand rubs without any associated promotional activities is much less effective than comprehensive programs.^[20]

The positive effect of inservice education and promotion to hospital staff has been well documented.^[4, 16, 17, 18, 21] Although little has been published on formal education,^[22] it appears reasonable to implement and promote the teaching of infection control theory and practices, including hand hygiene, at an early stage in the education of doctors, nurses and other health professionals. This education would be delivered at a time when students are more open to learning, rather than when they are in a busy workplace environment.

Two particular hand-hygiene campaigns serve as models for understanding successful strategies:

- The Geneva program, described earlier, employed a number of different strategies simultaneously; these included education, promotion, observation and feedback. Also, the program was underpinned by strong clinical leadership.^[5] Although successful, the program seemed to depend on strong clinical leadership by the project team to be sustained.^[20]
- In the United States, the Washington program focused on organisational and institutional culture change; it employed hospital executive support, role modelling by clinical leaders, educational activities, staff participation and staff selection of an alcohol-based product.^[16] The Washington program produced consistent and sustained improvement in hand-hygiene compliance in all wards where it was introduced.

14.4.3 Promoting compliance in Australian health-care facilities

The promotion of hand hygiene has been implemented in almost all states in Australia at either a hospital or jurisdictional health department level. This promotion has taken different forms, from awareness weeks at individual hospitals through to fully funded state-wide campaigns. A summary of key state initiatives is given in Table 14.1.

Although not exhaustive, Table 14.1 illustrates a diverse range of implementation methods and, to a lesser extent, evaluation strategies adopted across Australia. All existing campaigns rely on the WHO guidelines^[4] as a key resource. Many campaigns also use other resources as models for planning their interventions to improve hand hygiene among HCWs; these additional resources include the CDC guidelines,^[6] the Geneva program^[9] and the *5 Million Lives* campaign of the Institute for Healthcare Improvement.^[23]

14.4.4 Evaluating compliance

Evaluation of hand-hygiene strategies is not straightforward. Improvement in MRSA infection rates has been reported at Austin Health^[8] and from the New South Wales campaign,^[11] but there is little other published work detailing the outcomes of the hand-hygiene strategies listed in Table 14.1. This may be a consequence of hand-hygiene efforts commonly being seen more as day-to-day quality improvement strategies rather than as publishable research projects; alternatively, it may be due to the relative novelty of hand-hygiene improvement projects being carried out as formal hospital-wide or state-wide campaigns, with the result that full analysis and evaluation of these projects' effectiveness have not yet been performed.

Hand-hygiene compliance in hospitals is an important patient safety indicator. This position has been embraced by the Australian Commission on Safety and Quality in Health Care by their announcement of a national hand hygiene campaign, although the details of such a campaign are not yet clear.

The Washington hand-hygiene program has been successful in enlisting support from individual hospital executives and in promoting staff participation and empowerment.^[16] A balance needs to be struck between central standardisation and local innovation adapted for specific hospital environments. An Australian approach should adopt successful elements from important

international campaigns and should also take behavioural theories, such as those underpinning the frameworks described earlier, into account.

Monitoring of hospital-acquired infection rates could be used as a marker for success, and many of the evaluation strategies outlined in Table 14.1 support this idea. However, measured infection rates often concentrate on a few marker pathogens (eg MRSA) or a few marker types of infections (eg BSIs); thus, such results may not accurately reflect the success or otherwise of hand-hygiene programs. Many programs are accompanied by other infection control efforts and the results may not be an accurate reflection of hand-hygiene efforts per se.

Observational auditing of hand-hygiene practice (compliance audits and feedback) is fraught with potential errors. For example, the ‘Hawthorne effect’ is the term used to describe the phenomenon whereby the act of observing in itself leads to a change of behaviour; in this case, increased frequency of hand hygiene.^[24] In addition, current procedures for observational auditing are time consuming, require specialised training and are only one of several components reflecting the success or otherwise of hand-hygiene promotion. Nevertheless, although the results of observational auditing are often skewed by errors, it is clear that auditing and feedback have a benefit through educating and reminding staff, and assessing the effect of programs designed to increase compliance.

A standardised tool for measuring hand-hygiene compliance has been developed at Austin Health and was used for the Austin hand-hygiene campaign.^[25] This tool — which is a paper-based method of observing and recording HCW hand-hygiene compliance in the field or ward — has subsequently been adopted by the Victorian state-wide campaign (see Table 14.1) and is currently being used in many Victorian hospitals. In addition, the conceptualisation of the ‘five moments for hand hygiene’ approach^[7] allows for the creation of a simple monitoring tool for hand-hygiene compliance. In this case, the ‘five moments of care’ becomes the denominator and the use of an approved hand-hygiene practice becomes the numerator. The advantage is that once an HCW understands this concept, he or she can rapidly teach and monitor the performance of others.

Gould and colleagues pointed out some of the shortfalls of observational audits of hand hygiene, such as inter-rater reliability and ethical issues.^[26] The authors state that ‘ideally an additional data collection method should be used to corroborate or refute the findings of observation, but no well-validated method is presently available’. Some states have attempted to address this problem by using both infection rates and observational audits as a measure of success (see Table 14.1). The ethical issues surrounding observational auditing appear to be largely unexplored.^[26] Issues of consent (both staff and patient), privacy and the dilemma for an observer when he or she witnesses gross breaches of hand hygiene need to be considered when planning compliance assessments.

If Australia is to have a successful standardised approach to monitoring hand-hygiene compliance, it will be important to engage all stakeholder groups, including infection control professionals, clinicians and hospital executives. Whatever format is chosen for an auditing process, a useful measure may be to benchmark the percentage of *increase* in compliance rather than the percentage of compliance itself.

14.5 Selection of an appropriate hand-hygiene product

An essential property of any hand-hygiene agent to be used in health-care settings is its ability to effectively kill or remove microorganisms from hands in order to interrupt the chain of pathogen transmission.^[3, 4, 9] Soap-based or detergent-based handwashing typically produces only a moderate reduction of microorganisms on hands of about 1–2 logs (10–100-fold).^[9, 27, 28] By

contrast, alcohols are generally the most rapid acting and effective hand and skin antiseptics.^[9, 28, 29] Effective preparations of alcohol-based hand rubs produce microbial reductions of about 3–4 logs (1000–10,000-fold) within about 30 seconds.^[28]

Alcohols have a broad spectrum of activity against many microorganisms, including gram-positive and gram-negative bacteria, mycobacteria, fungi and many viruses.^[29] Alcohols are somewhat less active against non-enveloped viruses, although viral reduction is usually greater than with soap-based handwashing.^[4, 28] Alcohols have no activity against bacterial spores, but are effective against vegetative forms in populations of spore-forming bacteria.^[4]

Alcohols have the greatest antimicrobial activity in the concentration range of about 60–80%.^[4] Different alcohol types have different antimicrobial activity.^[28] For example, the antibacterial activity of 60% n-propanol is roughly equivalent to that of 70% isopropanol and 80% ethanol.^[28] Non-enveloped viruses are an exception to this general guideline, with high percentages of ethanol (eg 80–90%) being the most active.^[30]

The two major sets of antimicrobial testing standards for hand-hygiene products are the European series of standards (referred to as EN standards) and the American series (referred to as ASTM standards).^[4] For example, standard (non-surgical) hand antiseptic testing is regulated by EN 1500 and by ASTM E-1174.^[4] These standards are not directly comparable, but the European standards tend to be more stringent and require greater reduction factors of microorganisms on hands before products pass antimicrobial testing. There are also separate testing standards for antimycobacterial, antifungal and antiviral activity, and these are usually employed when manufacturers make claims of such activity.

The WHO guideline includes two suggested hand-rub formulations that can be made from standard chemicals and are mainly targeted at resource-poor settings.^[4]

- *formulation I* contains ethanol 80%, glycerol 1.45% and hydrogen peroxide 0.125%
- *formulation II* contains isopropanol 75%, glycerol 1.45% and hydrogen peroxide 0.125%.

Both formulations pass the stringent EN 1500 testing standards.

Significant antimicrobial activity — in the range of a 3–4 log kill within about 30 seconds — is usually achieved by products containing about 70–75% isopropanol or 75–80% ethanol,^[4, 28] and such products typically pass EN 1500. Hand gels often have significantly less activity than liquid hand-hygiene products and gels often fail to pass EN 1500.^[31] Those gels that do pass EN 1500 typically contain 75% or more isopropanol^[32] or 80% or more ethanol.^[33, 34]

Other important but less objective features of hand antiseptics are user acceptability and skin tolerability. Generally, alcohol-based hand antiseptics cause significantly less skin damage than detergent or soap-based handwashing.^[9] Several studies, including blind crossover trials, show that user acceptability and skin tolerability are mainly determined by the overall hand-rub composition and by emollient additives, both of which are largely independent of the product's antimicrobial activity.^[35, 36, 37] The most suitable product for health-care settings should therefore combine excellent user acceptability and skin tolerability with significant antimicrobial activity.

A major distinguishing feature of hand-rub composition is its consistency: either gel or liquid. Different health-care settings have different preferences and the need for a gel or liquid should be evaluated on an individual basis.^[38, 39] In some instances, it may be useful to provide both in order to provide a choice for HCWs.^[32, 39]

At present, few commercial alcohol-based hand-hygiene products in Australia reach the levels of antimicrobial activity of the standardised WHO formulations. Europe has a range of more than 80 different alcohol-based hand-hygiene products that fulfill the stringent EN testing standards and that have different compositions and emollient additives.^[40] In addition, Australian product approval has no current requirement for independent, non-manufacturer-based antimicrobial testing, which is a prerequisite for objective product assessment.^[4, 41]

14.6 Limitations of alcohol-based hand hygiene

14.6.1 Hospital-acquired outbreaks with spore-forming bacteria

Hospital-acquired disease outbreaks mediated by spore-forming organisms (eg *Clostridium difficile*) are difficult to control using alcohol-based hand hygiene because spores are not susceptible to alcohol. However, this should not affect everyday use of alcohol-based hand hygiene, and to date there has been no increase of *C. difficile* infections in health-care settings that report intensive use of alcohol for hand hygiene.^[42] If a facility is experiencing a specific outbreak of a spore-based transmissible infection such as *C. difficile*, use of traditional soap and water for handwashing, in conjunction with strict isolation, intensive cleaning, gloves and gowns, is recommended.

14.6.2 Non-enveloped viruses

Alcohols have less activity against non-enveloped viruses such as noroviruses, rotaviruses and enteroviruses, and alcohol products with proven virucidal activity are currently not available on the Australian market. In Victoria, the Department of Human Services is currently recommending that handwashing with soap and water should be the standard of care during a norovirus outbreak. However, in many situations there are insufficient (or no) hand basins to allow HCWs to incorporate soap and water in their process of care with current staffing and accommodation configurations. Alternative alcohol products with proven virucidal activity^[30, 43] should be evaluated as to whether they are suitable for the Australian health-care sector.

Table 14.1 Summary of key state hand-hygiene initiatives

State or territory; dates	Key agencies	Hand-hygiene promotion strategy	Implementation approach	Evaluation strategies	Evaluation results
New South Wales ^a 27/3/2006 (12 months)	Clinical Excellence Commission and all Public hospitals	'Clean Hands Save Lives' Campaign	Implementation guide Geneva-like program Accessibility of alcohol-based hand rubs Posters (changed monthly) Brochures for patients Other resources	Evaluation plan: Observational audit Infection data (ACHS) Alcohol-based hand rub use Staff/patient survey Economic audit	http://www.cec.health.nsw.gov.au/campaigns/cleanhandssavelives/index.html
Queensland ^b	QLD Health – CHRISP	'Clean Hands are Lifesavers' Merchandise including T-shirts for 'life savers' and posters	Implementation guide outlining phased behavioural change approach Policy template Website development Education E-learning program Team development for advocates across the state State-wide recognition program	Local hand-hygiene compliance reports State-wide hand-hygiene compliance reports including trends, multiresistant organisms and burden data Education evaluation – workshops, team development and e-learning programs	CHRISP Evaluation report – 08 Future publication: CHRISP Descriptive analysis — 08–09 Health Quality Complaints Commission reports Research: [4, 14, 44]

State or territory; dates	Key agencies	Hand-hygiene promotion strategy	Implementation approach	Evaluation strategies	Evaluation results
South Australia Jul–Dec 2007	South Australian Department of Health	'Wash, Wipe, Cover...don't infect another' Hand and Respiratory Hygiene resource development project	Resources designed for health care, community and schools Posters Brochure Fact sheets Questions and answers CD/website access	Stakeholder/user survey	Nil published
South Australia Planned for April 2008	South Australian Department of Health	'Wash, Wipe, Cover...don't infect another' Hand and Respiratory Hygiene Campaign	Build on resources developed Media campaign aimed to reach all South Australian community	Pre- and post-absenteeism data from pilot schools Focus groups Surveys before, during and after campaign	n/a
Victoria ^c Feb 2006–2008	Victorian Quality Council Dept of Human Services, all Victorian Public Hospitals	Victorian Hand Hygiene project	Resource manual and education toolkit: Introduction of alcohol-based hand rubs Education in hand hygiene to health-care workers Promotional tools (posters etc) Pilot wards Sustainability forum	Alcohol-based hand rub usage (litres/1000 bed days/month) Rates of infection; number of MRSA bacteraemia per 100 separations. Rates of hand-hygiene compliance, via HH observational audit tool HH credentialing	Grayson (in press) ^[45]

State or territory; dates	Key agencies	Hand-hygiene promotion strategy	Implementation approach	Evaluation strategies	Evaluation results
Western Australia ^d (WA) Mar 2007 ongoing	Western Australian Department of Health (Office of Safety and Quality in Healthcare; Infection and Immunity Network)	Clinical Practice Improvement Program: Hand Hygiene Based on '100k Lives' campaign using model for improvement	Brochure – Hand hygiene and cough etiquette Establish multidisciplinary improvement teams at each WA hospital using Model for Improvement, and support collaboration between teams. Funds from SQulRe CPI program. Supported by social marketing promotional campaign produced in 2007 by Infection and Immunity Network.	Audit and data collection tools developed to collect: % staff scoring 5/5 in hand-hygiene knowledge assessment survey % staff using alcohol-based hand rubs, gloves and performing hand hygiene correctly % bed spaces with gloves and alcohol-based hand rub dispensers % encounters where correct hand hygiene observed Health care associated MRSA infection rate	Nil published
Australian Capital Territory (ACT) July 2006 ongoing	Canberra Hospital Calvary Healthcare ACT Community Health	Badges, posters, patient information brochures	ACT-wide education to all health-care workers, onsite promotion	Measured hand-hygiene products	Hand-hygiene product limited increase The project was not an overwhelming success due to limited funds and resources. In future, a formal business case to ACT Health could address these issues.

State or territory; dates	Key agencies	Hand-hygiene promotion strategy	Implementation approach	Evaluation strategies	Evaluation results
Tasmania April 2008	Tasmanian Infection Prevention and Control Unit Health Services (Public Hospitals, Primary Health, Ambulance) Private Hospitals Mental Health Population Health (Public Health)	Currently reviewing and scoping existing work being undertaken in Tasmania. Holding off strategy until scope and role of National Hand Hygiene Committee determined	To be decided The Tasmanian Infection Prevention and Control Unit was formed in January 2008 and is progressing quickly with a range of work in relation to HAIs. At this stage, the unit will be the focal point of implementation and evaluation of hand hygiene in Tasmania.	To be decided	To be decided
Northern Territory (NT) April 2008	Acute-care hospitals in the NT (5)	Orientation, education, monthly Hand-hygiene weeks, yearly Alcohol hand rub pocket packs	Part of formal orientation program Structured program for the week, including posters and competitions NT-wide hand-hygiene products tender	All staff fill in evaluation forms Attendance number, evaluation forms Usage rates	Overall there has been a consistent rise in the usage of HH products. HAI rate in all acute-care hospitals remains stable or has reduced slightly

ACHS= Australian Council on Healthcare Standards; CHRISP = Centre for Healthcare Related Infection Surveillance and Prevention; HAI = health care associated infections; HH = hand hygiene ; MRSA = methicillin-resistant *Staphylococcus aureus*; n/a = not available; SQUIRE CPI = Safety and Quality Investment in Reform Clinical Practice Improvement.

a <http://www.cec.health.nsw.gov.au/campaigns/cleanhandssavelives/index.html>

b http://www.health.qld.gov.au/chriscp/hand_hygiene/about

c http://www.health.vic.gov.au/qualitycouncil/activities/handhyg_gen.htm

d <http://www.safetyandquality.health.wa.gov.au/squire/hand.cfm>

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15 Antimicrobial usage: monitoring and analysis

Authors: M Duguid, J Ferguson, V McNeil, I Wilkinson

Key points

- Monitoring and analysis of antimicrobial usage is critical to understanding antibiotic resistance and to monitoring effects of containment strategies.
- Methods of antimicrobial data collection differ, but most institutions provide population surveillance data obtained from computerised pharmacy records.
- Surveillance data can be used to identify changes in usage that may be linked to development of resistance and to measure the impact of antimicrobial stewardship programs.
- Antimicrobial stewardship programs have been shown to reduce resistance rates, morbidity, mortality and cost.
- Comprehensive, integrated surveillance programs operate in the United States and Europe, where programs include the European Surveillance of Antimicrobial Consumption, the Danish Integrated Antimicrobial Resistance Monitoring and Research Program, a surveillance program for antimicrobial consumption and resistance in the Netherlands, and the Swedish *Antimicrobial Utilisation and Resistance in Human Medicine* report. In Europe, reports on antimicrobial consumption and resistance are published annually.
- In Australia, the National Antimicrobial Usage Surveillance Program provides monthly reports on hospital inpatient antibiotic usage to contributing hospitals, and bi-monthly reports to the Australian Department of Health and Ageing. Data are contributed by 50% of principal referral hospitals from six states.
- Comparison with international data shows that Australian usage rates in hospitals are high for some antimicrobial classes. The total use of antibiotics in the Australian community falls in the middle of the range recorded in European countries.
- The Drug Usage Subcommittee of the Pharmaceutical Benefits Advisory Committee reports on antibiotic use in the community sector to the Expert Advisory Group on Antimicrobial Resistance, the Australian Institute of Health and Welfare and the World Health Organization International Committee on Drug Statistics Methodology. Antibiotic usage data are also published in The Australian Statistics on Medicines. The data are used by the National Prescribing Service to inform program planning.
- Australian antimicrobial usage data are incomplete and not linked with resistance surveillance data, which limits their potential use.

Recommendations on antimicrobial usage: monitoring and analysis

1. Monitoring of national antibiotic usage and resistance surveillance data, resistance management, and intervention strategies requires a comprehensive integrated surveillance program.
2. National antibiotic stewardship guidelines are required for all health-care settings; surveillance data should guide the development and updating of prescribing guidelines, decision support systems (including computerised approval systems), clinical guidelines and education.
3. Antibiotic resistance and usage data should be made available at clinical service, hospital and national levels.

15.1 Background

The World Health Organization (WHO) and other international bodies have nominated antimicrobial resistance as a major public health concern. Surveillance of antimicrobial usage and resistance in human and animal populations is widely recommended as part of ongoing management and containment plans.

There is a well-documented causal relationship between prior antibiotic usage and the emergence of bacterial resistance.^[1] The use of particular antibiotic classes is linked with the emergence of specific pathogens. Chapter 7 examines the relationship between prior antibiotic use and the development of antibiotic-associated diarrhoea or colitis due to *Clostridium difficile*. Similarly, Chapter 6 considers risk factors associated with antibiotic use for methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococcus (VRE) and multiresistant gram-negative organisms.

Monnet proposed three levels of evidence for a link between prior antibiotic use and resistance,^[2] based on an earlier publication by McGowan:^[1]

- patient-level data on exposure to antimicrobials, with infection or colonisation by resistant bacteria as the outcome (ie case–control analyses)^[3, 4, 5]
- aggregated, non-longitudinal data, at one point in time, for a large number of similar and independent settings^[6, 7, 8]
- aggregated, longitudinal data for a long period of time but for a single ward, hospital, region or country.^[9, 10]

Multivariate time series analysis is now used to show how month-to-month variation in use of specific antibiotic classes correlates closely with subsequent variation in antibiotic resistance (eg changes in hospital MRSA incidence).^[11] The most instructive example of this method of analysis is the study by Monnet and colleagues,^[12] which examined antibiotic use and the emergence of two particular clones of MRSA in the Aberdeen Royal Infirmary in 1996–2000. Dynamic, temporal relationships were found between monthly prevalence of MRSA in hospitalised patients and MRSA prevalence, and the use of macrolides, third-generation cephalosporins and fluoroquinolones in previous months. Figure 15.1 shows the summed monthly use of macrolides, third-generation cephalosporins and fluoroquinolones (taking into account their respective lags for direct effects) plotted against monthly MRSA prevalence. The parallel nature of the relationship between the lagged use of these specific antibiotic classes and MRSA prevalence is striking.

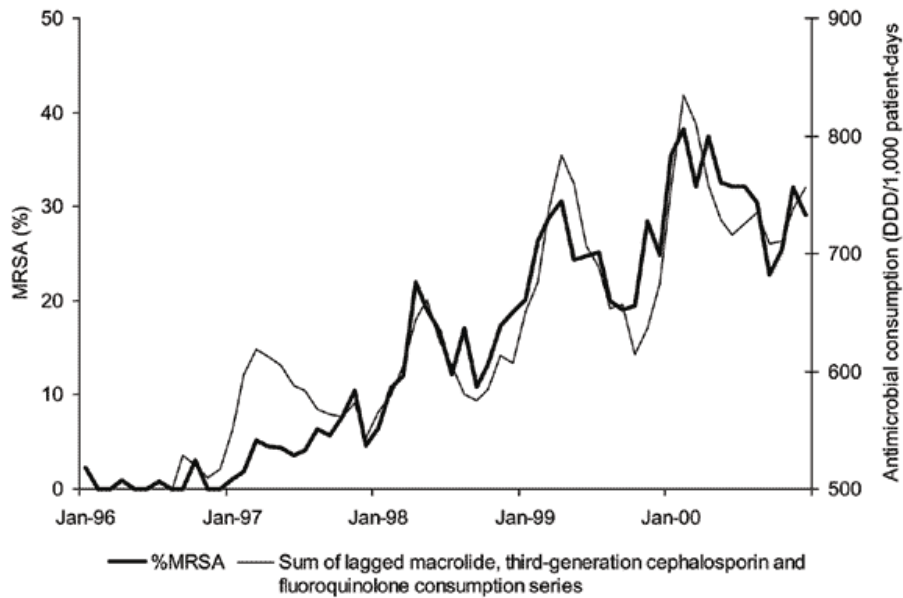


Figure 15.1 Evolution of the monthly per cent methicillin-resistant *Staphylococcus aureus* (MRSA) and monthly sum of lagged antimicrobial use as identified in a polynomial distributed lag model: macrolides (lags of 1–3 months), third-generation cephalosporins (lags of 4–7 months) and fluoroquinolones (lags of 4 and 5 months), Aberdeen Royal Infirmary, January 1996–December 2000

DDD = defined daily dose

The R^2 value describing the overall correlation of these variables with MRSA prevalence was 0.902.

Source: Adapted from Monnet et al (2004)^[12]

The seriousness of the antimicrobial resistance problem in Australia came into national focus in 1998 when the Commonwealth health and agriculture ministers established the Joint Expert Technical Advisory Committee on Antibiotic Resistance (JETACAR), which includes experts from the health, veterinary and agricultural areas. JETACAR reviewed antimicrobial resistance in Australia; in particular, the evidence that antibiotic use in food animal production may be contributing to the emergence and spread of resistant bacteria in Australia.^[13] The committee recommended an integrated management plan for antibiotic resistance in Australia including research, monitoring and surveillance, education, infection control, and regulation.

In 2000, in response to the JETACAR report, the Australian Government established an Expert Advisory Group on Antimicrobial Resistance (EAGAR). One of the terms of reference for EAGAR was to provide expert advice on ‘the monitoring of antibiotic use’. Recently, EAGAR commissioned a report to develop the rationale for a comprehensive integrated surveillance program to improve Australia’s response to antimicrobial resistance.^[14] In line with the previous JETACAR recommendations, EAGAR proposed an integrated surveillance program coordinating efforts to measure antibiotic use and resistance in both animal and human settings. Such surveillance data might then drive significant and beneficial change, similar to that seen as a result of the Danish Integrated Antimicrobial Resistance Monitoring and Research Program (DANMAP).^[15] The proposed surveillance program would be cross-disciplinary and nationally coordinated, and would consolidate and build on existing surveillance systems and initiatives. Key components of the proposed program for Australia are development and implementation of national surveillance systems for antimicrobials in hospitals and the community.^[14] Section 15.4.2 discusses the current status of this program.

Surveillance data on antibiotic usage provide data that are needed for determining the impact of usage patterns on bacterial resistance. Such data are also important for supporting containment strategies, such as antimicrobial stewardship programs (see Case study 1).

The density of antimicrobial use within specialised units such as intensive care units (ICUs), haematology and oncology units, and solid-organ transplant units is several-fold higher than in other hospital settings. This increased use has been shown to generate high rates of antimicrobial resistance; therefore, these areas should be a particular focus for surveillance and intervention.

Case study 1 Use of ceftriaxone at a South Australian hospital

High usage of third-generation cephalosporins in South Australian metropolitan hospitals was noted in 2002 through data collection and analysis by the South Australian Antimicrobial Usage Surveillance Program. One hospital implemented an antimicrobial restriction policy in January 2003, with a focus on community-acquired pneumonia treatment protocols, which had been identified through pharmacy audit as an area of inappropriate use of ceftriaxone.

Figure 15.2 shows that usage of ceftriaxone decreased significantly following the implementation of the new policy and that this level of use was sustained for about four years. However, ceftriaxone use appears to again be on the rise. This has been at least partly attributed to the lack of input from specialist antibiotic pharmacists in recent years; a follow-up intervention is being considered.

This case study demonstrates the usefulness of surveillance of antimicrobial use. Surveillance allowed the detection of high usage of a specific group of agents; this stimulated investigation and the implementation of a targeted intervention, which was followed by monitoring of the effect of the intervention.

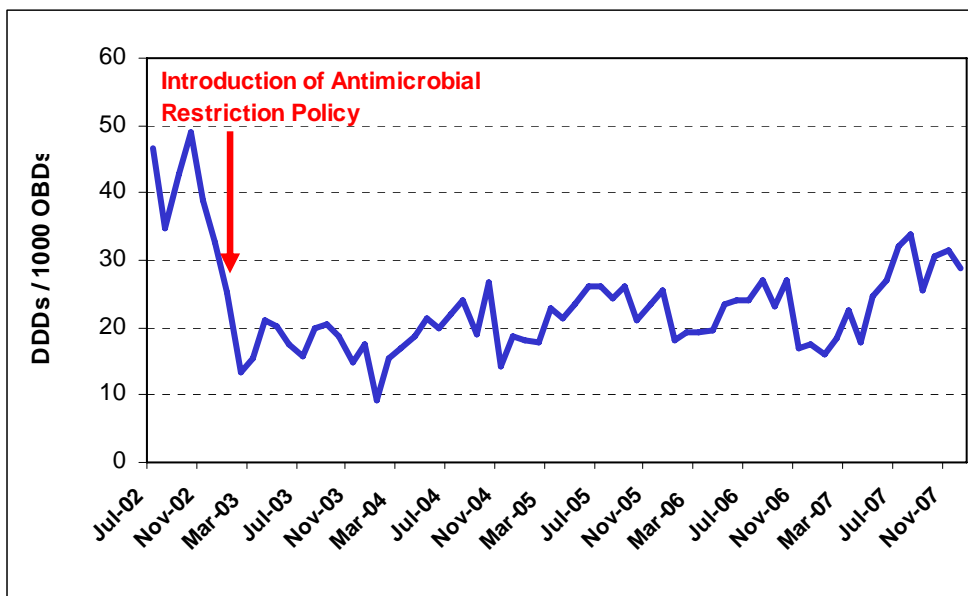


Figure 15.2 The usage of ceftriaxone at a South Australian hospital

DDDs = defined daily doses; OBDs = occupied bed days

15.1.1 Antimicrobial stewardship programs

Hospital programs

Antimicrobial stewardship has been defined as ‘an ongoing effort by a health-care institution to optimise antimicrobial use among hospital patients in order to improve patient outcomes, ensure

cost-effective therapy and reduce adverse sequelae of antimicrobial use (including antimicrobial resistance)',^[16] Stewardship programs aim to change antibiotic prescribing to reduce unnecessary use and promote the use of agents less likely to select resistant bacteria, in line with guidelines and demonstrated incidence of antibiotic resistance (as shown by antibiograms, an antibiogram being the result of laboratory testing on an isolated pathogen to find out what treatments the pathogen is resistant to). Successful programs have been shown to reduce institutional resistance rates as well as morbidity, mortality and cost.^[17]

Minimum requirements for hospital antimicrobial stewardship programs have been set down by the European Society of Clinical Microbiology and Infectious Disease (ESCMID) Study Group for Antibiotic Policies (ESGAP). They detail the responsibilities of clinicians, clinical governance, hospital managers and health-care executives, pharmacies, microbiology laboratories, and pharmaceutical industry members.^[18]

Key requirements of an antimicrobial stewardship program include:

- provision of appropriate administrative support for programs
- provision of effective medical education about antibiotic usage and resistance, and responsible prescribing
- implementation of effective clinical guidelines for common infections and promotion of compliance with accepted standards such as *Therapeutic Guidelines (Antibiotic)*⁵¹
- use of clinical decision-support systems — including computerised systems — to promote best evidence-based practice (eg Australian systems such as Guidance DS® and IDEA³S®)
- active processes to restrict prescribing of broad-spectrum antimicrobials to those patients where use is clinically indicated
- active regular clinical liaison between clinical microbiologists, infectious disease physicians and pharmacists to improve individual patient management in intensive care and other settings
- close cooperation between microbiology or infectious diseases departments and pharmacy departments to ensure best use of antibiotics
- regular drug usage evaluations (DUEs) under the auspices of each institution's drug and therapeutics committee.

Intervention programs that restrict use of broad-spectrum antibiotics have shown dramatic effects on antibiotic prescribing, as shown, for example, by Case study 1. Some Australian hospitals with antimicrobial stewardship programs have demonstrated significant cost savings through reduction in drug costs; an example is shown in Case study 2.

⁵¹ <http://etg.tg.com.au/complete/>

Case study 2 Effect of active antimicrobial stewardship program in a large tertiary hospital in New South Wales

A large tertiary teaching hospital in New South Wales has had an active approach to antimicrobial stewardship for many years, underpinned by locally relevant antibiotic guidelines and enthusiastic staff in the areas of pharmacy, infectious diseases and microbiology. Clinical teams are regularly engaged in guideline review, development and implementation at local and national levels. Specific discussions about patients are prompted by an online anti-infective registration (approval) system, where clinicians who prescribe broad-spectrum agents register the indication for use and are advised on correct dosage. Twice-weekly infectious diseases and microbiology patient rounds take place in intensive care units (ICUs). These frequently lead to changes in antibiotic therapy, generally to early cessation.

A drug usage evaluation pharmacist regularly audits antibiotic use for particular agents (eg meropenem) or clinical syndromes or situations, mainly community-acquired pneumonia and surgical prophylaxis. These audit data are used to provide feedback to clinicians to encourage more appropriate use.

Monthly data on usage are supplied to the National Antimicrobial Utilisation Surveillance Program. This allows for benchmarking of ICU and non-ICU usage against 22 other large Australian hospitals. A study of usage of selected high-cost (predominantly broad-spectrum) antibiotics in 2006 indicated that, for most agents, use in ICU and non-ICU situations in this hospital was far lower than the national average. Based on purchase cost alone, the net cost difference in 2006 was \$278,000 (\$59,000 of this was for ICU use).

Computerised decision support systems have been developed and are in use in several Australian hospitals.^[19] These systems can reduce the consultation burden for infectious diseases physicians, but it is not clear whether they produce positive patient outcomes overall.^[20]

Community programs

In the 1990s, community antibiotic use in Australia was high compared with other developed nations.^[21] Today, multiresistant bacteria, such as community strains of MRSA and extended-spectrum beta-lactamase-producing gram-negative bacteria, are causing increasing human morbidity and there is concern that past excessive antibiotic use in the community or in animal production systems (or both) is responsible.

The National Prescribing Service (NPS) delivers programs across Australia that promote judicious antibiotic prescribing in general practice through educational visiting, guideline dissemination, prescribing practice reviews and public education programs. NPS targeting of antibiotic prescribing contributed to a significant decline in antibiotic prescribing over the five year period 1999–2004.^[22] In addition, the use of amoxicillin as a proportion of total antibiotic use increased, while use of cefaclor decreased. These changes are consistent with a shift in prescribing towards guideline recommendations.^[22]

Comparable programs in veterinary practice are poorly developed.

The NPS also supports drug-usage evaluation programs in hospitals in collaboration with state DUE groups. One such program was Community-Acquired Pneumonia: Towards Improving Outcomes Nationally (CAPTION).^[23] This study was a multicentre cross-sectional audit to assess compliance with *Therapeutic Guidelines (Antibiotic)*⁵² for treatment of community-acquired pneumonia in Australian emergency departments, and occurred between April 2003 and February 2005. Compared with the baseline audit, a 1.5-fold increase in the rate of guideline-compliant antibiotic prescribing was seen.^[24]

⁵² <http://etg.tg.com.au/complete/>

15.2 Impact on the health-care system

The emergence and selection of resistant bacteria and other organisms driven by inappropriate antimicrobial use and subsequent transmission among hospital patients has a significant impact on morbidity, mortality and treatment costs. This applies to both current and future hospital patients due to changes in hospital microbial ecology resulting from this emergence and selection (see Chapter 6 Multiresistant organisms).

Additional costs of infections caused by resistant organisms include:

- the need for more expensive antibiotics to treat the infections
- the need to isolate patients colonised with resistant organisms in order to prevent cross-infection.

Another cost is through inappropriate prescribing of expensive broad-spectrum antibiotics. The existing NAUSP demonstrates unexplained wide variation in usage rates for these agents.^[25] While this variation may be due to a difference in patient-mix and acuity, the degree of variation seen across 23 large tertiary hospitals suggests that different approaches to antibiotic restriction are also responsible. Case study 2 is a good example of the costs and benefits of a successful antimicrobial stewardship program.

If unchecked, high levels of antimicrobial usage increase the pool of patients who are colonised or infected with resistant organisms both in the community and in hospitals.^[26] This situation is an important externality that has not yet been captured in economic evaluations of health care associated infection (HAI).^[27]

15.3 Surveillance methods

15.3.1 Measurement

There are two main methods of antimicrobial data collection: patient-level surveillance and population surveillance.^[28]

Patient-level surveillance involves collecting data about the dose, dosage interval and duration of therapy for individual patients. This approach gives the most accurate information, particularly if the aim is to link excessive antimicrobial use with development of resistance in a particular area of practice. Such information is usually only available through labour-intensive reviews of drug usage. Electronic prescribing and recording of drug administration will make patient-level surveillance a possibility in the future.

Population-surveillance data refer to aggregate antibiotic use data, and most hospitals supply such data from pharmacy reports, summarised at the level of a hospital or unit. Although possibly not as accurate as patient-level surveillance, population-level surveillance is the only realistic alternative for ongoing and systematic monitoring of antibiotic use. The data are generally derived from the volume of antimicrobial medications issued to wards and clinical units or from individual patient prescription data. The latter method is preferred because it provides a more accurate measure of the quantity used during the data collection period. However, in most hospitals in Australia, comprehensive data at the individual patient level are not available and aggregate data from issues to wards combined with individual patient dispensing records are used. Another data collection method is to use pharmacy purchase data; however, this is less representative than aggregation of ward issues and individual inpatient supplies.

Measurement of community antibiotic use is generally based on prescription data. In Australia, this is collected from two sources: Medicare Australia records of prescriptions submitted for payment under the Pharmaceutical Benefits Scheme (PBS) and Repatriation Pharmaceutical Benefits Scheme (RPBS); and an estimate of nonsubsidised medicines obtained from an ongoing survey of a representative sample of community pharmacies. These data also include antimicrobials dispensed to outpatients and discharged patients in three states (Queensland, Western Australia and Victoria).

15.3.2 Definitions

The anatomical therapeutic chemical (ATC) classification system is the international drug classification system recommended by WHO. The ATC code enables reporting at the levels of anatomical group, therapeutic subgroup, pharmacological subgroup, chemical subgroup and chemical substance. The ATC code for antimicrobials is JO 1.

A defined daily dose (DDD) is the international unit for comparing drug use, as defined by WHO, and corresponds to the assumed average maintenance dose per day for the main indication of a drug in adults.

Use of this internationally accepted standard enables:

- comparison of the usage of antimicrobial agents with differing doses
- aggregation of data to assess usage of antimicrobial classes
- comparison with data from other surveillance programs or studies.

Because DDDs are based on adult dosing, this parameter cannot be used to measure antimicrobial usage in paediatric populations. Age-group specific DDDs are being investigated as a potential standard measure for children.

15.3.3 Validation

Information about validation of antibiotic usage data collection is scarce. The South Australian program and NAUSP, based in South Australia, implement a system of semi-automated data validation steps before loading contributor data. This database can data map synonymous drug terminology and filter out exclusions such as topical antibiotics.

15.3.4 Reporting

Hospitals

Usage in DDDs is calculated from the quantity of antimicrobial used and reported by antibiotic type or class (ATC subgroup). These data are used to produce an aggregate measure of total usage. Intensive care usage is generally reported separately.

To facilitate comparisons, DDD data are normalised into usage density rates, which are calculated as follows, where OBDs are occupied bed days:

$$\text{Usage density rate} = \frac{\text{No. of DDDs / time period}}{\text{OBDs / time period}} \times 1000$$

OBD has been widely accepted as the most appropriate denominator in the non-ambulatory (hospital) setting and has been adopted by most international programs. Antimicrobial usage data for outpatient areas, including hospital-in-the-home, day-treatment centres, day surgery and

dialysis clinics, are variably excluded from some surveillance programs to ensure that data correspond to OBDs.

Standard methods for reporting usage in paediatric groups have not been established. In neonatal intensive care, measures (stratified by birthweight or gestational age cohorts) that have been reported include the proportion of:^[29, 30, 31]

- admitted patients who receive an antibiotic course
- patient days that the patient receives antibiotics
- patient days that the patient receives a specific antibiotic (eg vancomycin).

Community

In Australia, the Drug Usage Subcommittee of the Pharmaceutical Benefit Advisory Committee (PBAC) uses number of prescriptions and DDD per 1000 population per day as units of drug usage measurement.^[32]

Future report formats

Statistical analysis of variation over time through use of control charts or time-series analysis is advisable. This enables detection of potentially significant changes in usage rates. Morton and Looke^[33] discuss the use of generalised additive models for the production of antibiotic use control charts. These enable better identification of out-of-control usage at a facility level. It is not known how useful aggregated reporting is at a national level.

Use of time-series analysis with transfer-function analysis enables statistical examination of seasonal and other variations as a prelude to correlation of usage with antibiotic resistance^[10] (see Figure 15.1).

15.4 Current surveillance systems and data

15.4.1 International

Europe

A number of surveillance programs have been initiated in Europe during the past decade with an increasing focus on detailed descriptions of patterns of:

- antimicrobial consumption in both hospital and community settings
- resistance in
 - zoonotic bacteria
 - specific (targeted) human pathogens
 - bacteria from diagnostic samples (human and animal).

Many of these programs have been developed since the European Union conference, *The Microbial Threat*, held in Copenhagen in 1998, where it was agreed that antimicrobial resistance was an international issue and required a common European strategy. A progress report was submitted in June 2001 summarising the status of various activities, obstacles encountered and considerations for the future.^[34] A further report detailing progress and proposals for future action was submitted in late 2005.^[35]

The European Surveillance of Antimicrobial Consumption program (ESAC) was launched in November 2001 to establish a system for standardised collection, analysis and interpretation of data on antibiotic consumption. The ESAC program includes data from 34 countries, including European Union states and other central and Eastern European countries. The initial phase of the ESAC project includes data on human antibiotic consumption and resistance only and reports rates representing total community use for each region, with aggregate hospital usage data also generated where available. A database accessed via a website is planned to allow continuous and standardised updates and exchange of internationally comparable data for benchmarking between contributors and other countries. Future initiatives include:

- agreement on evidence-based guidelines for therapeutic and prophylactic human use
- agreement on threshold resistance levels for total cessation of use of particular antimicrobial agents
- development and assessment of intervention strategies to improve antimicrobial prescribing in hospitals and the community
- improved patient education on antimicrobial use.

A corresponding program — European Antimicrobial Resistance Surveillance System (EARSS) — coordinates surveillance of antimicrobial resistance.

The ARPAC (Antibiotic Resistance; Prevention and Control) project established a network of European hospitals and recommended collation of data on antibiotic use. The project ran from January 2002 to June 2005, with work being carried out by four study groups under the auspices of ESCMID. ARPAC recommended that whole-hospital antibiotic usage data, categorised by class, should be recorded quarterly using the WHO-defined unit of DDD per 1000 patient days and the ATC classification system.^[36]

The project CARE-ICU (Controlling Antibiotic Resistance in ICUs) was piloted in 2005 through funding from the European Commission. This project enabled the continuous monitoring of antibiotic use and resistance with automatic feedback through a website. Antibiotic usage was expressed as DDD/1000 bed days.^[37]

Denmark

DANMAP is a collaborative, ongoing program involving the Danish Veterinary Laboratory, Danish Veterinary and Food Administration, Statens Serum Institute and the Danish Medicines Agency. It is the best long-standing example of an integrated country-wide approach to surveillance. DANMAP was established in 1995 to collect data and report trends in resistance in pathogenic bacteria and in the use of antimicrobial agents in food animals and humans. The Danish Medicines Agency has legal responsibility for monitoring consumption of all human medicines; it receives data on all antimicrobial issues from community pharmacies (since 1994) and hospital pharmacies (since 1997). Consumption data from monthly reports from all Danish pharmacies, including hospital pharmacies, is provided to the Danish Medicines Agency. Annual reports have been produced since 1996.^[9, 15]

Other European countries

The Netherlands, Sweden and Germany have established antimicrobial surveillance programs in response to increases in antibiotic resistance. All programs collect data on human antimicrobial consumption and resistance rates. In the Dutch program, NethMap (surveillance program for antimicrobial resistance in the Netherlands), in-hospital usage data are provided for antibiotics used systemically; data are provided by ATC classification in DDD per 1000 patient days and DDD per 1000 admissions.^[38]

The Swedish Strategic Program for Rational Use of Antibiotics (STRAMA) was established in 1995. It produces an annual report — Swedish Antibiotic Utilisation and Resistance in Human Medicine (SWEDRES) — that includes data on total antibiotic use in terms of DDD per 1000 population per day and prescriptions per 1000 per day, and hospital use as DDD per 100 patient days and DDD per 100 admissions. ICU data are collected separately. Data from 2001 to 2006 are available.^[39] STRAMA provides the website application for the European Union CARE-ICU project.

In Germany, the SARI project (Surveillance of Antimicrobial Use and Antimicrobial Resistance in ICUs) collected data on the use of antimicrobials in ICUs from 2001 to 2004. Consumption was expressed as DDD per 1000 patient days.^[40]

United States

Project ICARE (Intensive Care Antimicrobial Resistance Epidemiology) started in 1996. It provides data on the prevalence of antimicrobial resistance, and use, in a subset of hospitals participating in the United States National Healthcare Safety Network (NHSN) (formerly the National Nosocomial Infections Surveillance System (NNIS)) system of the United States Centers for Disease Control and Prevention (CDC).^[41] A DDD was designated and usage density rates were provided as number of DDD per 1000 patient days. Unfortunately, the DDDs used were not consistent with the WHO definitions.

15.4.2 Australia

Hospital usage

South Australia

A state-wide antimicrobial usage surveillance program was established in November 2001 as an initiative of the Infection Control Service, Communicable Disease Control Branch and the Pharmaceutical Services Branch of the South Australian Department of Health in response to recommendations arising from the JETACAR report. This program now collects in-hospital antimicrobial usage data from metropolitan and country hospitals and private and public hospitals.

Complete usage data from November 2001 are available for eight metropolitan hospitals. Four additional metropolitan hospitals have provided data since 2002 and one more since 2003, making a total of 13 metropolitan contributors. This group includes seven public and six private hospitals, ranging in size from about 100 to 650 beds. Stratification by hospital type or size has been avoided due to the limited number of contributors. ICU usage rates are reported for five hospitals (three public and two private). Accurate ICU data are not available for a number of small units and total hospital usage is reported for these hospitals.

Contributing hospitals submit antimicrobial consumption and bed occupancy data on a monthly basis. Each hospital is sent monthly reports detailing antimicrobial usage density rates within that hospital. DDDs, as defined by WHO, are used for all rate calculations. Usage rates for six antibiotic classes, and for individual agents within those classes, are routinely reported to each contributor. Reports are presented as time-series graphs, generated automatically by a custom-built database. Corresponding 'state-wide' rates, calculated from aggregate data, are also supplied for comparison. Usage rates for other classes or agents can be extracted from the purpose-built database as required. Specific usage rates for ICUs are also supplied where data are provided. Routine monthly reports are distributed to hospital executive officers, specialist antimicrobial or drug committees, infection control committees and pharmacy directors. Separate reports detailing monthly usage rates within ICUs are supplied to unit directors on a quarterly basis.

Several country hospitals submit data, and individual reports are generated, but the data are not aggregated due to the diversity among these hospitals and the lack of a suitable benchmark for smaller hospitals.

State-wide aggregate reports are publicly available from the Infection Control Service website.⁵³

Queensland

The Centre for Healthcare Related Infection Surveillance and Prevention (CHRISP) provides Queensland Health, and other interested organisations, with information on the epidemiology, economics and prevention of HAIs. CHRISP is developing a program to monitor antimicrobial usage data for all Queensland Health facilities based on data extracted from the state-wide pharmacy database. Monthly state-wide reports will be available on the Queensland Health intranet and detailed reports from the database will be available to Queensland Health infectious diseases physicians, microbiologists, pharmacists and infection control practitioners. The reports will provide evidence to better support local antimicrobial stewardship programs.

The main emphasis of the reporting is longitudinal analysis of data within a facility or district. Improvement of the existing antibiogram system is also planned to provide clinicians with efficient access to state-wide and local antibiograms and antibiotic resistance data. CHRISP intends to correlate antimicrobial usage with antibiograms by extracting data from pharmacy and pathology systems. The aim is to identify and quantify the effects of antimicrobial prescribing habits on antibiotic resistance.

Other states

There are no other state-based antibiotic usage monitoring programs in Australia.

National

NAUSP, which was based on the South Australian program, started in July 2004. It is funded on an annual basis by the Australian Government Department of Health and Ageing. Data are processed using the South Australian database, which is currently being redeveloped to be able to accept a larger number of contributors and provide improved reporting capabilities, including statistical analysis.

In-hospital antimicrobial usage data are collected from 23 tertiary referral hospitals from all states except Queensland. This represents 50% of Australian principal referral hospitals. Hospitals range in size from about 300 to 700 adult acute-care beds. Monthly reports, as described earlier for South Australia, are provided electronically to nominated infectious diseases physicians, clinical microbiologists and pharmacy representatives at these hospitals. ICU usage rates are currently reported for 21 level 3 units (ie tertiary ICUs). Where ICU data cannot be supplied, total hospital usage is reported. Corresponding 'national' rates, calculated from aggregate data, are included for comparison.

Analysis of usage data for NAUSP from July 2004 to June 2007 shows a slight decrease in total aggregate antibiotic consumption. However, there are both upward and downward trends in usage of individual antibiotic classes and agents within classes. Increasing usage has been demonstrated in some hospitals, providing targets for possible intervention programs.

The data on national antibiotic use surveillance also highlight priorities for change and the potential to document the effect of future multicentre interventions.^[25]

⁵³ www.health.sa.gov.au/infectioncontrol

Quinolone usage is a risk factor for hospital MRSA^[12, 40, 42, 43] as well as antimicrobial resistance in various gram-negative organisms.^[44, 45] Figure 15.3 shows increasing use of the quinolone ciprofloxacin in Australian hospitals between July 2004 and June 2007. Increases in total ciprofloxacin use between 2005–06 and 2006–07 have been demonstrated at 10 of 21 sites, with increases of greater than 30% at two sites.

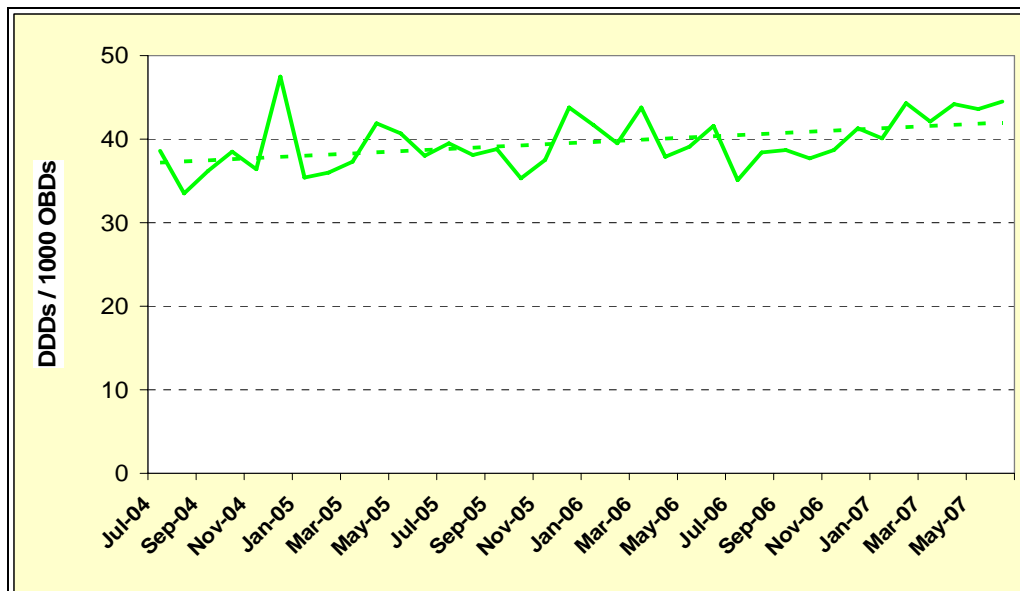


Figure 15.3 Usage of ciprofloxacin between July 2004 and June 2007 by National Antimicrobial Utilisation Surveillance Program contributors

DDDs = defined daily dose; OBDs = occupied bed days

Source: National Antimicrobial Utilisation Surveillance Program, *Annual Report 2006–07*^[25]

The aggregate rate for total antibiotic usage for 2006–07 was 916 DDDs/1000 OBDs compared to 928 for 2005–06 and 939 for 2004–05. For ICUs, the aggregate rate was 1658 DDDs/1000 OBDs in 2006–07, a slight decrease from the figure of 1684 in 2005–06.

Comparison with international data demonstrates that Australian usage rates in the contributing hospitals remain high for some antibiotic classes (see Figure 15.4). This may be related to the incidence of particular infections, prescribing policies and drug availability. Total aggregate antibiotic usage rates for the 23 Australian hospitals for which data have been analysed were 916 DDDs/1000 OBDs compared with 649 DDDs per 1000 OBDs for Denmark,^[9] 583 DDDs per 1000 OBDs for the Netherlands^[46] and 589 DDDs per 1000 OBDs for Sweden.^[47]

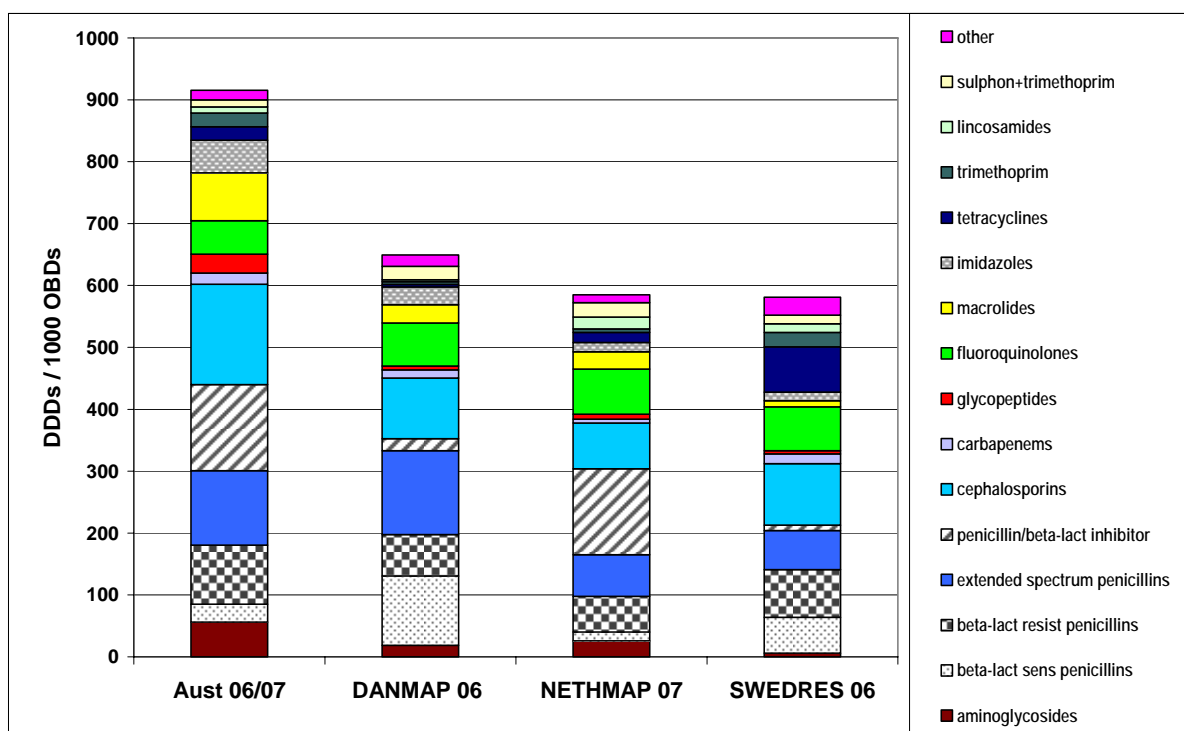


Figure 15.4 Comparison of aggregate antibiotic usage rates in Australian hospitals with international benchmarks

Aust = Australia; DANMAP = Danish Integrated Antimicrobial Resistance Monitoring and Research Program; DDD = defined daily dose; NethMap = surveillance program for antimicrobial resistance in the Netherlands; OBD = occupied bed days; SWEDRES = Swedish Antibiotic Utilisation and Resistance in Human Medicine

Source: National Antimicrobial Utilisation Surveillance Program, *Annual Report 2006–7*^[25]

Note: NethMap 07 is based on 2005 data. SWEDRES 06 is based on 2005 data.

Although the current national data collection is limited to 50% of tertiary referral hospitals, it has laid the groundwork for the establishment of a comprehensive national surveillance program for hospital antimicrobial drug use.

The 2006 EAGAR report specified the requirements of a comprehensive national surveillance system for hospitals as follows:^[14]

- a generic computer program capable of accepting antimicrobial usage data from individual hospitals from all states and territories
- automated analysis of the data with production of reports and charts that provide individual hospital, state and national usage rates.

Data generated from the system would be used to:

- enable examination of trends in hospital antimicrobial use at state and national levels as the basis for larger-scale interventions to rationalise hospital antimicrobial prescribing
- evaluate the impact of interventions in the hospital setting at local, state and national levels
- produce longitudinal antimicrobial usage data that could be used to demonstrate a link between antimicrobial use and future development of resistance, both at local hospital and national levels

- provide an Australian peer group benchmark for comparison and enable comparison with international data
- inform antimicrobial stewardship programs and monitor intervention strategies.

NAUSP currently fulfils most of these requirements. However, it needs to be expanded, with appropriate resourcing, to include data from all tertiary hospitals and selected smaller hospitals and to include reporting by hospital peer group with appropriate case-mix adjustment. Reporting should also be expanded to include usage by specific clinical specialties and within area health regions.

Community usage

The consumption data on community antibiotic usage collected by the PBAC Drug Usage Subcommittee is reported biennially in *Australian Statistics on Medicine*. Information on this type of data collection is given in Section 15.3.1. The data are reported at a national level and can be provided at the state level; they can be obtained directly from the Drug Usage Subcommittee. Antibiotic usage data are routinely monitored by the Drug Usage Subcommittee and periodic reports are sent to EAGAR. Annual reports are provided to the Australian Institute of Health and Welfare (AIHW) and to the WHO International Committee on Drug Statistics Methodologies. As explained, these data also include antimicrobials dispensed by hospital pharmacies to outpatients and discharged patients in three Australian states. The volume of data will increase as more states implement the pharmaceutical reforms that allow dispensing of PBS prescriptions for outpatients and on discharge.

The Drug Usage Subcommittee also reports to government on the prescription rate for oral antibiotics most commonly used to treat upper respiratory tract infection. This is reported for individual states and Australia-wide. Due to data restrictions, the report is based only on PBS concession card holders.

The total use of antibiotics in the Australian community falls in the middle of the range recorded in European countries: in 2002, Australian community antibiotic use was 21 DDDs per 1000 population per day.^[32] Usage was highest in France at 32 DDDs/1000/day, while the Netherlands had the lowest usage at 10 DDDs/1000/day.^[48, 49]

The Bettering the Evaluation and Care of Health project (BEACH) of the Australian General Practice Statistics and Classification Centre⁵⁴ collects data on clinical activities in general practice. These data include medications (prescribed, advised and provided), clinical treatments and procedures provided. As of July 2007, there were 90,000 general practitioner encounters in the database. BEACH reports on rates of prescribing; it also contributes to AIHW reports.^[50] Data from the BEACH project demonstrated a significant decline in antibiotic prescribing in general practice over the five-year period 1999–2004.^[50] No comprehensive resistance data were available to monitor the effect of this decline. Prescribing for upper respiratory tract infections decreased during that period from 42% of patient general practitioner visits for upper respiratory tract infections in 1998–99 to 35% in 2002–03.^[51] This change represented a shift towards recommended management as promoted through NPS-targeted interventions.^[22]

In 2004, antibiotic prescriptions began to increase again. An increase in doctor visits for respiratory tract infections and the ability of Queensland hospitals to directly access the PBS for outpatient and discharge prescriptions from early 2004 may have contributed to this increase. The increase was mainly in penicillins (amoxicillin), which indicates continuing adherence to NPS recommendations. Rates now appear to have stabilised at a rate less than that of 2001.^[32]

⁵⁴ www.fmrc.org.au/beach.htm

Future developments should include integrating the antimicrobial usage data from all care sectors (primary through to tertiary) and linking usage data with resistance patterns in a similar manner to DANMAP.

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16 Health-care worker immunisation

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Key points

- Immunising health-care workers (HCWs) can prevent infection associated with health care.
- HCW immunisation currently occurs at the level of individual health-care units for the protection of individual HCWs. State and territory governments have begun to consider or initiate systematic programs aimed at disease prevention for the whole health-care population, but Victoria is the only jurisdiction to have established a limited surveillance program. The international situation seems similar.
- In Australia, national recommendations for HCW immunisation were republished in 2003. A national program is warranted given the existence of the national recommendations, the mobility of the Australian health-care workforce, inconsistencies between states and territories, and duplications of effort.
- HCW immunisation should be an integral part of national disease control programs. An effective national program would need to be underpinned by national surveillance, with standards comparable to those already in place for the National Immunisation Program.

Recommendations on health-care worker immunisation

1. All Australian HCWs should be immunised in accord with the National Health and Medical Research Council *Australian Immunisation Handbook* to protect HCWs and patients from vaccine-preventable diseases, including influenza.
2. National surveillance of vaccine-preventable infections should include data on employment status as an HCW (ie when a person is vaccinated, information should be collected as to whether the person is an HCW).
3. Standardised recording of HCW immunity and immunisation status is required.

16.1 Background

Transmission of immunisation-preventable diseases such as influenza, varicella and measles occurs in the health-care setting. In some cases, including within Australia, health-care workers (HCWs) have been implicated in the spread of these diseases.^[1, 2, 3, 4, 5, 6] Such reports underpin national and international recommendations for immunisation of HCWs to protect both the workers and their patients.

Herd immunity, including that resulting from childhood immunisations and other scheduled or voluntary immunisation programs, also contributes to preventing the spread of infection in health-care settings as well as in the community.

16.1.1 Recommendations for health-care worker immunisation

The *Australian Immunisation Handbook*^[7] provides a national standard for immunisation of HCWs; the standard is included in the recommendations for those at risk of occupationally-acquired vaccine-preventable diseases. The recommendations for HCWs are as follows:

- hepatitis B immunisation for those directly involved in patient care, embalming or the handling of human blood or tissues

- hepatitis A immunisation for HCWs who frequently attend paediatric patients from rural and remote Indigenous communities or HCWs who work with rural and remote Indigenous communities
- annual influenza immunisation for HCWs and staff of nursing homes and long-term care facilities
- measles-mumps-rubella vaccine for HCWs born during or since 1966
- varicella immunisation for all seronegative HCWs directly involved in patient care
- pertussis immunisation (using diphtheria-tetanus-acellular pertussis) for HCWs in paediatric and maternity departments.

In addition, Japanese encephalitis immunisation is recommended for HCWs assigned to the outer Torres Strait Islands for a month or more during the wet season. Immunisation for tuberculosis (TB) is as recommended by the state and territory TB control authority.

In the United States, the Healthcare Infection Control Practices Advisory Committee recommended in 2005 that HCW influenza immunisation coverage be used as a health-care quality measure in those states that mandate public reporting of health care associated infections (HAIs)^[8]

16.2 Harm to patients

Systematic studies of the effect of HCW immunisation on patient outcomes are rare, with the possible exception of influenza. Despite the publication of a somewhat controversial Cochrane Review,^[9] the consensus view in Australia remains that HCW immunisation against influenza helps to protect patients.

Immunisation of HCWs against influenza is associated with less absence from work and fewer deaths among hospitalised patients.^[10, 11]

Immunisation of HCWs against other vaccine-preventable diseases can potentially prevent outbreaks of varicella, pertussis and measles.^[12, 1, 3, 5, 6] It can also potentially prevent transmission of bloodborne viruses such as hepatitis B from HCWs to patients.^[2, 13, 14] Box 16.1 provides a case study of a possible case of hepatitis B transmission from HCW to patient.

Box 16.1 Possible case of hepatitis B transmission from health-care worker to patient

An Australian surgeon had serum collected to check for susceptibility to hepatitis B infection after suffering a needlestick injury. Testing revealed that the surgeon had already been infected with hepatitis B before the injury. Less than five years previously, the surgeon had tested negative for hepatitis B infection but had not been immunised. While the hepatitis B infectivity was only moderate ($<10^5$ virus/mL) at the first positive test, it was clear that, for at least some time in the previous few years, the surgeon would have been highly infectious. Thousands of medical records were reviewed to identify more than 500 patients at risk of hepatitis B infection following surgical procedures. Almost all of these patients, some of their family members and more than 150 health care workers were counselled and tested. The investigation was estimated to have cost more than \$50,000. Ten patients tested positive for past hepatitis B infection. Although six of these patients had other prominent risk factors for hepatitis B infection, the surgeon could not be definitively ruled out as the source of infection. The surgeon was excluded from carrying out exposure-prone procedures.

16.3 Impact on health-care systems

In a 2004 review, Ruef concluded that immunisation of HCWs is a highly cost-effective preventive measure and that HCWs should do their utmost to prevent the transmission of infectious pathogens to their patients.^[15]

16.4 Surveillance methods

The *Australian Immunisation Handbook*^[7] makes no recommendations for surveillance of HCW immunisation other than the statement ‘medical facilities or health departments are encouraged to formulate a comprehensive immunisation policy for all health care workers’ (page 74).

Individual recall of past infection or immunisation is unreliable. Generally, the only reliable methods for determining whether HCWs are immune or vaccinated are one of the following:

- antibody levels (where measurable and relevant)
- documentation of each dose of vaccine given.

Possible exceptions to this situation are a personal history of chickenpox as a measure of immunity against varicella-zoster or birth before 1966 as a measure of measles immunity.

Such records are currently held piecemeal by health units but are rarely collated, let alone validated, analysed or published, even at the level of individual institutions.

The ultimate measure of the effectiveness of an immunisation program is the prevention of disease. In Australia, the individual communicable disease control authorities in the eight states and territories are responsible for surveillance of vaccine-preventable disease under the eight public health Acts. The state and territorial authorities coordinate their activities through the voluntary Communicable Disease Network Australia.⁵⁵ National data are updated fortnightly. However, there is no systematic collection or publication of data to show which notified cases are HCWs or which patients acquired their infection through health care.

A national whole-of-life immunisation register, supplementing the existing Australian Childhood Immunisation Register, could facilitate surveillance, although there would be difficulties in extracting population data from a data management system designed for longitudinal, individual records. A whole-of-life register would also provide data on the other members of the health-care community; that is, patients and clients.

16.5 Current surveillance systems and data

Surveillance provides data to prompt action. If a national population-based program to provide immunisation for all HCWs is planned, with the aim of reducing disease incidence in the whole health-care population (workers, patients and clients), then national surveillance is warranted. If HCW immunisation is to be left largely as a matter for local initiative at the health-unit level, and aimed chiefly at protecting (however ineffectually) the individual HCW, then the collection, validation, analysis and publication of national data is not warranted.

International

In the United States, the National Surveillance System for Health Care Workers (NaSH) collaborates with health-care facilities to systematically collect information, including immunisation programs, that is important for preventing occupational exposures and infections

⁵⁵ <http://www.health.gov.au/internet/main/publishing.nsf/Content/cda-cdna-index.htm>

among HCWs. There are a few cross-sectional studies, mainly dealing with influenza and hepatitis B immunisation,^[16, 17, 18] but none of these constitute or pretend to be surveillance programs. The NaSH data are published spasmodically and piecemeal.^[19]

Cross-sectional studies from a number of countries indicate very low levels of HCW immunisation, particularly to influenza (<40%).^[16, 17, 18] As these studies usually depend on HCW recall rather than immunisation records, the immunisation rates are possibly even lower.

Australia

Five of the eight state and territory health and human services departments have policies relevant to HCW immunisation and two have such policies in development.^[20, 21, 22, 23, 24] While generally consistent with the recommendations of the *Australian Immunisation Handbook*,^[7] vaccine recommendations vary between jurisdictions. Of potential importance for national surveillance is the classification of HCWs into clinical and non-clinical categories for different immunisations; New South Wales and South Australia have two categories, whereas Queensland, Victoria and Western Australia have four.

No state or territory has comprehensive state-wide surveillance of HCW immunisation or immunity. Most policies encourage or require health-care institutions to have registers that are readily accessible to individual HCWs. The primary purpose of these registers seems to be the management of occupational health incidents.

In Victoria, Victorian Hospital-Acquired Infection Surveillance (VICNISS) collects and publishes information on measles immunisation and immunity (13 hospitals), hepatitis B serology (35 hospitals) and influenza immunisation (by occupational category rather than by the risk categories of the Victorian Department of Human Services Immunisation for Health Care Workers).^[25]

The VICNISS data indicate that in 45 smaller hospitals (<100 beds), many staff are still potentially unprotected, with about 35% of medical staff reported as having received less than three doses of hepatitis B vaccine and a confirmatory blood test. This is despite the fact that among the recommended immunisations for HCWs, hepatitis B is probably one of the most readily accepted, and routine immunisation of HCWs has been recommended in the United States since 1982 and in Australia since the vaccine became available.

These data are consistent with the 1995 VICNISS survey of 30% of public and private hospitals, which showed that there was no consistent policy in place for hepatitis B prevention and that a considerable number of potentially susceptible HCWs remain unprotected.^[26]

The new NSW Policy Directive 2007_006 requires reporting of percentage vaccinated in one of two categories⁵⁶ to the central health department, implying that both numerator and denominator data will now need to be collected at the health-unit level.^[22]

Box 16.2 gives a case study of the situation with influenza immunisations in aged-care facilities.

⁵⁶ The two categories are Category A (Contact with clients or contact with blood, body substances or infectious material) and Category B (No contact with clients or blood or body substances).

Box 16.2 Influenza immunisations in aged-care facilities

During September 2004, six aged-care facilities in the Greater Newcastle region experienced major outbreaks of respiratory illness affecting a total of 132 residents and contributing to 18 deaths. Information on influenza immunisation coverage for residents and staff was not readily available at each facility and immunisation registers were not routinely used.

At one facility, detailed information on influenza immunisation coverage was collected by manually reviewing residents' charts and surveying staff. A total of 38 residents and 18 staff developed respiratory illness, representing attack rates of 76% and 27% respectively. Respiratory illness resulted in 10 hospital admissions and contributed to the deaths of 10 residents. Influenza A was subsequently confirmed in three residents.

Routine infection control measures were implemented. These included:

- closing the facility to new admissions
- cohorting affected residents and staff
- increasing the use of personal protective equipment.

Oseltamivir prophylaxis was used for both residents and staff.

Recent influenza immunisation was documented for 56% of residents. The immunisation status was unknown for a further 38%. Only 17% of staff had received influenza immunisation for that season, and 76% were known not to be immunised.

The Northern Territory late-draft policy proposes a territory-wide register.

Tasmania has a state-wide register of HCWs immunised against hepatitis B.

South Australia collects state-wide data on influenza immunisation, and denominator data by health units staffed by government HCWs, but these data are not broken down into clinical and non-clinical personnel.

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Part F — Human and economic costs

17 Costs of health care associated infection

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Key points

- The costs of health care associated infections (HAIs) are difficult to measure and value.
- The costs are an important consideration for any decision to increase investment in infection control programs.
- The greatest cost is the bed days lost to infection within the hospital sector.
- The value of these bed days depends on the need of the general population to access hospital services and the willingness of decision makers to pay for these services.
- Based on the available data and a number of assumptions, it is estimated that almost two million bed days are lost to infection per year in Australia.
- The data must be interpreted carefully because not all infections can be prevented.
- There are also many private and difficult-to-value costs associated with infection: these include pain and suffering for patients and their families.

Recommendation on costs of health care associated infections

1. The process of attributing cost to HAI should be expressed in terms of the number of bed days that are released by effective infection control programs as well as any savings in variable costs.

17.1 Background

Estimates of the cost of health care associated infections (HAIs) can be used to argue for increased funding for infection control. For example, a recent United Kingdom study found that adults who developed HAI remained in hospital 2.5 times longer, occupying valuable bed days.^[1] Thus, preventing a case of HAI can save money by freeing up bed days for alternative uses. Often, the savings from preventing HAIs more than compensate for the additional cost of the extra infection control needed and costs decrease overall. Infection control has been called a ‘win–win’ because costs can be saved and health outcomes improved, with potentially dangerous and unpleasant episodes of infection prevented.^[2] A win–win is unusual in today’s overburdened and stressed health-care sector.

It can be difficult to demonstrate that infection control saves costs and improves health outcomes, but the methodological framework exists.^[3, 4] An important part of building the argument is to show that infections themselves are costly, and that is the aim of this chapter. The chapter:

- reviews some of the methodological difficulties with estimating costs (Section 17.2)
- summarises the literature for all settings (Section 17.3)
- estimates some costs for Australia (Section 17.4)
- describes case studies of individuals’ experiences (Section 17.5)
- summarises and discusses the way forward (Section 17.6).

17.2 Methodological difficulties with cost estimates

Two issues must be considered when estimating the costs of HAI:

- the difference between how accountants and economists view costs — this distinction is important because errors in attributing costs can lead to erroneous conclusions
- the range of epidemiological methods used to attribute increased length of stay to HAI.

These two issues are discussed in the following text.

17.2.1 Accounting versus economics

Most cost data used to value the adverse outcomes of HAIs are retrieved from accounting departments in hospitals. Those who manage hospital budgets will estimate a cost per bed day by allocating fixed costs (eg staff, heating, lighting, insurance and ancillary services) across a measure of usage, such as bed days. They will also allocate variable costs using a weighting system, such as diagnosis related groups (DRGs⁵⁷). The result is that total expenditures are allocated to patients based on length of stay, DRGs or other weightings. This practice is useful to those who run the organisation because expenditures can be tracked, helping the hospital to stay financially solvent. However, using such data to make economic arguments about preventing HAI is problematic.

Where economics is applied to HAI and used to argue for increased investment in infection control, it is important to understand how infection control will affect costs. On one hand, additional infection control increases costs; for example, employing infection control practitioners to undertake surveillance and education is costly. On the other hand, by preventing infections, effective infection control frees up bed days and reduces expenditure on variable costs, such as pharmaceuticals and dressings. However, the rate of HAI has no effect on the fixed costs of running the hospital: these are the same whether rates of HAI are 30% or 0.3%. In the short term, about 90% of the operating costs of a hospital are fixed.^[5, 6] Also, bed days freed up by prevention of infection are valuable only if there is surplus demand (ie waiting lists); they are worth nothing if there are no waiting lists for access to hospital.

We therefore recommend that the process of attributing cost to HAI be couched in terms of the number of bed days that are released by effective infection control programs, as well as any savings in variable costs (although these are likely to be small given the structure of costs in the hospital sector). The bed days associated with HAI can then be valued outside of any process that attributes them to HAI.

17.2.2 Attributing bed days to health care associated infection

It is important to disentangle the effect of HAI from other factors associated with cost outcomes, such as length of stay. If patients who acquire HAIs are sicker, older and have more comorbidities than those who do not, then costs for those patients may be higher, regardless of any HAI. This point is illustrated by the work of Graves and colleagues, who collected data on length of stay and factors that might affect length of stay from 4500 hospitalised patients, summarised in Table 17.1.^[7] Of the patients surveyed, 4230 did not acquire an HAI, 27 acquired a lower respiratory tract infection (LRTI), 59 acquired a urinary tract infection (UTI) and 41 acquired an infection at another site.

⁵⁷ Diagnosis related group is a system for classifying hospital cases into one of about 500 groups that are expected to have similar use of hospital resources.

Table 17.1 Differences between groups with lower respiratory tract infection, urinary tract infection or other health care associated infections (HAIs) and the group without HAI

	Absence of HAI (<i>n</i> = 4230)	LRTI (<i>n</i> = 27)	UTI (<i>n</i> = 59)	Other (<i>n</i> = 41)
Cost outcomes	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Length of hospital stay (days)	4.80 (5.01)	15.19 (8.32)	14.86 (10.52)	15.49 (11.41)
Variable costs — drugs (A\$)	100.61 (471.95)	963.70 (1842.56)	139.29 (143.01)	1022.34 (3380.29)
Variable costs — other (A\$)	21.21 (58.03)	133.19 (209.23)	37.66 (173.57)	120.27 (284.21)
Variable costs — total (A\$)	121.77 (486.90)	1097.00 (1887.51)	176.93 (276.22)	1142.61 (3395.30)
Demographic and social factors	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age on admission (years)	56.90 (20.02)	67.00 (14.04)	71.59 (19.20)	64.93 (18.49)
Socioeconomic status score (0–100)	37.23 (21.39)	44.40 (24.92)	32.33 (20.53)	38.08 (25.39)
	Proportion (no.)	Proportion (no.)	Proportion (no.)	Proportion (no.)
Male	51.47% (2177)	70.37% (19)	30.51% (18)	53.66% (22)
Caucasian	91.55% (3872)	95.83% (26)	94.55% (56)	91.89% (38)
Current drinker	62.30% (2635)	70.83% (19)	44.06% (26)	58.61% (24)
Current smoker	25.01% (1058)	13.15% (4)	22.96% (14)	6.97% (3)
Self-caring before admission	71.49% (3024)	54.17% (15)	39.29% (23)	58.97% (24)
Obese	74.81% (3164)	87.99% (24)	83.78% (49)	81.70% (33)
Admission/discharge characteristics	Proportion (no.)	Proportion (no.)	Proportion (no.)	Proportion (no.)
Discharged home	95.08% (4022)	70.37% (19)	74.58% (44)	70.73% (29)
Died in hospital	2.08% (88)	22.22% (6)	13.56% (8)	17.07% (7)
Elective admission	43.33% (1833)	29.63% (8)	32.20% (19)	34.15% (14)
Teaching hospital	65.32% (2763)	92.59% (25)	71.19% (42)	73.17% (30)
Adverse events in hospital	Proportion (no.)	Proportion (no.)	Proportion (no.)	Proportion (no.)
Fall	1.32% (56)	7.41% (2)	10.17% (6)	4.88% (2)
Cardiac arrest	2.48% (105)	22.22% (6)	13.56% (8)	17.07% (7)
Pulmonary embolus	0.12% (5)	7.41% (2)	1.69% (1)	0.00% (0)
Pressure ulcer	3.07% (130)	25.93% (7)	13.56% (8)	14.63% (6)
Gastrointestinal bleeding	4.42% (187)	25.93% (7)	6.78% (4)	14.63% (6)
Comorbidities	Proportion (no.)	Proportion (no.)	Proportion (no.)	Proportion (no.)
Faecally incontinent	5.22% (221)	29.63% (8)	28.81% (17)	21.95% (9)
Anaemic on admission	17.80% (753)	44.44% (12)	33.90% (20)	29.27% (12)
Anaemic during admission	37.90% (1603)	92.59% (25)	71.19% (42)	70.73% (29)
Admitted with fracture or dislocation	5.32% (225)	14.81% (4)	16.95% (10)	4.88% (2)
Chronic obstructive pulmonary disease	10.57% (447)	25.93% (7)	20.34% (12)	12.20% (5)
Cirrhosis of the liver	1.13% (48)	3.70% (1)	0.00% (0)	7.32% (3)

	Absence of HAI (<i>n</i> = 4230)	LRTI (<i>n</i> = 27)	UTI (<i>n</i> = 59)	Other (<i>n</i> = 41)
Congestive heart failure	6.36% (269)	14.81% (4)	13.56% (8)	9.76% (4)
Coronary artery disease	13.83% (585)	11.11% (3)	10.17% (6)	14.63% (6)
Diabetes	15.79% (668)	33.33% (9)	33.90% (20)	17.07% (7)
Underlying gastrointestinal disease	30.09% (1273)	51.85% (14)	44.07% (26)	31.71% (13)
Underlying neurological disease	10.54% (446)	25.93% (7)	45.76% (27)	29.27% (12)
Ever had a stroke	6.86% (290)	11.11% (3)	20.34% (12)	19.51% (8)
Hypertension	34.54% (1461)	44.44% (12)	50.85% (30)	41.46% (17)
Dyspnoea	24.75% (1047)	66.67% (18)	37.29% (22)	36.59% (15)
Hyponatraemic on admission	8.04% (340)	14.81% (4)	27.12% (16)	17.07% (7)
Multitrauma	0.14% (6)	0.00% (0)	0.00% (0)	2.44% (1)
Neurogenic bladder	0.28% (12)	3.70% (1)	1.69% (1)	2.44% (1)
Peripheral pulses absent	1.30% (55)	7.41% (2)	0.00% (0)	4.88% (2)
Device, procedure or therapy during admission	Proportion (no.)	Proportion (no.)	Proportion (no.)	Proportion (no.)
Urinary catheter	25.37% (1073)	70.37% (19)	76.27% (45)	41.46% (17)
Arterial catheter	12.58% (532)	33.33% (9)	10.17% (6)	24.39% (10)
Central venous catheter	6.12% (259)	29.63% (8)	3.39% (2)	24.39% (10)
Epidural/intrathecal catheter	3.10% (131)	7.41% (2)	8.47% (5)	7.32% (3)
Indwelling or suprapubic urinary catheter	24.61% (1041)	70.37% (19)	72.88% (43)	39.02% (16)
Instrumentation of bladder	3.40% (144)	3.70% (1)	6.78% (4)	0.00% (0)
Intracranial pressure monitor	0.12% (5)	3.70% (1)	1.69% (1)	2.44% (1)
Peripheral parenteral device	89.76% (3,797)	96.30% (26)	94.92% (56)	87.80% (36)
Transfusion of blood or blood products	9.31% (394)	40.74% (11)	23.73% (14)	46.34% (19)
Parenteral nutrition	0.24% (10)	0.00% (0)	0.00% (0)	9.76% (4)
Oxygen therapy	67.07% (2837)	96.30% (26)	76.27% (45)	78.05% (32)
Nasogastric tube	7.49% (317)	48.15% (13)	20.34% (12)	29.27% (12)
Patient unable to protect airway from aspiration	36.17% (1530)	62.96% (17)	42.37% (25)	48.78% (20)
Pleural drainage	16.36% (692)	29.63% (8)	18.64% (11)	39.02% (16)
Drain tube of any type	34.21% (1447)	55.56% (15)	40.68% (24)	34.15% (14)
Anticoagulant therapy	11.35% (480)	29.63% (8)	6.78% (4)	14.63% (6)
Given non-steroid anti-inflammatory	37.45% (1584)	40.74% (11)	50.85% (30)	39.02% (16)
Stress ulcer prophylaxis	30.43% (1287)	77.78% (21)	44.07% (26)	53.66% (22)

HAI = health care associated infection; LRTI = lower respiratory tract infection; UTI = urinary tract infection

Patients with an HAI had a longer stay in hospital (mean = 15.19 for LRTI, 14.86 for UTI and 15.49 for other) compared with those who were free of infection (mean = 4.80 days). However, factors other than HAI might have caused these differences. For example, a lower proportion of patients with HAI were discharged home, were elective admissions or were classified as self-

caring before admission and a higher proportion experienced additional adverse events. A well-designed epidemiological study of the cost of HAI could tease out the independent effect of HAI on length of stay by controlling for other relevant factors. Two main approaches that have been used in the literature to achieve this — ‘concurrent attribution’ and ‘comparative attribution’ — are discussed in the following text.

Concurrent attribution

In concurrent attribution, experts review the medical record and other relevant clinical information and decide whether to attribute each day of hospitalisation to the primary reason for hospitalisation or to HAI.^[8] This method is time consuming and possibly subjective, with critics arguing that the results are unreliable and inconsistent.^[9] The ‘appropriateness evaluation protocol’ is a variation of the method in which explicit criteria are used to assign hospital days as either infection-related or not.^[10, 11] This approach does not compare HAI patients to non-HAI controls.

Comparative attribution

There are several different approaches to comparative attribution. The least sophisticated is to use unmatched group comparisons, in which those with HAI are compared with those without HAI by cost outcomes. This provides biased results because it fails to consider any of the other differences between the two groups that might explain cost differences. There are two main ways to control for differences between groups:

- matching infected patients with uninfected controls who are similar on other characteristics likely to explain cost outcomes — this method relies on adjusting for difference at the study-design stage
- using a statistical regression model to identify associations between factors thought likely to cause cost outcomes, with the primary focus being on any association between HAI and cost outcomes — this method adjusts for differences at the analysis stage and addresses some important sources of bias that arise with matching.

Two reviews of the strengths and weaknesses of these two comparative methods suggested that statistical procedures are likely to give less biased results.^[12, 13]

17.3 Costs reported in the literature

A literature search identified 254 separate estimates of the length of stay attributable to HAI. These estimates described single infections arising in the bloodstream, digestive tract, ‘other’ single sites, respiratory tract, surgical wounds and the urinary tract. Studies that estimated a cost for all types of infection were labelled ‘mixed’. Figure 17.1 illustrates the distribution of these estimates by country and by site of infection. The figure shows that studies have been undertaken in 20 different countries; most were conducted in the United States but some were published in middle-income countries such as Thailand, India and Mexico.

The remainder of this section summarises the results by site of infection.

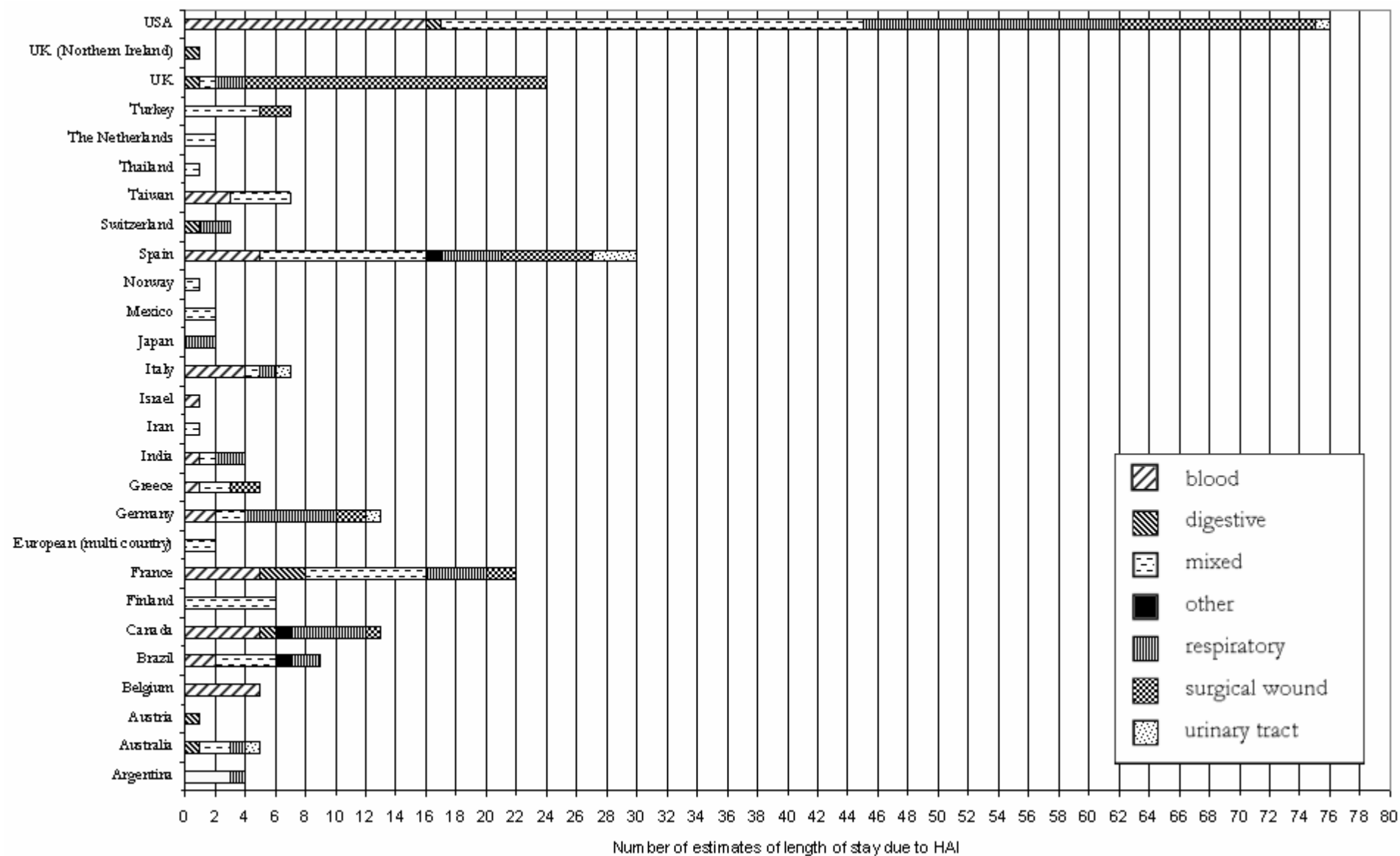


Figure 17.1 Studies of the costs of health care associated infection, by region and site

Bloodstream infections

A total of 48 estimates of excess length of stay due to bloodstream infection (BSI) were reported from Belgium,^[14, 15, 16, 17, 18] Brazil,^[19] Canada,^[20, 21] France,^[22, 23, 24] Germany,^[25, 26] Greece,^[27] India,^[28] Israel,^[29] Italy,^[30, 31, 32] Spain,^[33, 34] Taiwan,^[35] the United Kingdom and the United States.^[36, 37, 38, 39, 40, 41, 42, 43, 44] Five of these estimates were for catheter related BSI (CR-BSI) only.^[18, 38, 42, 45] A summary of the excess lengths of stay for BSI (CR-BSI excluded), by different study design, is presented in Figure 17.2.

Estimates of extra days due to BSI were:

- 15.5 days — from one study that used a concurrent design^[32]
- 23 days (SD 15.42) — the mean of six estimates from studies that did not make any adjustment for differences between those with and without infection^[23, 28, 33, 40, 43]
- 13.25 days (SD 7.32) — the mean of 32 estimates reported in matching studies^[14, 15, 16, 17, 18, 19, 20, 22, 25, 27, 29, 30, 31, 34, 35, 37, 41, 44, 45, 46]
- 7.07 days (SD 6.74) — the mean of five estimates reported in studies that used statistical procedures to control for differences^[21, 26, 34, 36, 38, 47]
- 18.4 days (SD 4.39) — the mean of four estimates reported for CR-BSI.^[18, 38, 45]

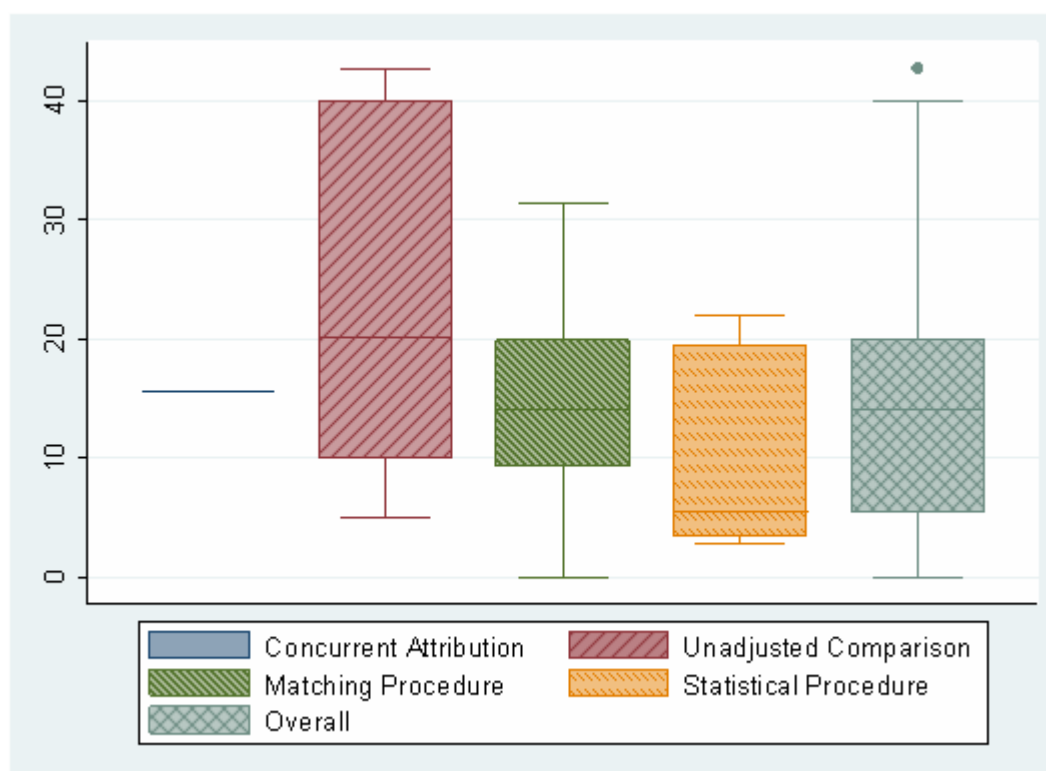


Figure 17.2 Extra days in hospital due to bloodstream infection, by study design

Digestive tract infections

Six estimates of excess length of stay due to digestive tract infections were reported from Canada,^[48] France,^[49, 50, 51] the United Kingdom (Northern Ireland)^[52] and the United States.^[53] Estimates of extra days due to digestive tract infections were:

- 13,^[52] 8.1^[49] and 4.4 days^[51] from three studies that reported the results of an unadjusted comparison
- 10.7^[48] and 4.9 days^[50] from two studies that used a matching procedure
- 3.6 days from one study that used a statistical procedure.^[53]

Respiratory infections

A total of 42 estimates of excess length of stay due to infection in respiratory sites were reported from Argentina^[54], Australia,^[7] Brazil,^[55] Canada,^[56, 57] France,^[49, 58] Germany,^[26, 59, 60] India,^[61] Iran,^[62] Italy,^[63] Japan,^[64] Spain,^[33, 34] Switzerland,^[65] Taiwan,^[66] the United Kingdom^[1, 67] and the United States.^[45, 68, 69, 70, 71, 72, 73, 74] A summary of the excess lengths of stay for infections of respiratory sites, by different study design, is presented in Figure 17.3.

Estimates of extra days due to respiratory site infections were:

- 26.03 days (SD 20.28) — the mean of 18 estimates reported in studies that did not make any adjustment for differences between those with and without infection^[33, 49, 55, 57, 59, 61, 64, 67, 68, 74]
- 9.95 days (SD 4.79) — the mean of 32 estimates reported in matching studies^[34, 54, 56, 58, 60, 62, 63, 65, 69, 71, 72, 75, 76]
- 11.93 days (SD 7.74) — the mean of nine estimates reported in studies that used statistical procedures to control for differences.^[1, 7, 26, 34, 70, 73]

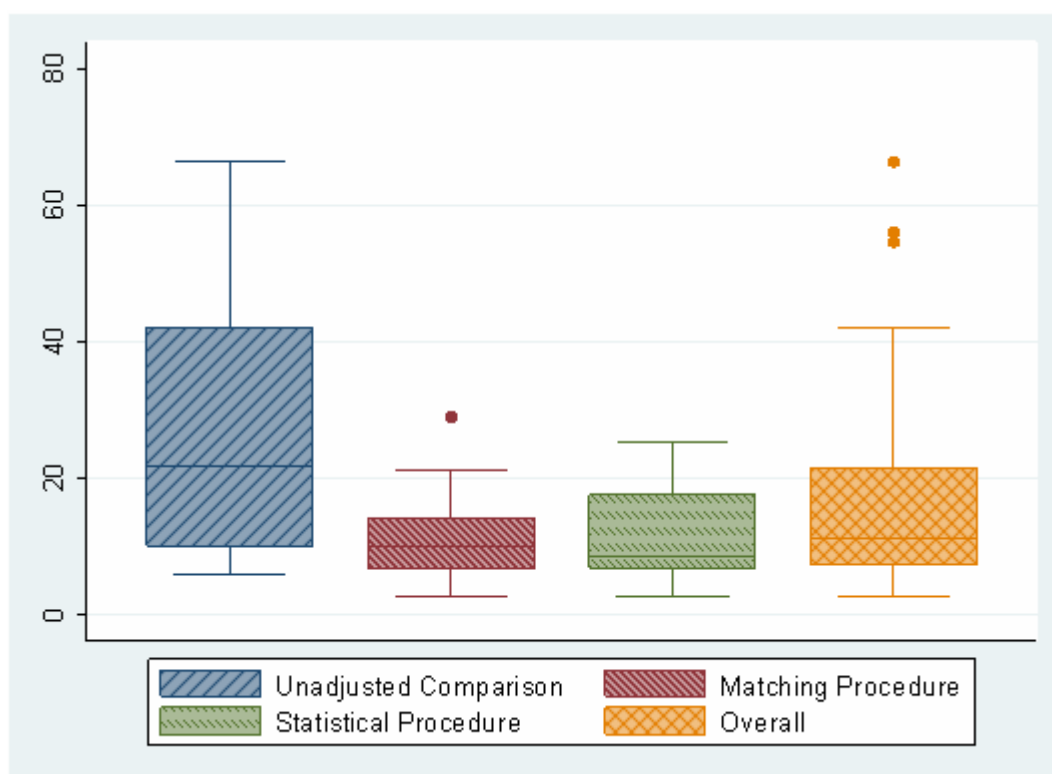


Figure 17.3 Extra days in hospital due to respiratory site infection, by study design

Surgical wound infections

A total of 43 estimates of excess length of stay due to infection of surgical wounds were reported from Canada,^[77] France,^[78] Germany,^[26, 79] Greece,^[80] Iran,^[62] Spain,^[34, 81, 82] Taiwan,^[66] the Netherlands,^[83] Turkey,^[84] the United Kingdom^[1, 85, 86, 87] and the United States.^[88, 89, 90, 91, 92, 93, 94]

A summary of the excess lengths of stay for infections of surgical sites, by different study design, is presented in Figure 17.4.

Estimates of extra days due to surgical site infections were:

- 10.2 and 3.5 days — from two studies that used the concurrent design^[77, 78]
- 13.65 days (SD 6.12) — the mean of 15 estimates reported in studies that did not make any adjustment for differences between those with and without infection^[80, 83, 85, 87, 91]
- 22.55 days (SD 22.82) — the mean of 19 estimates reported in matching studies^[34, 62, 76, 78, 81, 82, 84, 86, 88, 89, 92, 93, 94]
- 9.38 days (SD 4.41) — the mean of six estimates reported in studies that used statistical procedures to control for differences.^[1, 21, 26, 34, 36, 38, 47, 79, 81, 90]

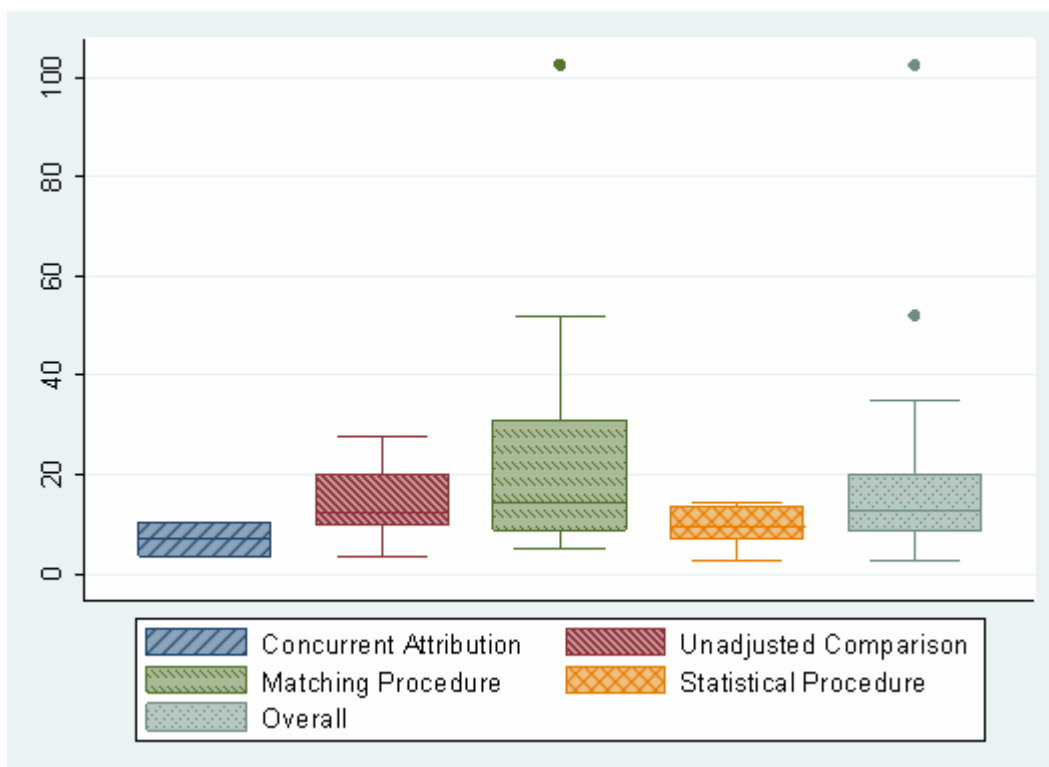


Figure 17.4 Extra days in hospital due to surgical site infection, by study design

Urinary tract infections

Eleven estimates of excess length of stay due to UTI were reported from Australia,^[7] Germany,^[26] Iran,^[62] Italy,^[32] Spain,^[33, 34] Taiwan,^[76] the United Kingdom^[1] and the United States.^[95] A summary of the excess lengths of stay for UTIs, by different study design, is presented in Figure 17.5.

Estimates of extra days due to UTIs were:

- 6 and 0 days — from two studies that used the concurrent design^[32, 95]
- 30.3 days — from one study that did not make any adjustment for differences between those with and without infection^[33]

- 11.82 days (SD 8.5) — the mean of four estimates reported from matching studies^[34, 62, 76]
- 2 days (SD 2.95) — the mean of four estimates reported in studies that used statistical procedures to control for differences.^[1, 7, 26, 34]

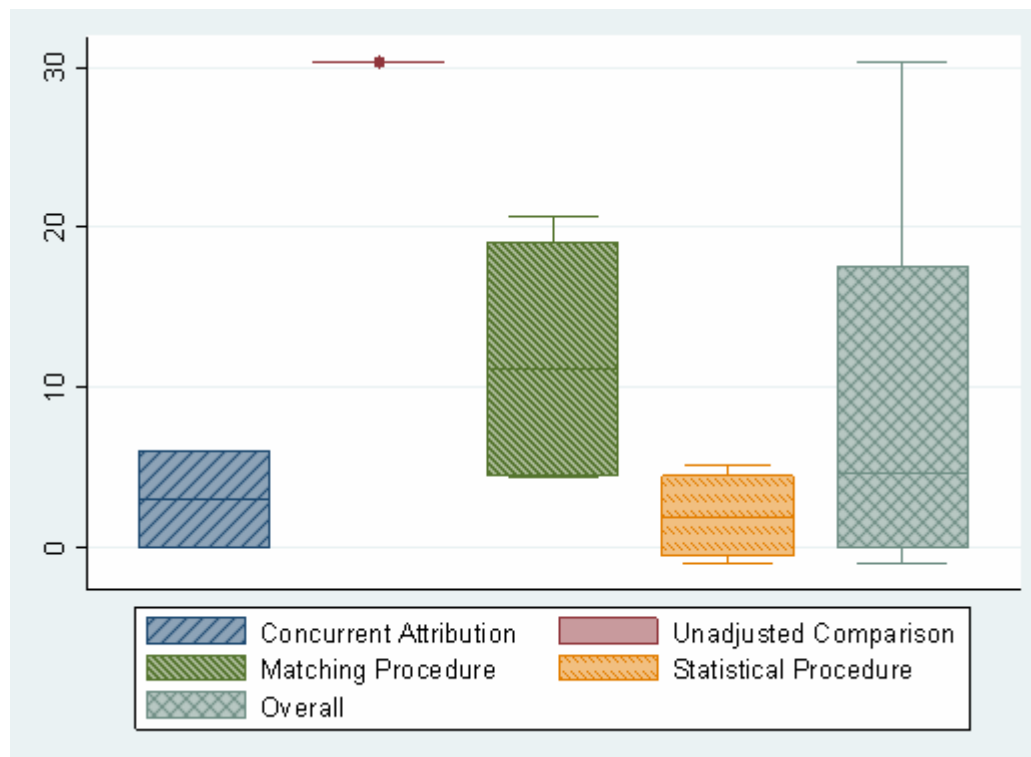


Figure 17.5 Extra days in hospital due to urinary tract infection, by study design

Other single site infections

Four estimates of excess length of stay due to infections at other single sites were reported from Brazil,^[96] Spain^[33] and the United Kingdom.^[1] Estimates of extra days due to single site infections were:

- 28.7 extra days for neonates in the intensive care unit (ICU) with conjunctivitis — from one study that did not make any adjustment for differences between those with and without infection^[33]
- 23.9 days — a matching study for patients with meningitis^[96]
- 10.6 days (skin) and 12.4 days (other infections) — from studies that used a statistical procedure.^[1]

Patients with multiple infections

Two estimates of extra length of stay among patients who acquired more than one infection during their admission were reported. Estimates of extra days due to infections were 29.1 days — from a study from the United Kingdom that used a statistical approach.^[1]

17.4 Data that describe the costs to Australia

The main causes of variation among estimates of length of stay appear to be site of infection and method used to attribute cost. The outcomes were quite stable across different regions. We therefore used these data to explore the likely costs of HAI in Australia. We used the mean value

derived from studies that employed a statistical procedure to attribute costs because we believe these estimates to be least biased.

17.4.1 Modelling costs to the hospital sector based on existing data

The total number of discharges from Australian Hospitals in 2004–05 is reported in *Australian Hospital Statistics*.^[97] These data are shown in Table 17.2.

Table 17.2 Total discharges to selected specialties from public and private hospitals in Australia, 2004–05

State	All relevant discharges	Surgical discharges
New South Wales	1,085,434	649,154
Victoria	928,719	536,683
Queensland	677,373	399,716
Western Australia	320,088	197,370
South Australia	289,329	173,968
Tasmania	45,323	22,024
Australian Capital Territory	29,623	16,271
Northern Territory	28,583	13,117
Total	3,401,552	2,006,062

Note: only those admissions to specialties considered to be at risk from health care associated infection are included. These are cardiology; ear, nose and throat; endocrinology; gastroenterology; geriatric; gynaecology; immunology and infections; interventional cardiology; neurology; non-subspecialty medicine; orthopaedics; respiratory medicine; rheumatology; surgery (breast, cardiothoracic, colorectal, head and neck, non-subspecialty upper gastrointestinal, vascular); urology.

Data published by Graves and colleagues were used to estimate an incidence rate for the following sites of infection: urinary tract, lower respiratory tract, other single sites, surgical sites and multiple sites.^[7] The authors recruited 4488 patients from a 712-bed tertiary care referral hospital and a 312-bed district hospital in southeast Queensland, Australia. Inclusion criteria were an age of 18 years or older and a minimum inpatient stay of one night. Patients were identified from a routinely generated list of all admissions. Patients with consecutive admissions were recruited from both hospitals between 13 October 2002 and 16 January 2003 by five registered research nurses who worked at the tertiary referral hospital and were seconded to collect the data from both hospitals. Table 17.3 presents the number of events and the incidence rates for the 95 days of recruitment.

Table 17.3 Number of infections reported and incidence rates for 95 days of recruitment from two Queensland hospitals, 2002–03

Number of events	At-risk population	Incidence (%)
79	4488	1.76
37	4488	0.82
49	4488	1.09
40	4488	0.89
18	1640	1.10

Source: Graves et al (2007)^[7]

Table 17.4 presents the predicted annual number of cases based on the data in Tables 17.2 and 17.3.

Table 17.4 Predicted number of annual cases of health care associated infection for Australia

State	UTI	LRTI	Other	Multi	SSI	All HAI
New South Wales	19,106	8,949	11,851	9,674	7,125	56,705
Victoria	16,348	7,657	10,140	8,277	5,890	48,312
Queensland	11,923	5,584	7,396	6,037	4,387	35,328
Western Australia	5,634	2,639	3,495	2,853	2,166	16,787
South Australia	5,093	2,385	3,159	2,579	1,909	15,125
Tasmania	798	374	495	404	242	2,312
Australian Capital Territory	521	244	323	264	179	1,532
Northern Territory	503	236	312	255	144	1450
Total	59,876	28,043	37,138	30,317	22,018	177,392

HAI = health care associated infection; LRTI = lower respiratory tract infection; multi = multiple sites of infection; SSI = surgical site infection; UTI = urinary tract infection

Numbers of bed days lost to HAI in Australian hospitals each year can be estimated by applying the mean value of the excess length of stay derived from the studies reported in Section 17.3 that used a statistical procedure to attribute costs. The results are shown in Table 17.5.

Table 17.5 Estimated bed days lost to health care associated infection, Australia

State	UTI	LRTI	Other	Multi	SSI	Total
New South Wales	38,213	106,756	136,284	281,516	66,831	629,600
Victoria	32,696	91,343	116,607	240,871	55,252	536,769
Queensland	23,847	66,622	85,049	175,682	41,151	392,351
Western Australia	11,269	31,482	40,189	83,017	20,320	186,277
South Australia	10,186	28,456	36,327	75,040	17,910	167,920
Tasmania	1,596	4,458	5,691	11,755	2,267	25,766
Australian Capital Territory	1,043	2,914	3,719	7,683	1,675	17,034
Northern Territory	1,006	2,811	3,589	7,413	1,350	16,170
Total	119,752	334,554	427,089	882,221	206,527	1,970,142

LRTI = lower respiratory tract infection; multi = multiple sites of infection; SSI = surgical site infection; UTI = urinary tract infection

17.4.2 Costs incurred after discharge due to surgical site infection

Graves and colleagues recruited 449 patients who had undergone knee or hip prosthesis insertion, cardiovascular procedures, femoropopliteal bypass graft or abdominal procedures (including abdominal hysterectomy and lower segment caesarean section) from three Australian hospitals in 2004.^[98]

These patients were followed up weekly in their homes on four occasions after discharge. Wound infections were diagnosed and the data required to estimate the additional costs due to infection were collected. A statistical procedure was used to isolate the independent effect of infection on cost outcomes. The authors found a post-discharge infection rate of 8.38%, which is consistent with the findings of a review article that reported rates of 2–14%.^[99] They also found strong statistical evidence that post-discharge surgical site infection (SSI) independently causes:

- 1.36 extra contacts with community-based services, with costs increasing by \$47.78

- 6.46 days of additional antibiotic therapy, with costs increasing by \$14.44
- total health service costs to increase by \$74 when the costs of readmission to hospital are excluded
- total health service costs to increase by \$123 when the costs of re-admission to hospital are included.

The costs reported by Graves and colleagues^[98] are lower than those reported by others (eg Plowman and colleagues^[1] and Perencevich and colleagues^[100]), which the authors attribute to their study avoiding some sources of bias that may inflate the true cost. The annual costs associated with SSI that first appears after discharge are summarised in Table 17.6. These data suggest an overall economic burden from SSI of \$21 million per year.

Table 17.6 Costs associated with post-discharge surgical site infection, Australia

State	Surgical discharges	Cases of infection	Cost outcomes (\$)
New South Wales	649,154	54,399	6,691,091.8
Victoria	536,683	44,974	5,531,805.0
Queensland	399,716	33,496	4,120,035.3
Western Australia	197,370	16,540	2,034,376.1
South Australia	173,968	14,578	1,793,154.8
Tasmania	22,024	1,846	227,009.2
Australian Capital Territory	16,271	1,363	167,709.8
Northern Territory	13,117	1,099	135,197.4
Total	2,006,062	168,108	20,677,283.9

Source: Graves and colleagues^[98]

17.4.3 Caveats

Before the cost data given are used to lobby or influence decision-makers, the following caveats must be considered:

- Data collected from just a few Australian hospitals are being used to describe the whole country; these data may not be representative.
- Attributing costs (eg in the form of length of stay) to HAI is difficult and, even though the best estimates of excess length of stay were used, they may still be biased.
- The effect of uncertainty in parameters has not been applied to these results (ie there is some natural variation around the rate and attributable length of stay).
- Not all infections can be prevented. Although HAIs appear to engender many bed days and costs, if these bed days cannot be released by infection control they are irrelevant to any decision about increasing funding for infection control.
- Bed days and other health-care resources are only worth what decision makers are prepared to pay at the margin. The rate of HAI does not affect the fixed costs of running a hospital. If, for example, more infection control were introduced and bed days were freed up, then the decision-makers' valuation of the next bed day that becomes available may diminish as more bed days become available. This empirical question has not been addressed.
- Not all types of HAI have been included in these estimates; therefore, the estimated cost of HAIs is likely to understate the size of the problem.

Despite these caveats, the data show that many bed days and health service costs are currently lost to HAI and that effective infection control programs may well offset these costs. Infection control will also deliver health benefits because morbidity and mortality risks will be reduced. More research is required on the economics of preventing HAI in the Australian and international settings.

17.5 Case studies — individual patient experiences

The costs presented in the previous section describe the health-care sector. The private costs incurred by individuals and their families, and the many non-market items such as pain and suffering associated with HAI, have not been described. The following scenarios are based on real cases from Australia. Some details of identification have been altered to preserve confidentiality.

Case 1 — Methicillin-resistant *Staphylococcus aureus* infection of surgical site following coronary artery bypass surgery

Mrs W, aged 64, had had a myocardial infarction some years previously and had recently been diagnosed with diabetes. She was admitted to hospital because her angina, which had worried her for two years, had become more severe during the previous two months. A coronary angiogram demonstrated extensive atherosclerotic disease in four coronary arteries. Mrs W had surgery to perform coronary artery bypass grafts. The operation was uneventful and she was discharged from hospital one week later. Four weeks after surgery she was readmitted with an increasing discharge from the surgical wound on her chest. She had developed fever and chest pain, and laboratory investigations revealed that her sternal wound and bloodstream were infected with methicillin-resistant *Staphylococcus aureus* (MRSA).

Mrs W had surgery to clean the wound and was then admitted to intensive care because her circulation was unstable. Three days later she was discharged from intensive care to a general ward where she was treated with intravenous (IV) antibiotics and the wound was regularly dressed. However, she had intermittent fever and the wound continued to discharge pus. Her diabetes was unstable despite treatment with insulin.

Three days after her discharge from intensive care, Mrs W had a prolonged and complicated operation performed by a plastic surgeon, who rotated muscles from her abdominal and chest walls in an attempt to heal the wound. She remained on IV antibiotics, required blood transfusions for anaemia and received careful wound management, including mechanical suction from beneath the muscle flaps. The chest wound remained infected and a new bacterium, *Escherichia coli*, was cultured from the discharge. A further antibiotic, gentamicin, was added. About three weeks after admission, Mrs W had another operation to clean the wound. Drain tubes from beneath the wound were finally removed three weeks after the first plastic surgery procedure. A peripheral IV central catheter was inserted for continued long-term IV antibiotic therapy. Some weeks later, the wound was clean and Mrs W was changed from IV to oral antibiotics.

Hospital-acquired infection certainly contributed to the patient spending almost seven additional weeks in hospital, including three days in the ICU. She had three major surgical procedures and required considerable nursing and medical expertise, including contributions from plastic surgeons, cardiothoracic surgeons, renal physicians, endocrine physicians, infectious disease physicians and cardiologists.

Case 2 — Vancomycin-resistant enterococcus infection in a haematology patient

A haematology patient in a large teaching hospital, who had transferred from a hospital in the United Kingdom two weeks previously, was the first patient in the hospital found to be infected with vancomycin-resistant enterococcus (VRE), an organism resistant to multiple antibiotics. The patient died two weeks after admission and VRE BSI was thought to have hastened his death.

The Infection Control Unit quickly developed a strategy to contain the spread of the organism and to determine whether any cross-infection had occurred among patients on the ward. Since VRE may be carried asymptotically in the bowel, all patients on the haematology ward at the time of the first isolate, all new admissions and all patients awaiting a bone marrow transplant were screened. In total, 128 haematology patients were screened over the following three months and eight were found to be colonised with VRE. All eight patients had the same type of resistant organism (vanB), suggesting that it had been transferred among them. However, the organism was different from that identified in the first patient (vanA). All of the patients colonised with the organism were subjected to additional precautions to reduce the risk of transmission to other patients. Infection control procedures included strict isolation precautions for colonised patients, including individual nursing care. Patients were isolated in a single room and staff wore protective attire such as gowns, gloves and sometimes a mask. Much time and effort was spent on the education of staff, patients and patients' families about the risks of infection and the rationale behind the measures taken to limit the spread of the organism.

On discharge of each patient from the ward, the room was comprehensively cleaned twice followed by wiping of all surfaces and patient care equipment with a disinfectant. This was followed by swabbing of environmental surfaces and microbiological culture for VRE, with the room being held vacant until results of cultures were available (usually three to four days). The hospital incurred considerable direct costs, but mortality and loss of productivity is a cost borne by society as a whole. Importantly, there was also a personal cost to patients of increased pain and suffering and additional anxiety caused by this complication of treatment. Some patients found it difficult to understand why the precautions were being taken and interpreted the precautions as an indication that they had a very serious disease.

Case 3 — Infected total knee replacement

Mr K, aged 74, had a history of type 2 diabetes, high blood pressure and glaucoma, and long-standing problems with his knee since an injury 26 years previously. Following several arthroscopies, Mr K had had a total left knee replacement about six years earlier. He had had another left knee arthroscopy to treat tissue adhesions about a year later. After a further six months, he experienced very restricted movement of his knee and walking became difficult, so he had further surgery to remove the adhesions and release the tendons. Two types of bacteria were detected in the knee, but they were thought to be contaminants from the skin or elsewhere and not indicative of infection in the joint, so no antibiotics were prescribed.

Almost two years later, Mr K had further surgery for scar tissue, which had spread from the knee into his thigh muscle. Two months later, he came back into hospital for surgical cleaning and wash-out of the knee because he had signs of infection, including the presence of pus and a painful, swollen joint. The wound was found to contain *Staphylococcus epidermidis* and was left open for four days until it was surgically closed and his knee remodelled using a skin graft from the thigh. Mr K stayed in hospital for a further three months, during which time he had five more operations. MRSA was also found in the joint and he was treated with the IV antibiotic vancomycin. Other organisms — *Proteus mirabilis*, group B streptococcus and *Pseudomonas aeruginosa* — were also identified.

Mr K was discharged from hospital one month after the last operation; however, about a year later his knee became infected with multiresistant *Enterobacter aerogenes*, *Enterobacter cloacae* and *Prevotella* species. After two months in hospital he was discharged home with a plan to provide 6–12 months of IV antibiotic therapy administered by community nurses. All of Mr K's infections were almost certainly acquired in hospital.

Case 4 — Urinary tract and bloodstream infection with methicillin-resistant *Staphylococcus aureus* following transurethral resection of the prostate contributing to mitral valve damage and death

An elderly man, Mr B, was re-admitted to hospital three weeks after a transurethral resection of the prostate. The procedure had been complicated by his prolonged need for a urinary catheter but this hospital stay was otherwise uneventful. He had a past history of rheumatoid arthritis, which was treated with drugs that suppressed his immune system. At home, he lost his appetite and developed fever and backache. On admission, he had a fever, was dehydrated and had haemorrhages beneath his fingernails and on the conjunctivae of his eyes. No heart murmur was heard but his condition suggested an infection on his heart valve.

Cultures of his blood and urine grew MRSA. An echocardiogram revealed a mass on the mitral valve of his heart and leaking of the mitral and aortic heart valves. A diagnosis of MRSA endocarditis was made. It appeared that Mr B acquired an MRSA urinary tract infection as a complication of his prostate surgery, which spread to the bloodstream, settled on a heart valve and then continued to seed into the bloodstream.

Despite antibiotic therapy with IV vancomycin, his fever persisted and he had an infection in a joint of his first toe. A second antibiotic, rifampicin, was added. However, the fever persisted and his blood cultures continued to grow MRSA. A second echocardiogram now revealed changes on his aortic valve in addition to the mitral valve. Antibiotics had not controlled the infection. Mr B then developed increasing shortness of breath and a very rapid pulse. A cardiac surgeon reviewed him as surgery was felt to offer the only hope of controlling this severe infection. After discussing his general condition with his doctors and his family, the patient chose not to pursue active medical treatment and died 14 days after his re-admission.

Case 5 — Caesarean section site infection with methicillin-resistant *Staphylococcus aureus* and probable cross-infection to that woman's child and eight other infants

Baby A, a girl, was delivered by caesarean section following a normal pregnancy. She was noted to have skin pustules and an abscess in the armpit three days after her birth. Swabs confirmed that the infection was caused by MRSA. Her mother also developed an infection of her surgical wound on the fourth day, which required surgical cleaning. The infections meant the baby and her mother spent longer than usual in hospital and required prolonged antibiotic treatment. Eight other babies suffered from MRSA infections at the same time. Four had pustules (usually on face, groin and neck), one had conjunctivitis, two had 'scalded skin syndrome' and one had an infected umbilical stump. Two other mothers developed wound infections that required visits to their general practitioners but their infections were due to a strain of non-multiresistant *S. aureus*.

All nine babies had prolonged admission to the special care nursery and children's ward while the staphylococcal infections were treated. There had been no staphylococcal infections in the unit in the three months before this outbreak and cross-infection from the first case was the most likely cause. The ward has approximately 2700 admissions per year and during this outbreak it was estimated that about 8% of the babies were infected with staphylococci. An unknown number of others may have become colonised (ie they were carrying the organism but it did not cause disease) because it was not possible to follow up all babies once they had been discharged.

Routine infection control surveillance detected the problem: the clinical staff involved were not aware of the cluster of cases. The MRSA problem was fully controlled in the ward through inservice education in infection control practices.

Case 6 — Neurosurgical site infection resulting in permanent neurological deficit

Mrs S, aged 35, had previously been well but suffered the sudden onset of a severe headache and soon became unconscious. She was brought to the emergency department and a diagnosis of subarachnoid haemorrhage (a bleeding on the surface of the brain) was made. The next day she underwent neurosurgery to clip a swollen, bleeding artery. The operation appeared to have gone well until five days later when she developed a fever. Antibiotics were given but the next day she was drowsy and complaining of a severe headache. Investigations revealed she had bacterial meningitis, probably caused by organisms introduced at the time of surgery.

Unfortunately, no bacteria were able to be cultured because antibiotics had already been given. As a result, she had to have a two-week course of two broad-spectrum IV antibiotics, vancomycin and meropenem. She recovered from the meningitis; however, on the 10th day of IV therapy she developed a clot in the external jugular vein. This was caused by the IV catheter that had changed its position. After some discussion, it was decided to treat her with an anticoagulant, warfarin, in order to prevent a pulmonary embolism. Mrs S recovered well, was discharged and was planning to return to work. Unfortunately, she suddenly deteriorated and fell into a coma. A computed tomography scan diagnosed a new and more extensive haemorrhage in her brain, probably resulting from the anticoagulant treatment. Another operation was performed to reposition the clip on the cerebral artery but this inadvertently blocked a major artery. She required a prolonged stay in an ICU and her course was complicated further by epilepsy, hydrocephalus requiring insertion of a drainage tube, and a deep vein thrombosis.

Mrs S regained consciousness but was paralysed on the right side of her body and unable to speak. She will probably require nursing care for the rest of her life.

17.6 Summary and the way forward

The cost data and case studies demonstrate the wide range of costs that arise from HAIs. The illustration in Figure 17.6 describes these costs.

A patient with an HAI will probably stay longer in hospital and will also be diagnosed and treated during this time, using up valuable health-care resources. Patients will also lose some quality of life and be at greater risk of dying from infection. Following discharge, patients are likely to use health-care resources more intensively because they suffer some residual morbidity or are worried about their infection. They may remain on antibiotics after discharge and may also incur some out-of-pocket expenses such as travel costs or child-care costs.

The indirect effects of HAI include lost production because individuals cannot undertake their normal activities — waged or otherwise — due to the effects of infection. The reputation of the doctors, nurses and hospital may be damaged and the hospital may even face a risk of litigation if the consequences of the infection are severe and a lawyer believes that negligence could be demonstrated. Finally, there is the problem of resistance to antimicrobials, which we have not considered in this chapter. The costs of resistance are complicated and difficult to predict. Although resistance is due to the misuse and overuse of first-line antimicrobials rather than to infection, it can be considered a cost arising from infection. The costs of HAI are therefore diverse and broad. While good economic appraisal should take into account all of these costs and thus represent the societal perspective, it is good practice to concentrate on estimating the items that contribute most to total costs and to ignore minor costs.

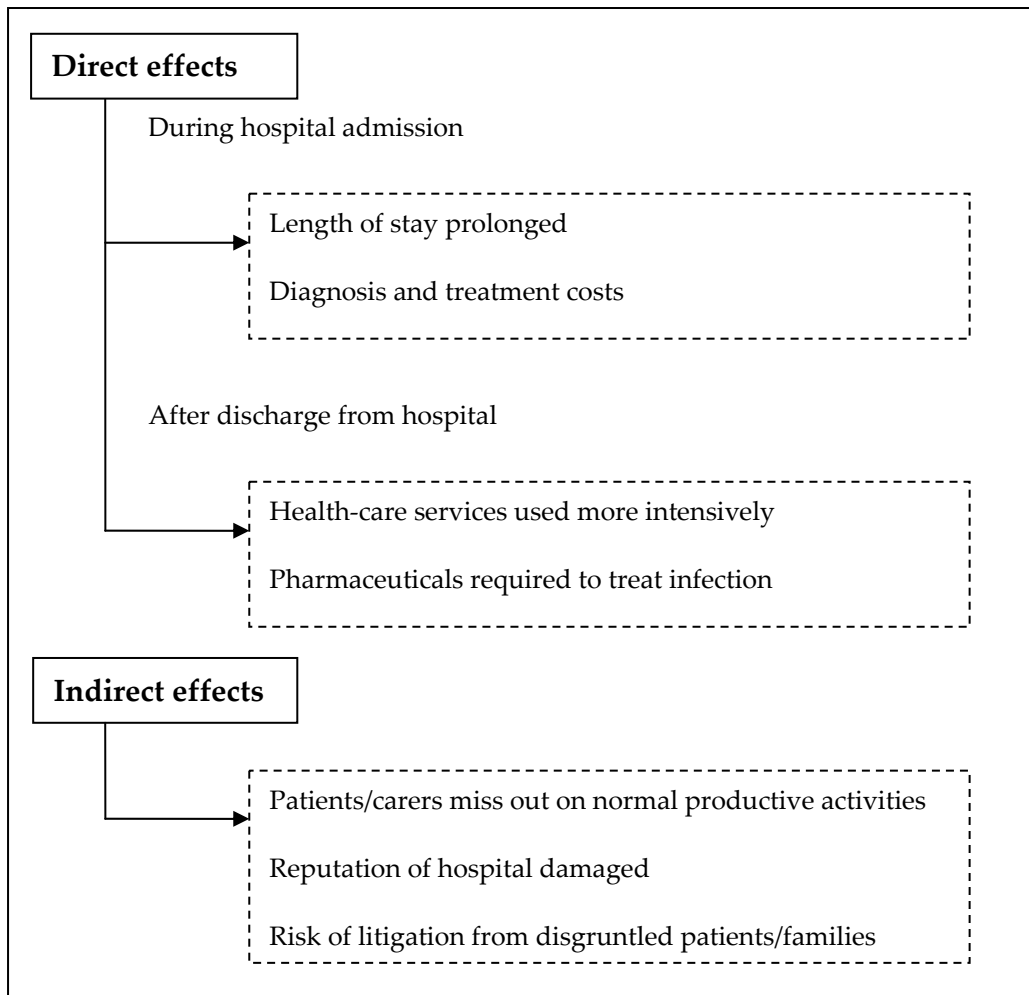


Figure 17.6 The range of costs that arise from health care associated infection

The way forward is for the research community to build high-quality models of the cost-effectiveness of programs that mitigate risk of HAI. These models must describe by how much costs change with increased investment in infection control; this will be the sum of:

- changes to costs from more infection control
- changes to costs from preventing HAIs.

The change to health benefits may also be included. Lives will be saved and quality of life improved. The ratio of ‘change to cost’ to ‘change to benefit’ will demonstrate the value for money of additional infection control. These data can be used to argue for reallocation of scarce health-care dollars toward infection control and away from less efficient allocations in the health-care system.

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Appendixes

Appendix 1: Australian health-care facilities surveillance survey

Authors: M Cruickshank, C Murphy

Key points

- Standardised and strategic approaches to surveillance of health care associated infection (HAI) is seriously lacking in most states and territories.
- Provision of professional time and expertise in infection control varies widely across facilities and affects the ability to perform surveillance.
- Most facilities have some form of surveillance of bloodstream or surgical site infection, and infection with multiresistant organisms.
- Most settings have process surveillance of health-care worker immunisation and hand-hygiene compliance.
- Specific deficiencies in current practice include lack of programs for *Clostridium difficile* and for surveillance of antibiotic use.

Recommendations

1. Work with content experts and jurisdictional representatives to develop a surveillance priority and preparedness checklist for all facilities to self-assess the status of their HAI surveillance program against a set of agreed national criteria.
2. Investigate the feasibility of developing a web-based HAI surveillance training course and mentoring system that recruits expert infection control professionals and uses those individuals to help novice professionals to develop their own local HAI surveillance strategies and related surveillance methodology.
3. Consider developing a national model of idealised HAI surveillance that includes two arms, the first including indicators suitable for private and public facilities of less than 60 beds and the second including a more diverse set of complex indicators suitable for facilities with 60 or more beds.
4. Develop a simple suite of spreadsheet-based applications that will facilitate standardised HAI collection, data entry and analysis. Analysis should include a range of simple and complex statistical functions that can be performed on either standalone or networked personal computers.

A1.1 Methods

A1.1.1 Questionnaire

Staff of the Australian Commission on Safety and Quality in Health care (ACSQHC) developed a questionnaire that was delivered via an online survey from 11 to 19 December 2007. The survey completion date was subsequently extended to 25 January 2008. The survey gathered data on demographics, staffing levels, surveillance activities, outcomes, processes, technology, information systems and barriers. The survey was not pilot tested. Respondents were advised that the survey should take less than 10 minutes to complete and that none of the questions were compulsory. The full survey questionnaire is available online.⁵⁸

⁵⁸ <http://www.safetyandquality.gov.au/internet/safety/publishing.nsf/Content/PriorityProgram-03>

A1.1.2 Sample

The study population was Australian health care facilities. The ACSQHC invited infection control professionals (ICPs) responsible for the coordination of infection control and prevention programs to complete the survey. The invitation was extended through all relevant state and territory health departments and professional bodies. Only one person per facility was required to complete the survey. Responses were collected electronically in comma-separated value compatible database format. Individual responses were coded by submission date and time. Responders were invited to provide identifying details but this was not compulsory.

A1.2 Analysis

Data were reviewed by origin and New Zealand data were excluded from the overall analysis. Individual responses to each question were reviewed. Incongruous, spurious or comma-separated value incompatible responses were deleted or reclassified as 'other', according to their frequency and their consistency with other responses.

Basic demographic data (questions 1–4) were analysed by frequency. Data from all remaining questions were stratified by state or territory of deployment. Due to the small size of the respective sample sizes, it was not possible to apply statistical tests to further examine the data.

Where possible, detailed text provided under the 'other' option was collapsed into meaningful subcategories according to key words occurring in individual text responses.

A1.3 Results

A1.3.1 The infection control practitioner

A total of 278 respondents completed the online survey. Figure A1 summarises the location of respondents.

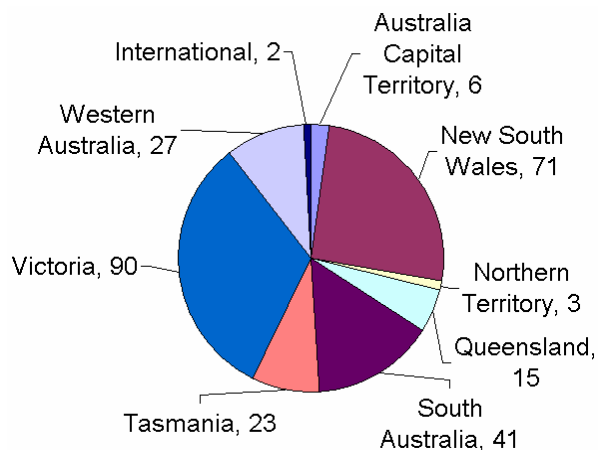


Figure A1 Location of survey respondents

Respondents answered the employment designation question as follows:

- registered nurse — infection control (22%)
- clinical nurse specialist — infection control (10%)
- clinical nurse consultant — infection control (27%)
- nurse manager — infection control (11%).

Two respondents were employed as infection control enrolled nurses. Thirty percent of respondents undertook surveillance data collection in addition to other duties (director of nursing, after-hours bed-flow managers, quality managers).

A1.3.2 Employment sector and status

Some ICPs (44%) worked full-time in the public sector. Of all respondents, 80% worked in public facilities. The proportions of respondents working full-time or part-time were equal. Almost all of the ICPs (98%) worked in either public or private facilities.

A1.3.3 Main health care associated infection surveillance facility

ICPs mainly performing health care associated infection (HAI) surveillance in rural hospitals accounted overall for 41% (92/224) of all responses, with ICPs surveyed in teaching hospitals making up 21% (48/224) of the total. Of the remaining, 34% of respondents mainly performed HAI surveillance in facilities with less than 60 beds and 34% were in facilities of between 100 and 399 beds. Of the group working in facilities with less than 60 beds, 86% (66/77) surveyed were in rural hospitals. Table A1.1 provides specific detail by bed size and facility type.

Table A1.1 Number of facilities by bed size and type where respondents mainly perform health care associated surveillance

	Community health service	Private acute-care general hospital	Residential aged care	Rural hospital	Suburban or regional hospital	Teaching hospital	Total
Under 60 beds	0	4	4	66	3	0	77
60–99 beds	0	7	7	14	6	1	35
100–199 beds	1	11	4	11	13	5	45
200–399 beds	0	9	1	0	3	19	32
400–599 beds	0	4	0	0	0	17	21
>600 beds	1	1	1	0	2	6	11
Area health service	2	0	0	1	0	0	3
Total	4	36	17	92	27	48	224

A1.3.4 Infection control staffing levels

A total of 40% (107/272) of facilities had less than half a full-time equivalent (FTE) of infection control staff. This included 7% (20/272) of the respondents who reported having no FTE infection control staff. Less than 10% (24/272) of facilities had three or more FTE infection control staff. Of the facilities with fewer than 60 beds, 93% (95/102) had less than one FTE infection control staff. Of the facilities with more than 600 beds, 75% (9/12) had more than 1.5 FTE infection control staff. Table A1.2 details FTE infection control staff by bed size.

Table A1.2 Number of full-time equivalent intensive care staff by facility size

FTE infection control staff	Under 60 beds	60–99 beds	100–199 beds	200–399 beds	400–599 beds	>600 beds	Area health service	Day procedure service	Total
0	17	1	0	0	0	0	2	0	20
0.1–0.49	60	17	7	2	0	0	1	0	87
0.5–0.9	18	12	25	3	0	1	0	0	59
1–1.4	6	8	14	12	3	2	0	1	46
1.5–1.9	0	0	2	11	2	1	0	0	16
2–2.9	0	1	3	8	6	2	0	0	20
3–3.9	1	0	0	1	8	3	0	0	13
4–5	0	0	0	2	2	2	0	0	6
>5	0	0	0	1	2	1	0	1	5
Total	102	39	51	40	23	12	3	2	272

FTE = full-time equivalent

A1.3.5 Other facilities

Of all respondents, 28% (62/223) reported performing surveillance in a facility in addition to their main facility. ICPs whose main facility was a rural hospital reported the highest scores — 40% (25/62) — for performing surveillance in an additional facility, with this being undertaken in ‘other’ facilities by 76% (19/25) of respondents, in hospitals with less than 60 beds by 31% (5/16) of respondents, and in a nursing home and hostel by one respondent each.

A1.3.6 Surgical site infection surveillance

The proportion of respondents undertaking either continuous or intermittent period surveillance for surgical site infection (SSI) up to 30 days postoperatively, by specific surgical procedures, was 49% (161/276). The most commonly surveyed procedures were joint replacement (100), lower segment caesarean sections (97) and cardiac surgery (30).

Most (146) respondents reviewed microbiological results to detect in-hospital infections. The other methods used were ward nurses reporting to infection control (141), direct wound observation performed by an ICP (43), direct observation of all wounds for procedure during admission by a surgical service nurse (35) and antibiotic audit (28).

Almost half of the respondents (131) gave ‘not applicable’ responses to the methods used for post-discharge evaluation of patients who are under surveillance for certain procedures. Of those responses detailing methods, the most common used was review of readmissions to the same facility (112), followed by letter to patient (28), review of admissions to all facilities within the area (26), and letter to surgeon (14) or general practitioner (14).

Many (179) respondents indicated that evaluation and detection of surgical wound surveillance in joint replacement procedures, up to one year postoperatively, were either not applicable to their setting or not performed. Of those performing such surveillance, most (68) used analysis of readmission data from the same facility to detect cases. Letters to the patient, their general practitioner or surgeon were used infrequently.

A1.3.7 Bloodstream infection surveillance

A total of 52% (146/276) of the survey respondents reported that they assessed and reported all health care associated bloodstream infections (BSIs). Table A1.3 details the other BSI surveillance components by state or territory. In applicable settings, 88% of respondents evaluated and reported all health care associated BSIs. Surveillance of health care associated *Staphylococcus aureus* BSI was conducted by 43% in applicable settings.

Table A1.3 Bloodstream infection surveillance components by state and territory

Component	ACT	NSW	NT	QLD	SA	TAS	VIC	WA	Total
Not applicable		18		2	8	11	15		54
Applicable, but no BSI surveillance performed or reported	1	3			8	3	4	1	20
All HAI BSI assessed and reported	5	34	2	13	22	7	47	16	146
Haemodialysis access associated BSI	1	8	2	1	3	2	13	5	35
ICU central line associated BSI	2	19	1	5	1	3	21	3	55
Other central line associated BSI	2	16	1	5	3	3	8	3	41
Other primary LCBSI (as per NHSN/NNIS)	1	2	1	1	1	1	7	1	15
<i>S. aureus</i> BSI — HAI	2	21	2	7	6	2	15	17	72
<i>S. aureus</i> BSI — Community	1	10	2	5	3	2	6	2	31

BSI = bloodstream infections; HAI = health care associated infections; ICU = intensive care unit; LCBSI = laboratory-confirmed bloodstream infection; NHSN/NNIS = National Healthcare Safety Network (formerly the National Nosocomial Infections Surveillance System (NNIS)); *S. aureus* = *Staphylococcus aureus*

A1.3.8 Intensive care unit and paediatric surveillance

Respondents in each state and territory reported surveillance for central line associated BSIs in adult and paediatric intensive care units (ICU). Surveillance of ICU cases of ventilator-associated pneumonia and catheter-associated urinary tract infections was reported by fewer than 10 respondents in every state and territory except the Australian Capital Territory and Western Australia, where no respondents reported surveillance for those conditions in ICUs.

Fewer than 10 responses were received from each state and territory in relation to neonatal ICU surveillance components. No state or territory respondents performed surveillance for every indicator and none of the indicators were uniformly surveyed across the country's neonatal ICUs.

Of the 100 respondents working in facilities with paediatric patients, 35% performed HAI rotavirus surveillance and 33% performed HAI respiratory syncytial virus surveillance. Surveillance for HAI cases of both diseases occurred in each state and territory, although in each location there were fewer than 10 respondents.

A1.3.9 Multiresistant organism and *Clostridium difficile* surveillance

Thirty-seven respondents reported no surveillance activity for multiresistant organisms. Respondents from each state reported surveillance for multiresistant organisms with each of the listed components. The most-used components were morbidity related to bloodstream or sterile site infections, which was used by 103 respondents, and non-ICU multiresistant gram-negative acquisition, which was used by 110 respondents. Table A1.4 provides multiresistant organisms surveillance components detailed by state and territory responses.

Table A1.4 Multiresistant organism surveillance components by state and territory

MRO components	ACT	NSW	NT	QLD	SA	TAS	VIC	WA	Total
No surveillance performed	1	10		1	5	11	8	1	37
Morbidity — bloodstream/sterile site infections	4	22	3	8	17	2	36	11	103
Morbidity — other non-sterile site infections	2	20	3	7	18	2	14	8	74
Acquisition (newly detected colonisation/infection >48 hours after ICU admission, patient not previously known to have the MRO) — ICU MRSA	3	25	3	10	11	6	22	11	91
Acquisition — ICU MRGN	1	21	1	8	8	2	9	10	60
Acquisition — ICU VRE	1	21	1	8	6	3	22	9	71
Acquisition — non-ICU MRGN	1	38	3	11	19	3	19	16	110

ICU = intensive care unit; MRGN = multiresistant gram negative bacteria; MRO = multiresistant organism; MRSA = methicillin-resistant *Staphylococcus aureus*; VRE = vancomycin-resistant enterococcus

Of all respondents, 42% (115/276) reported performing no *Clostridium difficile* surveillance. Most (87) of these respondents indicated that *C. difficile* surveillance was ‘not applicable’ (reasons for this response were not assessed). Of those respondents who reported performance of *C. difficile* surveillance, the most often used component was surveillance in the event of an identified outbreak (128). The next most often used component was routine assessment of *C. difficile* patients and determination of HAI status (87).

A1.3.10 Statistical techniques and tools

Many respondents answered ‘not applicable’ for use of statistical techniques for SSI, central line associated bacteraemia (CLAB) and multiresistant organism surveillance –87, 96 and 63 respondents, respectively. For each of the three indicators, statistical comparisons against state or national benchmarks were performed by more respondents than any of the other statistical

options. Control charting was the least often used technique for SSI and CLAB surveillance and risk adjustment the least often used technique for multiresistant organism surveillance. Control charting was the second least used technique for multiresistant organism surveillance.

Tables A1.5, A1.6 and A1.7 detail the frequency with which respondents in each state used specific statistical techniques for SSI, CLAB and multiresistant organism surveillance.

Table A1.5 Statistical technique use frequency for surgical site infection surveillance by state and territory

Statistical technique	ACT	NSW	NT	QLD	SA	TAS	VIC	WA	Total
Run charts (counts)	3	13		1	16	2	6	5	46
Rate charts	3	12	2	7	7	4	19	12	66
Control charts — CUSUM		4		3		4		8	19
Control charts — other		2		1	1	3	2	3	12
Risk adjustment (eg NHSN/NNIS risk index for surgical site infection)		4		3	1		28	9	45
Confidence intervals around rates		7		2	2		24	5	40
Statistical comparisons against other facilities within your area	1	16		3	8		22	6	56
Statistical comparisons against state or national benchmarks	3	25	1	9	8	6	45	15	112

CUSUM = cumulative sum; NHSN/NNIS = National Healthcare Safety Network (formerly the National Nosocomial Infections Surveillance System)

Table A1.6 Statistical technique use frequency for central line associated bacteraemia surveillance by state and territory

Statistical technique	ACT	NSW	NT	QLD	SA	TAS	VIC	WA	Total
Run charts (counts)	2	12		1	14	2	12	6	49
Rate charts	3	12	2	6	11	6	15	9	64
Control charts	3			3	1	2	2	5	16
Risk adjustment (eg NNIS risk index for surgical site infection)		1		1			19	3	24
Confidence intervals around rates		4		1	1		21	2	29
Statistical comparisons against other facilities within your area	2	14		3	8		25	6	58
Statistical comparisons against state or national benchmarks	1	26	1	6	9	4	40	12	99

NHSN/NNIS = National Healthcare Safety Network (formerly the National Nosocomial Infections Surveillance System)

Table A1.7 Statistical technique use frequency for multiresistant organism surveillance by state and territory

Statistical technique	ACT	NSW	NT	QLD	SA	TAS	VIC	WA	Total
Not applicable		12		3	11	15	19	3	63
Run charts (counts)	3	25	1	1	18	2	19	6	75
Rate charts	3	12	1	8	11	3	24	10	72
Control charts		3		3	1	1	5	3	16
Risk adjustment (eg NHSN/NNIS risk index for surgical site infection)		2		1	1		10	1	15
Confidence intervals around rates		7		2	1		7	2	19
Statistical comparisons against other facilities within your area	1	21		1	7		18	7	55
Statistical comparisons against state or national benchmarks	2	34	1	5	12	3	36	15	108

NHSN/NNIS = National Healthcare Safety Network (formerly the National Nosocomial Infections Surveillance System)

A1.4 Health care associated infection surveillance reporting

In every state and territory, HAI infection outcome surveillance reports were generally provided to facility management. Of the 276 overall survey respondents, the following proportions from each state and territory reported HAI outcomes to their state health department or other state group:

- Australian Capital Territory, 17% (1/6)
- New South Wales, 44% (31/71)
- Northern Territory, 67% (2/3)
- Queensland, 20% (3/15)
- South Australia, 22% (9/41)
- Tasmania, 22% (5/23)
- Victoria, 53% (48/90)
- Western Australia, 67% (18/27).

Reporting to a national group was undertaken by less than 1% (16/276) of all survey respondents. Only three respondents publicly reported HAI outcomes related to their facility or facilities.

A1.5 Health care associated infection process surveillance

A1.5.1 Hand-hygiene audits

Overall, health-care worker (HCW) hand-hygiene compliance audits were most often performed every 3–6 months. A total of 59 respondents reported that no compliance audits had been performed in 2007. A further 49 respondents reported annual audits and 15 reported monthly audits.

Almost 70% (191/276) of respondents reported auditing of hand-hygiene compliance; this was either in every clinical area, with 40% (104/276), or in selected clinical areas, with 29% (87/276). Of the respondents auditing in selected clinical areas, 99% (86/87) rotated the clinical area.

A1.5.2 Antibiotic usage

Over half of the survey respondents did not track internal antibiotic usage, contribute to a national antibiotic usage data collection or restrict access to certain broad-spectrum agents. Less than a third (77/276) restricted access to certain broad-spectrum agents and just over 10% (36/276) tracked intensive care antibiotic usage.

A1.5.3 Aged-care surveillance

Aged-care surveillance applied to 49% (135/276) of the survey respondents. Of the 135, 13% did not do any aged-care surveillance despite it being applicable. The most commonly performed types of aged-care surveillance were urinary tract infections, respiratory infections and gastrointestinal infections, which were performed by 99, 93 and 88 respondents, respectively. Other infections were surveyed by 78 respondents.

A1.5.4 Health-care worker immunisation and other audits

Of all respondents, 88% (244/276) measured annual influenza immunisation compliance and 73% (203/276) measured hepatitis B protection compliance. Measles, mumps and rubella immunity was measured by 47% (131/276) of respondents and varicella immunity was measured by 43% (118/276).

Nearly 80% of respondents reported performing ‘other’ infection control related audits at least once a year. The subject matter and scope of these varied widely; easily categorised and frequent responses included sharps and waste audits (43), cleaning (15), intravenous therapy (10) and compliance with Australian Standard 4187: Sterilisation or central sterilising services (9).

A1.6 Technology and software

Of all respondents, 87% (241/276) used a desktop computer to assist with surveillance. Handheld and tablet computers were used infrequently.

Excel was the software program most used (56%; 155/276) for surveillance. Department of Health software and Infection Control Assessment Technology (eICAT) were used by 44 and 40 respondents, respectively. Every state other than Queensland used Department of Health software and eICAT was used in all states and territories other than the Northern Territory and South Australia. EpiInfo was the least used piece of software, used only in four states.

A1.7 Time per week on surveillance

Of all respondents, 62% (144/234) spent eight or less hours a week on surveillance-related activity and 47% (110/234) reported spending 4–8 hours a week on surveillance data collection, analysis and reporting. A further 17% (40/234) spent between 9 and 16 hours a week on these activities.

There was little difference in time spent on surveillance activities between private and public facilities. The following proportions spent 8 hours or less on surveillance-related activities:

- 41% of full-time staff and 83% of part-time staff in private facilities
- 43% of full-time staff and 77% of part-time staff in public facilities.

In both private and public facilities, 25% of full-time staff spent more than 25 hours per week on surveillance-related activities. Table A1.8 provides extensive detail on the weekly surveillance hours.

Table A1.8 Weekly hours spent on surveillance by sector and employment

Number of hours/ week	Private <i>n</i> = 42				Public <i>n</i> = 192				Total	
	Full-time	%	Part-time	%	Full-time	%	Part-time	%		%
<4	1	8	3	10	9	9	21	23	34	15
4–8	4	33	22	73	33	34	51	54	110	47
9–16	2	17	3	10	21	22	14	15	40	17
17–24	2	17	2	7	10	10	3	3	17	7
25–32	3	25	0	0	9	9	3	3	15	6
33–40	0	0	0	0	10	10	1	1	11	5
41–56	0	0	0	0	1	1	1	1	2	1
57–72	0	0	0	0	1	1	0	0	1	0
>73	0	0	0	0	4	4	0	0	4	2
Total	12	100	30	100	98	100	94	100	234	100

A1.8 Barriers in surveillance work

Most (214) of the respondents cited barriers to their surveillance work. The single most frequently reported barrier was time constraints at 41% (87/214). Similar numbers of respondents identified information technology or computer issues (35), case finding (31) and lack of institutional priority (31) as barriers. Other issues were methodological difficulty, inexperience and small facility size.

A1.9 Discussion and gap analysis

This survey is an important piece of work that validates and builds on previous surveys and reports of the demographics and surveillance practices of Australian ICPs.^[1, 2, 3, 4, 5, 6, 7] Most important is the relationship between this recent survey and the earlier 2001 draft Commonwealth document.^[8] This relationship will be explored further in the individual issues discussed.

Despite its usefulness as a tool to measure and describe the surveillance activities and methods of Australian ICPs, this survey and its results had some serious, and previously identified, limitations:

- Public facilities, small (less than 60 beds) rural hospitals and Victorian respondents were all over-represented in the sample.
- The survey did not include questions regarding length of time working in infection control or formal qualifications in the field, both of which may influence the surveillance priorities and methods of an ICP.
- Respondents were able to provide multiple answers to many questions; this complicated the analysis and excluded assessment of the extent to which a response represents an extreme such as the ‘most’ or ‘least’ appropriate response.

- Many respondents provided lengthy and complicated text responses to several questions. Collapsing these responses into meaningful subcategories was difficult and may have inadvertently excluded an important but infrequent response.

The survey confirmed previous findings of irregular infection control staffing designations, levels and composition as well as substantial variation in surveillance activity even between similarly sized or located organisations. Some immediate concerns are the absence of any designated infection control staff in 7% of facilities and the designation of infection control duties to enrolled nurses in two facilities and to a patient care assistant in one other facility. Variation in titles used by staff performing the infection control role probably reflects differences in nursing award terminologies between different states and territories.

Surgical site surveillance patterns were consistent with international trends of targeting high-volume surgical procedures and potentially serious infections relating to prosthetic devices or delayed healing (such as joint replacement and cardiac surgery). The main method used for postoperative surgical site surveillance — identification of readmission — is consistent with recognised global norms.

The substantial level of hospital-wide health care associated BSI surveillance activity probably reflects the historic Australian Council on Healthcare Standards BSI indicator requirements. Alternatively, it may be easier to find and apply a definition to a case of BSI than it is with other, less often surveyed conditions, such as ventilator-associated pneumonia.

Australian and international reports of increasing cases of health care associated multiresistant organisms may be influencing ICP surveillance activity because surveillance of multiresistant organisms was frequently reported. Of note was the substantial specific type of multiresistant organism surveillance undertaken, including differentiation between non-ICU and ICU multiresistant organism acquisition, and BSI and other site multiresistant organism morbidities. These specific indicators are recognised as being very useful for targeting specific interventions to reduce multiresistant organisms.

As with previous surveys, this survey confirmed the diverse analytical approaches used by ICPs to analyse and interpret specific HAI data. This variety is both heartening and alarming. On one side it reflects a growing adoption by ICPs of more complex and contemporary production-like measurement methods, such as process and control charts. On the other side, this variety limits the nationalisation of surveillance and the aggregation of data for purposes of developing comparable results.

The reporting practices loosely reflect the recommendations of the dominant surveillance bodies in each state, as well as an increasing trend by local health departments to know HAI outcomes. Few facilities report data nationally, which is understandable given the absence to date of any substantial, sustainable and credible national data aggregation system or body.

It is notable that few Australian facilities report data publicly given that there are substantial and increasing trends in other countries with mature infection control programs, notably the United States and the United Kingdom, to publicly report aggregate and individual facility-level HAI data. Considering the probable lack of validity, reliability and generalisability of current Australian HAI data, it is perhaps fortunate that these data are not often released in the public domain.

Hand-hygiene audits were common among respondents, although their timing and specific targets varied. These results indicate that a standardised national initiative such as the ACSQHC's planned hand-hygiene campaign will potentially add value to current practice.

The absence of antibiotic usage monitoring and active antibiotic stewardship by more than half of the respondents is concerning given their obvious substantial efforts in multiresistant organism surveillance.

HCW immunity monitoring for several of the diseases to which HCWs may routinely be exposed is substantial and highlights the likely overlap between traditional infection control and staff or occupational health functions.

Although most respondents used a computer to assist their surveillance activity, software use was not uniform. This finding may be further illustrated by additional responses that identified computer systems and information technology as impediments to surveillance. This finding has been well described in previous Australian studies of a similar nature, which have also included recommendations for the introduction of practical, easy-to-use, affordable software that ICPs can readily use for HAI surveillance and analysis.^[9, 8]

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Appendix 2: Computer software products to support surveillance programs

The software descriptions in this appendix have been provided by the vendors. The accuracy of the statements and assessments has not been assessed and potential users are encouraged to investigate the various products carefully before deciding whether to implement them. It was beyond the brief of this document to make a comprehensive review of all available products. For information about software products in current use, see Appendix 1, Section A1.6 (Australian health-care facilities surveillance survey).

A2.1. General systems for infection prevention and control services

A2.1.1 Infection Control Management Suite (formerly eICAT)

Company/Organisation

AnalyzeIT in association with Centre for Healthcare Related Infection Surveillance and Prevention, Queensland Health

Website

<http://www.analyzeit.com.au/index.html>

Contact

Jason.Murphy@analyzeit.com.au

System description

The Infection Control Management Suite is a collection of infection control applications that provide and promote a quality control framework that supports all aspects of infection control.

The Infection Control Management Suite includes the electronic Infection Control Assessment Technology (eICAT) application originally developed by Queensland Health. eICAT was developed with national input from infection control practitioners, infectious diseases physicians, microbiologists, epidemiologists, statisticians and information technology units by infection control practitioners for the collection, organisation and structured reporting of health-care related infection surveillance data. eICAT is a standalone application with desktop PC client, database (Microsoft SQL Server) and palm-based portable digital assistant (PDA) client.

The eICAT application has been expanded to improve the functionality and value proposition of the base eICAT application by providing various integration tools to minimise data entry from patient administration systems, theatre management systems, pathology systems and human resource management systems. The Infection Control Management Suite is available as an upgrade for eICAT licensees, as a full product or as individually licensed components.

The Infection Control Management Suite (including the updated eICAT) provides support for the following infection control functions:

- surgical site surveillance
- bloodstream infection surveillance
- significant organism surveillance

- device-related nosocomial infection surveillance
- respiratory syncytial virus surveillance
- rotavirus surveillance
- staff health screening and vaccination management
- staff occupational exposure management.

In terms of general application functionality, the Infection Control Management Suite (including eICAT) provides the following functions:

- data normalisation using clinical denominators (eg patient days, line days)
- automated or manual data collection
- internal quality assurance of data collection
- structured reporting with statistical analysis of trends and comparisons
- ad hoc report writer
- statistical analysis including:
 - cross-tabulations using Microsoft Excel pivot tables
 - statistical tests and confidence intervals for rates and proportions
 - for larger institutions, EWMA (exponentially weighted moving average) and CUSUM (cumulative sum) control charts.
 - bedside data collection on PDAs.

An ongoing enhancement schedule to the Infection Control Management Suite is expected that will release new components regularly. This system is used extensively throughout Australia by both public and private hospitals and provides a total quality management system to collect and report information for the surveillance of health-care related infections at facility and multi-facility levels.

A2.1.2 SHIIne (Safer Hospitals Integrated Information Network)

Company/Organisation

Victorian Hospital-Acquired Infection Surveillance (VICNISS)

Website

<http://www.health.vic.gov.au/ideas/infcon/publications/vicniss>

Contact

VICNISS Coordinating Centre, philip.russo@mh.org.au

System description

SHIIne (Safer Hospitals Integrated Information Network) is a new software application designed specifically for VICNISS-related surveillance. SHIIne is an integrated multi-user information system designed to monitor, track and report on infections and infection control practices within the hospital environment. One of its aims is to bring together relevant data from existing databases within a hospital into one system. It provides an information base for daily activities, quality control, research and benchmarking. This makes data collection more efficient by removing manual data input. The system schedules and automates routine and time consuming

tasks through real-time linkage with existing systems to minimise manual data collection and enhance the speed of reporting. SHIINE can then be used as a tool for specific surveillance activities and reporting and also provide for aggregation of the data at the VICNISS Coordinating Centre.

A2.1.3 Infection Monitor Pro (IMPro)

Company/Organisation

rL Solutions

Website

<http://www.rl-solutions.com/infection-control/infection-monitorpro.html>

Contact

sales@rl-solutions.com

System description

Infection Monitor Pro (IMPro) is for infection control practitioners looking to spend less time on administrative tasks and more time preventing and controlling infections. This powerful and flexible software application is designed specifically to help hospitals better detect, manage, prevent and control infection risks.

Developed and refined in collaboration with a team of infection control experts over a three-year period, IMPro is designed around hospital-based infection control surveillance practices and uses a simple four-step workflow process:

Detect. Infections and risks are identified through automated surveillance of existing hospital systems like ADT (admission, discharge and transfer) and microbiology. This surveillance is constantly running so that infection control practitioners are immediately alerted as soon as laboratory results are available and as soon as patients are admitted.

Prioritise. Patients and specimens are sorted by infection control practitioners to prioritise their daily workload. Urgent cases are quickly identified.

Manage. Infection control information is managed easily through the use of run sheets, recording of observations/discussions and online forms to capture infection classification as well as patient classification information.

Report. Flexible reporting options present the latest infection control information in an easy-to-understand format. Ad hoc and scheduled reports are available to infection control practitioners.

System features include:

- comprehensive infection histories for patients that are easily searchable
- ability to add audited notes and comments
- flexible reporting on all classification data
- automated reports that can be scheduled and emailed
- charts that allow for drill-down to granular details
- always the latest surveillance data available.

These features helped IMPro win the Australian National eHealth ‘IT Secrets’ award in 2004.

rL Solutions is a company that is dedicated to the health-care industry. With over 500 successful clients in five countries, we are committed and truly passionate about improving the quality of health care and improving patient safety through the application of advanced technology.

A2.2 Software for antibiotic usage and resistance surveillance

A2.2.1 National Antimicrobial Utilisation Surveillance Program

Company/Organisation

South Australian Department of Health

Website

No website (though reports available online, as indicated in following text)

Contact

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South Australia Department of Health
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System description

Individual participating hospitals provide monthly downloads of pharmacy data concerning aggregate antibiotic issues (drug type and quantity) to intensive care and non-intensive care locations. Hospital occupancy data are also supplied for use as denominators. The National Antimicrobial Utilisation Surveillance Program’s software cleans these data and calculates total number of defined daily doses (DDD) against each of the World Health Organization’s antibiotic subclasses. Plots of DDDs/1000 patient days for individual antibiotic subclasses are created and portrayed in comparison to the aggregate mean for all submitting hospitals (see example in Figure A2.1). Reports are returned monthly (in an editable format) to contributing hospitals. National reports are also produced.⁵⁹

No actual software is provided to the hospitals. Software redesign is in progress to accommodate a wide range of hospitals and to enable benchmarking within an area health service’s hospital group.

⁵⁹ <http://tinyurl.com/4n4o9o>

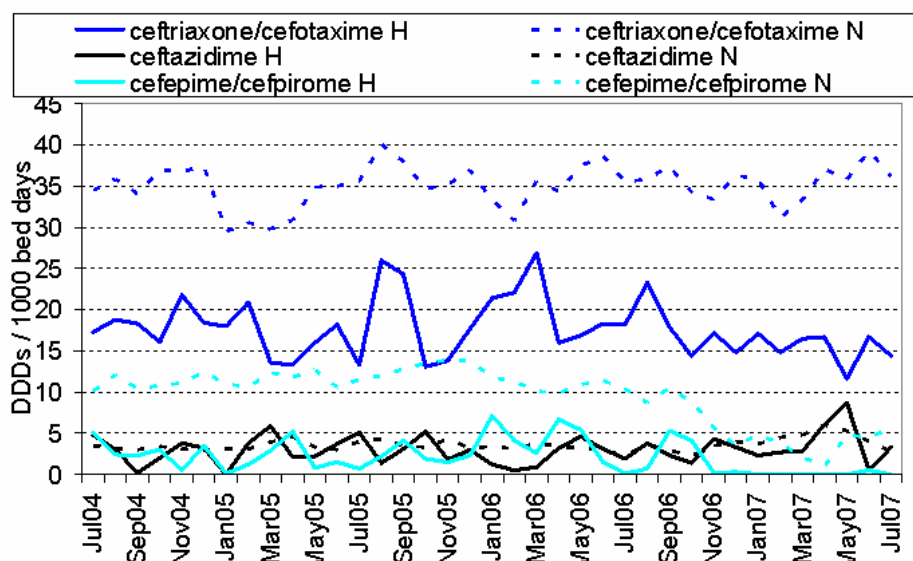


Chart 15: 3rd/4th generation cephalosporins (ceftriaxone and cefotaxime grouped together)

Figure A2.1 Example antibiotic usage report plot from the National Antimicrobial Utilisation Surveillance Program

DDDs = defined daily doses

The dotted lines represent the average usage across all contributing sites. The solid lines refer to the reporting hospital. One can appreciate that this hospital's usage is far below the aggregate mean for these types of antibiotic.

A2.2.2 Queensland Centre for Healthcare Related Infection Surveillance and Prevention antibiotic usage and antibiogram software

Company/Organisation

Centre for Healthcare Related Infection Surveillance and Prevention (CHRISP), Queensland Health

Website

<http://www.health.qld.gov.au/chrisp/default.asp>

Contact

Dolly_Olesen@health.qld.gov.au

System description

Antimicrobial usage data for all Queensland Health facilities will be collected by CHRISP, commencing in 2007, based on data extracted from the state-wide pharmacy database (a STOCCAtm-based system). Monthly state-wide reports will be available on the Queensland Health intranet and detailed reports from the database will be available to Queensland Health infectious diseases physicians, microbiologists, pharmacists and infection control practitioners, which will provide them with the evidence to better support their local antimicrobial stewardship programs. The main emphasis of the reporting is longitudinal analysis of data within a facility or district. Alongside this is an enhancement of the existing antibiogram system which provides

efficient access to state-wide and local antibiograms and antibiotic resistance data for clinicians. CHRISP intends to correlate antimicrobial usage with antibiograms in an effort to identify and quantify the effects of antimicrobial prescribing habits on antibiotic resistance. This correlation is made possible as CHRISP has mapped the WHO anatomical therapeutic chemical groupings to both the antibiogram and antibiotic usage data.

The software applications have been developed as market-ready (ie not Queensland Health specific) offerings as they both have flexible integration mechanisms. At present, Queensland Health is using a combination of flat-file import and business objects data integrator functionality to populate the database from their pharmacy and pathology systems. The applications store the data within a Microsoft SQL database, which is then presented to clinicians as a flexible reporting solution.

Appendix 3: Definitions of surgical site infections

This appendix lists the definitions of surgical site infection (SSI) from the United States National Healthcare Safety Network (NHSN) (formerly the National Nosocomial Infections Surveillance System (NNIS)).

Superficial incisional infection

A superficial incisional SSI must meet the following criteria:

- infection occurs within 30 days after the operative procedure; and
- involves only skin and subcutaneous tissue of the incision; and
- patient has at least **one** of the following:
 - purulent drainage from the superficial incision
 - organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision
 - at least one of the following signs or symptoms of infection: pain or tenderness, localised swelling, redness or heat, and the superficial incision is deliberately opened by the surgeon, and is culture-positive or not cultured (a culture-negative finding does not meet this criterion)
 - diagnosis of superficial incisional SSI by the surgeon or attending physician.

Deep incisional infection

A deep incisional SSI must meet the following criteria:

- infection occurs **within 30 days** after the operative procedure if no implant is left in place or **within 365 days** if implant is in place and the infection appears to be related to the operative procedure; and
- involves deep soft tissues (eg fascial and muscle layers) of the incision; and
- patient has at least **one** of the following:
 - purulent drainage from the deep incision but not from the organ/space component of the surgical site
 - a deep incision spontaneously dehisces or is deliberately opened by a surgeon and is culture-positive or not cultured when the patient has at least one of the following signs or symptoms: fever (>38°C) or localised pain or tenderness (a culture-negative finding does not meet this criterion)
 - an abscess or other evidence of infection involving the deep incision is found on direct examination, during re-operation, or by histopathologic or radiologic examination
 - diagnosis of a deep incisional SSI by a surgeon or attending physician.

Organ/space infection

An organ/space SSI involves any part of the body, excluding the skin incision, fascia, or muscle layers, that is opened or manipulated during the operative procedure. Specific sites are assigned

to organ/space SSI to further identify the location of the infection. Listed below are the specific sites that must be used to differentiate organ/space SSI. An example is appendectomy with subsequent subdiaphragmatic abscess, which would be reported as an organ/space SSI at the intraabdominal specific site.

An organ/space SSI must meet the following criteria:

- infection occurs **within 30 days** after the operative procedure if no implant is left in place or within **365 days** if implant is in place and the infection appears to be related to the operative procedure; and
- infection involves any part of the body, excluding the skin incision, fascia, or muscle layers, that is opened or manipulated during the operative procedure; and
- patient has at least **one** of the following:
 - purulent drainage from a drain that is placed through a stab wound into the organ/space
 - organisms isolated from an aseptically obtained culture of fluid or tissue in the organ/space
 - an abscess or other evidence of infection involving the organ/space that is found on direct examination, during re-operation, or by histopathologic or radiologic examination
 - diagnosis of an organ/space SSI by a surgeon or attending physician.

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Glossary

Antibiogram	The result of laboratory testing on an isolated pathogen to find out what treatments it is resistant to. Antibiograms can be collated to form cumulative antibiograms, which can help to form prescribing guidelines at a regional or national level.
Antibiotic	A substance that kills or inhibits the growth of bacteria, fungi or parasites.
Antimicrobial	A chemical substance that inhibits or destroys bacteria, viruses, fungi, yeasts or moulds. (See also: <i>antibiotic</i> , which is a class of antimicrobials)
Attributable mortality	The increased mortality that is greater than occurs in the control group.
Bacteraemia	A bacterial infection of the blood or the lymph system.
Bloodstream infection	The presence of live pathogens in the blood, causing an infection. (See also: <i>pathogen, infection</i>)
Bundle	A bundle is a set of evidence-based practices that have been shown to improve outcomes when performed collectively and consistently. The concept was developed by the Institute for Healthcare Improvement in the United States to improve the care process and patient outcomes.
Catheter	A thin, flexible, hollow tube used to add or remove fluids from the body.
Colonisation	A process in which an organism (such as a bacterium) grows inside someone without causing illness.
Community-acquired infection	Infections related to health care but acquired in the community rather than in hospital. A person might be treated at the hospital as an outpatient and later develop an infection at home; for example, during home intravenous therapy. (See also: <i>outpatient</i>)
Comorbidity	The presence of more than one disease or other health condition in a person at one time. (See also: <i>morbidity</i>)
Control	A standard against which other conditions can be compared in a scientific experiment. For example, if an experiment tested the effects of a new antibiotic, the results might be compared against a control group of people given standard antibiotics.
Day patient	See <i>outpatient</i> .
Diagnosis related groups	A system for classifying hospital cases into one of about 500 groups that are expected to have similar use of hospital resources. The same name is also used to refer to groups within this system.
Epidemic	A widespread outbreak of an infectious disease. Many people are infected at the same time.
Epidemiology	The study of factors that have an impact on disease in the human community. Often used in the control of health problems.
Health care associated infection	Infections acquired as a direct or indirect result of health care.
Immunocompromised	Having an immune system that has been impaired by disease or treatment.
Infection	The invasion and reproduction of pathogenic (disease-causing) organisms

	inside the body. This can cause tissue injury and progress to disease.
Infection control or infection control measures	Infection control aims to prevent the spread of pathogens between people in a health-care setting. Examples of infection control measures include hand washing, protective clothing, isolation procedures and audits of compliance with hygiene measures.
Inpatient	A patient who visits a health-care facility for diagnosis or treatment and stays in the hospital for at least one night.
Inpatient associated health care associated infection	Infection occurring more than 48 hours after hospital admission or within 48 hours of discharge.
Intravenous	Within or into a vein (eg an intravenous <i>catheter</i> would be a catheter that is inserted into a vein).
Morbidity	The state of being ill, diseased or injured. ('Morbidity rate' describes the occurrence of a disease or condition that causes morbidity.)
Mortality	Death, or the frequency or number of deaths. For example: infections are a major cause of mortality worldwide, and the mortality rate of this type of infection is 30%.
Multiresistant organism	An infectious agent that has evolved resistance to several treatments commonly used against it. Multiresistant organisms are dangerous because they are difficult to treat. An example is methicillin-resistant <i>Staphylococcus aureus</i> (MRSA), a strain of infectious bacteria that can survive treatment with the antibiotics used to treat normal <i>Staphylococcus aureus</i> infections.
Negative predictive value	The proportion of patients reported as not having an infection that actually do not have the infection.
Nosocomial infection	An infection acquired in hospital.
Occupied bed days (OBDs)	Total number of bed days of all admitted patients accommodated during the reporting period, taken from a count of the number of <i>inpatients</i> at about midnight each day. Details for patients being admitted and leaving on the same day are also recorded as OBDs, counting OBD for each same day patient. In the United States, OBDs are referred to as 'patient days'.
Onset	The time of appearance of the first symptoms of a condition (eg a 'community onset' infection is one in which the person first felt ill while not in a hospital).
Outbreak	A classification used in epidemiology to describe a small, localised group of people infected with a disease.
Outpatient	A patient who visits a health-care facility for diagnosis or treatment without spending the night. Sometimes called a day patient, day-stay patient or day-only patient.
Pandemic	An epidemic that is geographically widespread, occurring throughout a region or even throughout the world. (See also: <i>epidemic</i>)
Passive surveillance	A process in which data are collated on the susceptibilities and resistances of disease-causing microbes to various antimicrobial treatments. Passive surveillance uses information generated by the routine susceptibility testing of clinical isolates. (See also: <i>targeted surveillance</i>)
Pathogen	A disease-causing agent. The term is often used to refer to infectious microorganisms, such as bacteria, viruses or fungi.

Positive predictive value	The proportion of patients reported as having an infection that actually have the infection.
Prophylactic	Medications or treatments that are preventive in the treatment of disease. For example, antibiotics are sometimes given prophylactically before surgery to prevent infection.
Quality of life	An individual's overall sense of wellbeing. This is usually measured using various standardized questionnaires to rate such factors as pain, treatment side-effects, mood, energy level, family and social interactions, sexual function, ability to work, and ability to keep up with routine daily activities.
Reporting	The reporting or recording of disease occurrence. These reports are used to help authorities monitor the patterns of occurrence of the disease. Reporting may be voluntary or mandatory.
Risk factor	An activity or factor that may increase the chance of developing a disease. For example, smoking is a risk factor for lung cancer.
Separation	A separation is a completed episode of care, equivalent to a discharge or admission of a patient to hospital, including day care.
Sepsis	A serious medical condition caused by the body's immune response to a blood infection.
Strain	A strain is a genetic variant or subtype of a microorganism (eg a virus, bacterium or fungus). Some strains may be more dangerous or difficult to treat than others.
Surgical site infection	An infection at the site of a surgical operation that is caused by the operation.
Surveillance	Disease surveillance is an epidemiological practice by which the spread of disease is monitored in order to establish patterns of progression. The main role of disease surveillance is to predict, observe and minimise the harm caused by outbreak, epidemic and pandemic situations, as well as increase our knowledge as to what factors might contribute to such circumstances.
Targeted surveillance	A process in which data are collated on the susceptibilities and resistances of disease-causing microbes to various antimicrobial treatments. Targeted surveillance gathers data that is not generated by routine testing: specific species or groups of species are examined in detail to answer important questions that cannot be addressed by passive surveillance. (See also: <i>passive surveillance</i>)
Virulence	The degree of ability of an organism to cause disease. A more virulent strain of a pathogen will cause more harm to people who become infected.

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