AUSTRALIAN COMMISSION ON SAFETY AND QUALITY IN HEALTH CARE

4 Information technology to support antimicrobial stewardship

Antimicrobial Stewardship in Australian Health Care

2018

Please note that revised antimicrobial stewardship actions are included in the Preventing and Controlling Infections Standard, which was released in May 2021. This version of the Standard supersedes the 2017 Preventing and Controlling Healthcare-Associated Infection Standard. The AMS Book will be updated to incorporate reference to the 2021 Standard.

Chapter contents

Acronyms and abbreviations

Acronym	Abbreviation
AMR	antimicrobial resistance
AMS	antimicrobial stewardship
AURA	Antimicrobial Use and Resistance in Australia
eCDSS	electronic clinical decision support system
EMM	electronic medication management
HL7	Health Level 7
ID	infectious diseases
IT	information technology

Key points

- Although primary care has had digital prescribing for some time, the digital transformation of Australian hospitals is now occurring rapidly. Digital prescribing allows sophisticated prescribing, digital decision support and digital transparency, where potentially all pathology results and prescriptions are available for review and curation in real time.
- Information technology (IT) systems can support the development and delivery of antimicrobial stewardship (AMS) programs in areas such as decision support and review, data management and reporting, and telehealth.
- Electronic clinical decision support systems (eCDSSs), in particular, can be useful tools in AMS programs. A range of eCDSS options are available, including mobile applications, approval systems, surveillance programs, and electronic medication prescription and management. eCDSSs complement the clinical, pharmacy and technical members of the AMS team, but are not able to replace their expertise.
- eCDSSs and other IT systems can be important data sources to identify patients who require post-prescription review, and to provide institutional data for audit and reporting. Data systems should be able to interface across the health service organisation and the Local Hospital Network or Local Health District, and enable input into national data surveillance programs.
- The future of AMS in an integrated digital healthcare system may involve redefining the role and remit of the antimicrobial steward.
- Telehealth can support improved access to clinical services, specialist advice, diagnostic information and education, over distance, as part of formalised service networks. Telehealth may include the use of the telephone, video, voice over internet applications (such as Skype), digital images, electronic diagnostic test results and remote monitoring links.

4.1 Introduction

Antimicrobial prescribing and antimicrobial stewardship (AMS) involve a range of complex tasks that can be supported and improved by using information technology (IT).

At the AMS program level, the AMS team requires relevant and timely information and data to review patients and optimise their care, as well as to support AMS initiatives and quality improvement. IT systems can be used to support AMS programs by enabling a range of strategies, including (see also Chapter 3: 'Strategies and tools for antimicrobial stewardship'):

- Restrictive strategies – for example, formularies, restricted indications and antimicrobial approval systems
- Persuasive strategies – for example, clinical guidelines, pathways and post-prescription review.

At the patient level, antimicrobial prescribing requires a complex sequence of decisions, often based on information from different sources. Clinicians need to consider the diagnostic criteria, the likely pathogens, the clinical significance of microbiology isolates and susceptibility data, and then select the appropriate antimicrobial at the optimal dose and duration. Potential drug interactions, contraindications and adverse reactions must also be considered. IT systems, such as electronic clinical decision support systems (eCDSSs), can enable this process by bringing together patient-specific data (for example, pathology, medicines) and knowledge bases that support the judicious use of antimicrobials (for example, rule-based alerts and approved indications for use).

IT systems can also be used in AMS programs to facilitate data collection and reporting on quantity and quality of antimicrobial use.

Figure 4.1 shows the IT systems associated with AMS and how they link with data sources from existing legacy IT systems.

This chapter considers the role of IT in supporting AMS activities, including eCDSSs, data collection and reporting, and telehealth.

Issues that are especially relevant for certain settings – rural and remote hospitals, private hospitals and aged care – are tagged as R, P and AC, respectively, throughout the text.

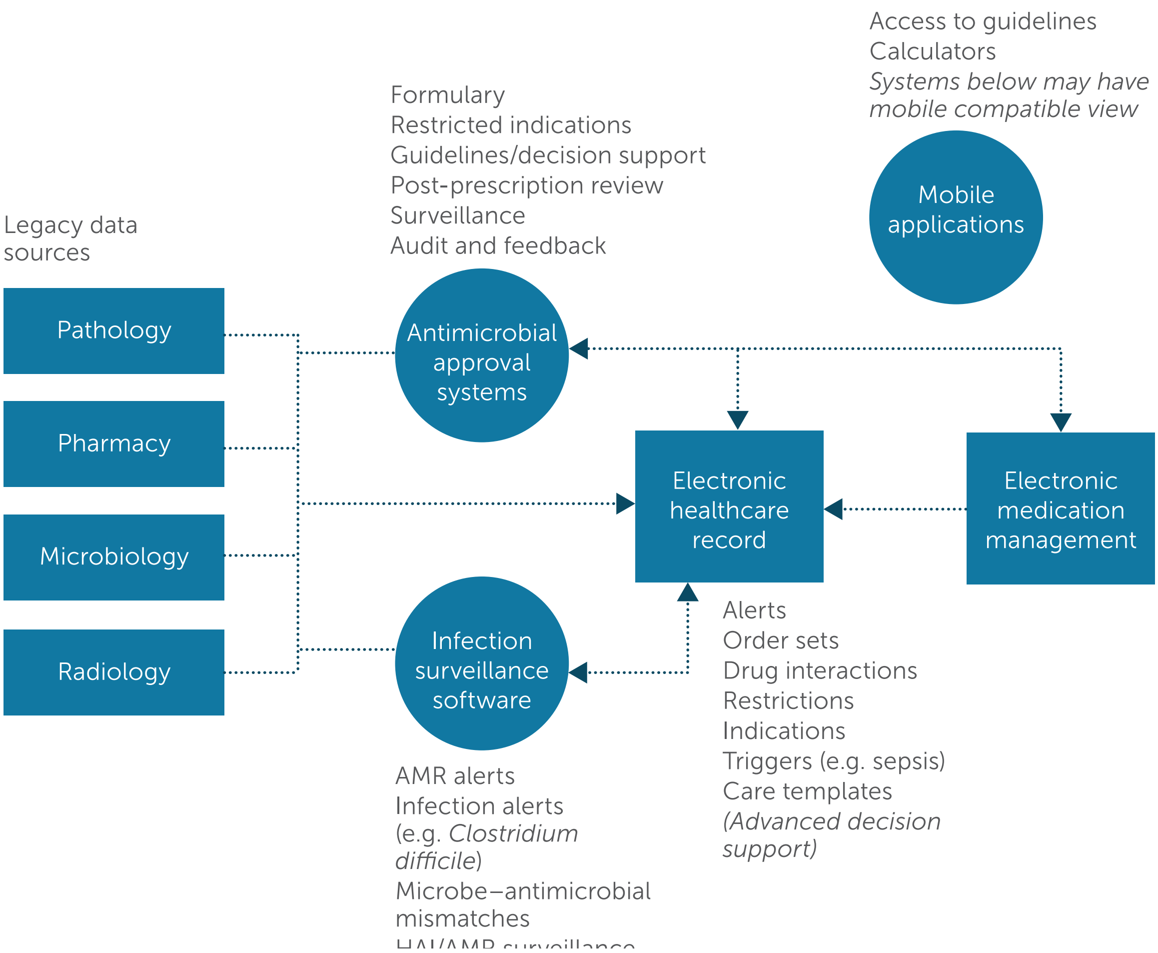
R P AC

4.2 Electronic clinical decision support systems

eCDSSs provide access to information that is stored electronically to enable prescribers to make decisions about health care. eCDSSs can organise and present appropriate information to the user in a way that supports them to make clinical decisions with increased accuracy and reduced error.

eCDSSs can assist clinicians to make more accurate and timely diagnosis, and aid in the decision to prescribe antimicrobials for a patient. Key infectious diseases (ID) bodies support the use of eCDSSs as potentially useful tools in AMS programs, especially for providing access to data that can support quality improvement initiatives.[1] eCDSSs can improve the quality and reduce the costs of antimicrobial prescribing. Many studies report cost avoidance or cost minimisation as a result of implementing an eCDSS, although rigorous cost-effectiveness or

Figure 4.1: Information technology systems and antimicrobial stewardship



AMR = antimicrobial resistance; HAI = healthcare-associated infection cost–benefit analyses are lacking. Reported savings include reduction in antimicrobial expenditure per patient or for the institution, reduction in the proportion of total medicine expenditure, reduction in length of stay, reduction in hospitalisation costs, and reduction in resistant organisms.[2-5]

eCDSSs do not need to be complex to be effective; they may include online access to documents such as formulary restrictions, local antimicrobial prescribing guidelines and *Therapeutic Guidelines: Antibiotic*[6] through the internet or an intranet. Providing an engaging and accurate presentation of information to prescribers or the AMS team (for example, using dashboards[7]) can influence prescribing, even in the absence of complex decision support. More complex systems can integrate eCDSSs within other applications (such as pharmacy dispensing systems or medication management systems) and advanced decision support (see Advanced decision support systems).

Because many systems are available, it is important for health service organisations to plan and implement an appropriate system that responds to current and future local requirements. The assessment of those requirements should involve the local multidisciplinary AMS team, and others with clinical, planning and IT expertise, and ensure that there is an effective interface with other corporate systems in the hospital, and in the Local Hospital Network or Local Health District. No single system is likely to meet all requirements, and a combination system may be required. Some systems have been developed by individual institutions, and are therefore adapted to the environment and culture of the institution. This means that these systems are not always readily transferable to other organisations. Systems may require substantial customisation to integrate with existing infrastructure and align with the organisation's workflow. The comparative cost, risk and benefit of bespoke and commercial systems need to be assessed, along with ongoing maintenance and support for these systems.

eCDSSs that effectively support the AMS clinical team incorporate alerts, prompts and restrictions, and allow integration with pharmacy and microbiology laboratory systems. Several of these elements may be asynchronous – that is, they do not provide decision support at the time of prescribing, but use knowledge-based expert systems to issue clinical alerts to the AMS team after the antimicrobial is ordered.

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eCDSSs for AMS can also be useful in private and rural and remote hospitals, especially where AMS expertise is provided remotely. As well as supporting the local workforce by streamlining the workflow for AMS interventions, they provide a valuable clinical resource and support the involvement of off-site experts, such as ID physicians. For example, an online approval system may be more effective and feasible to implement than a telephone approval system.

Although eCDSSs are a valuable support for AMS, expert advice is needed to improve the quality of decision-making, and support safe and appropriate prescribing. eCDSSs are not effective in isolation. The health service organisation needs to ensure that AMS is appropriately directed through the advice of ID physicians and other experts. To ensure that eCDSSs remain relevant to clinical practice and are sustainable, they need to continue to receive ongoing support from expert advisors.

The most common uses of IT systems to provide decision support for AMS include:

- Passive decision support through electronic access to guidelines and mobile applications
- Electronic antimicrobial approval systems
- Electronic infection prevention surveillance systems
- Electronic prescribing (e-prescribing) and electronic medication management (EMM)
- Advanced decision support.

The following sections discuss each of these systems, and Table 4.1 shows the opportunities, potential advantages and issues in the application of different types of eCDSS.

4.2.1 Passive decision support systems and smartphone apps

Passive decision support includes electronic access to guidelines and mobile applications. This can occur at many entry points in hospital systems, such as within pathology reports.

Clinical systems are increasingly becoming mobile device compatible to support ready access to data, and passive decision support for prescribing can be made available at the point of care using smartphone apps. Clinicians are likely to have ready access to a mobile phone, in contrast to pocket guides, desktop computers and reference handbooks. Information available on a smartphone might be accessed more often at the patient bedside than other forms of information. It will also be easy to update remotely without needing to issue new physical copies.[8]

Table 4.1: Antimicrobial stewardship information technology systems with electronic clinical decision support system functionality

IT option	Intervention opportunities	Benefits	Considerations during implementation
Smartphone applications	• Dissemination of disease- or medication-based guidelines • Dosing calculators • Antibiograms	• Allow rapid dissemination • Useful for hospitals with poor IT infrastructure	• May not be able to be integrated with hospital systems • Need to ensure a system for version control and a process for timely uptake of revisions • May not influence prescribing of senior clinicians
Approval systems (standalone or integrated with e-prescribing systems)	• Enforcing a formulary • May be pre-prescription or post-prescription • Enforcing approved indications by medicine • Educational opportunity for the prescriber • Can include clinical decision support • Reports and feedback	• Can work well in the absence of electronic health records or e-prescribing • Support an organisational approach to AMS • Should trigger post-prescription review • Best combined with an antimicrobial team to review patients 24–48 hours after approval	• Consider appropriate human resources to perform post-prescription review
Computerised physician order entry (e-prescribing)	• Alerts • Drug–drug interactions • Dosing • Restriction prompts • Automated stop orders (e.g. surgical prophylaxis) • Order sets (community-acquired pneumonia, sepsis)	• Will reduce transcription errors, but not incorrect choice or indication (unless combined with decision support) • Best combined with decision support	• Require more resources to develop customised AMS reports
Infection prevention surveillance systems, including data-mining tools	• Pharmacy ± laboratory integration • Microbe–antimicrobial mismatches • Double coverage • Restricted medicine use • Surveillance and real-time alerts for poor practice	• Support an organisational approach • Can be integrated with an electronic healthcare record	• Require substantial resources to review reports and determine clinically relevant alerts that need action • Require dedicated pharmacist time • Commercial systems can be expensive

IT option	Intervention opportunities	Benefits	Considerations during implementation
Electronic healthcare records, including those that include a medication record	• Error alerts, such as allergy, dosing, drug–drug interactions • Chart abstraction tools to screen and identify patients at risk for sepsis, or collate information for AMS (medicines, results) • Pre-prescription restriction rules • Record AMS recommendations and interventions • Support order sets for syndromes (e.g. community-acquired pneumonia) • Alerts and triggers identify patients suitable for intravenous-to-oral switching, or AMS review • Care protocols (templates or phased order sets)	• Eliminate the cost of external vendor • Allow real-time interventions and alerts • Allow retrieval of data for research	• Require substantial institutional investment up front • Require considerable hospital IT time to create the tools • Templates must be incorporated into electronic healthcare records at each site • Local adaptation still required for each build • Less responsive to change
Advanced electronic clinical decision support systems	• Interventions based on the development of a causal probabilistic network of pathogens, by specimen type or underlying condition of patient • Case-based probability • Pathogen prediction	• Sophisticated decision support based on predictive capabilities and machine-learning algorithms • Highly patient specific	• Complex, usually bespoke, systems • Currently in early phase of adoption • Ability to be translated to other sites is unclear

AMS = antimicrobial stewardsip; IT = information technology

A range of smartphone apps have been developed for use in health care, including for AMS[9] (see Resources) and ID.[10] Some studies suggest that the medical workforce may prefer these to traditional intranet guidelines.[11] In the United States, UpToDate was identified as the most commonly used resource for learning about antimicrobial prescribing in a survey of medical students[12]; this app is also used in Australia. Another common use of mobile technology is to provide access to guidelines available through mobile-enabled web pages.

However, the knowledge bases for third-party mobile apps may not support local practices, guidelines, formularies, restrictions or antibiograms (although some apps, such as MicroGuide, support local customisation). Another consideration is that the user must initiate updates on their own device, which may lead to the potential for multiple versions to be in use in the same health service organisation.

The impact of mobile apps on prescribing appropriateness is uncertain, because prescribing decisions are often made by senior doctors, who might not use the apps while on ward rounds.[13] Another consideration is that limited wi-fi access may affect the types of smartphone apps that can be used in hospitals. However, this situation is likely to evolve quickly. Unintended consequences of the use of smartphones for antimicrobial use or infections have not been studied. One example of the use of a smartphone app is in Case study 4.1.

Case study 4.1: A smartphone application for delivering antimicrobial policy

A free smartphone application – the Imperial Antibiotic Prescribing Policy (IAPP) app – was developed and made available across five teaching hospitals associated with the Imperial College Healthcare NHS Trust. The app was developed using an iterative clinician-led approach supported by mixed methods research. It included guidelines based on medicines or infections, calculators, intravenous-to-oral switching recommendations, allergy guidelines and therapeutic medication monitoring. A pre-implementation questionnaire found that more than 75% of doctors and pharmacists used their own mobile device at work, and 50% used commercial applications. There was 100% uptake by junior doctors at 12 months.

However, several issues were encountered. Poor wi-fi in the hospitals meant that the app was developed as 'native' software to allow use offline. This meant that the app was not automatically updated and much of the workforce did not update the app until 12 months later, which led to different versions being in use. A post-intervention structured questionnaire was designed and disseminated at one month and at 12 months after the launch of the app. There was a 20% response rate by doctors, 70% of whom reported that the IAPP improved their knowledge and 81% of whom reported that it improved their compliance with the policy. However, 20% of doctors reported that they did not feel comfortable using the app in front of patients.[13]

4.2.2 Electronic approval systems

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Authorisation or approval systems for antimicrobials are an essential strategy for AMS (see Section 3.3 in Chapter 3: 'Strategies and tools for antimicrobial stewardship'), and are very effective in reducing consumption of targeted antimicrobials and reducing medication costs.[14] They act as a restrictive strategy for prescribing and support the post-prescription review process.

Electronic approval systems support the formulary system and streamline the approvals process for general prescribers and pharmacists. The systems can direct attention towards antimicrobial prescriptions that should be reviewed by the AMS team. Importantly, electronic approvals support antimicrobial use auditing, which enables feedback to individual prescribers, units and committees. Successful implementation of electronic approval systems requires close collaboration with the pharmacy, the clinical microbiology and ID workforce, and individual hospital units. This includes customising the system content to support the local formulary and indications for use, as determined by the AMS committee or drug and therapeutics committee.

Electronic antimicrobial approval systems have had high uptake in some Australian states. These locally developed, third-party systems (see Electronic prescribing and medication management systems and Case study 4.2) have usually been implemented in sites without electronic healthcare records or e-prescribing systems and have streamlined the workflow for AMS programs.[15,16] For example, one web-based approval system has been adopted at more than 60 sites, including public, private and regional hospitals. The program supports a bundle of AMS interventions, including formulary support, restricted indications for target antimicrobials, access to national guidelines, administration alerts by pharmacists if medicines are given without approval, targeted post-prescription review, feedback and reporting. The system has been associated with:

- Improved appropriateness of antimicrobial use[17]
- Improved resistance patterns in some gram-negative isolates in intensive care units[4]
- Reduction in hospital-acquired *Clostridium difficile* infections[17]
- No observed increase in length of stay or mortality in serious infections[17]
- Acceptable usability for clinicians.[18]

Case study 4.2: Electronic antimicrobial approval systems in Victoria

Eight networks in Victoria implemented a third-party electronic antimicrobial approval system from 2009 to 2011. All but two hospitals introduced an antimicrobial stewardship team at different times (ranging from immediately to three years) after the system was implemented.

Implementation of the electronic system was associated with a significant reversal in the consumption of antipseudomonal penicillins, azithromycin, ceftriaxone and vancomycin, and a trend towards reduced consumption of broad-spectrum antibiotics (4.53% reduction per year; P = 0.027). Data from the 2014 National Antimicrobial Prescribing Survey also showed a mean appropriateness of use of all antimicrobials in the study group of 82.2% (n = 1,518) compared with the national average in Peer Group A hospitals of 74.4% (n = 10,955).

Source: Australian Commission on Safety and Quality in Health Care[19]

Pre-prescription approval processes are being introduced in most EMM systems as a key component of AMS. In some cases, these processes will interface with a third-party electronic antimicrobial approval system or be a part of the EMM system. However, electronic systems (including computerised physician order entry) do not prevent inappropriate antimicrobial prescribing. Just as for traditional prescribing, prescribers can select an erroneous indication that will provide access to the antimicrobial agent of their choice.

4.2.3 Electronic surveillance and infection prevention systems

Antimicrobial prescribing can be optimised with effective communication between pharmacy and laboratory systems. These systems can:

- Direct antimicrobial choice based on microbiology results
- Identify opportunities for de-escalation
- Improve antimicrobial dosing and monitoring (based on pathology results)
- Shorten clinician response time
- Contribute to broader quality improvement issues (such as surveillance of antimicrobial resistance and simultaneous microbiology).[20]

Both locally developed and commercial infection prevention systems are available to integrate the electronic patient record with the pharmacy system, and with microbiology, pathology and sometimes radiology results. These systems help to identify patients at high risk of nosocomial infection or with suboptimal antimicrobial therapy. They also assist with monitoring antimicrobial resistance (AMR) and with routine surveillance activities, including reporting and generating antibiograms. In Australia, these systems have not yet been fully integrated because there are still interoperability barriers with legacy pathology and pharmacy systems, or because there are other priorities for local funding or support.

In Australia, surveillance programs such as the National Antimicrobial Prescribing Survey and the National Antimicrobial Utilisation Surveillance Program, which are part of the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System, may be used in future eCDSSs.

Electronic surveillance and infection prevention systems can help to guide appropriate antimicrobial prescribing (see Box 4.1). However, such systems, like antimicrobial approval systems, require processes and a clinical workforce to monitor and act on the alerts, and generate reports and feedback. Systems that are able to mine large amounts of data and provide real-time alerts for infection prevention or patients requiring review do not necessarily save time.[21] A number of studies have shown that the increased information flow needs to be supported by increased resources for interpretation and triaging of information.[22] The human resources required to achieve this may be a barrier to success (Box 4.1). The licensing costs of these systems are also a consideration for organisations already dealing with other e-health strategies. However, as these systems are purpose designed to support infection prevention activities, they are likely to continue to have an important role in AMS.

Box 4.1: Use of surveillance systems to generate alerts for prospective review

A study in Texas found that the addition of a data-mining tool to an antimicrobial stewardship program decreased inappropriate antimicrobial use, provided a greater reduction in overall antimicrobial use and provided increased cost savings without negatively affecting patient outcomes.

Rules and alerts were built into the data-mining tool to aid in identifying inappropriate antimicrobial use. During 2012, 2,003 antimicrobial interventions were made in response to alerts such as restricted antimicrobials, duration of therapy or intravenous-to-oral switching, with a 90% acceptance rate. Targeted broad-spectrum antimicrobial use decreased by 15% in 2012 compared with 2010, which represented a cost saving of US$1,621,730. No adverse patient outcomes were noted.[23]

In Nebraska, a third-party electronic clinical decision support system was evaluated in a 624-bed medical centre. The system triggered prospective alerts for the following rules: eligibility for influenza or pneumococcal vaccine; polyantimicrobials; microbe–antimicrobial mismatches; redundant anaerobic coverage; vancomycin use; and positive blood cultures for coagulase-negative staphylococci or methicillin-sensitive *Staphylococcus aureus*, or no positive cultures in the previous seven days.[22]

A total of 8,571 alerts were generated in 791 patients over five months, and 284 interventions were made. Coupled with review and feedback, the system resulted in an increase in interventions and recommendation acceptance.

However, only 30% of alerts were actionable. The system required 2–3 hours per day for review and 1–2 hours per day for intervention and documentation. This was associated with alert fatigue.[22]

4.2.4 Electronic prescribing and medication management systems

E-prescribing systems are computer applications that allow clinicians to generate paper or electronic medication prescriptions. E-prescribing is often delivered as part of an electronic health record. EMM systems are information systems that manage each phase of the medication management process, including:

- Computerised entry of physician orders (e-prescribing)
- Medication review
- Medication reconciliation
- Dispensing
- Recording medication administration
- Decision support (optional).

These systems can support more appropriate prescribing and more efficient medication management.

The use of systems for e-prescribing and EMM has substantially increased around the world in recent years, after government-sponsored initiatives to modernise healthcare technology infrastructure in Europe, the United States and Australia. In the United States, more than 70% of prescriptions are now written electronically[24], and the United States Government has offered financial incentives for deploying these systems. In 2014, approximately 35% of English hospitals had begun implementation of eCDSS functionality within their EMM systems in at least one ward or hospital department; in the United States, this figure was more than 60%.[25]

In Australia, the uptake and implementation of e-prescribing and EMM systems in public hospitals have been slower. Each state and territory now has an implementation program for EMM in place and is progressively rolling out systems. All prescribing in Northern Territory hospitals is electronic, and New South Wales, Queensland, South Australia, Tasmania and Victoria already have e-prescribing in place. Several private hospitals have also implemented EMM.

Cost-effectiveness studies have demonstrated that e-prescribing systems – particularly those with decision support – are likely to lead to long-term savings due to reductions in adverse drug events, readmissions and healthcare costs.[26-30]

EMM and e-prescribing can be harnessed to support AMS. Almost all commercial e-prescribing systems are associated with front-end decision support that can be used in AMS, such as default values, routes of administration, doses and frequencies; they may also include allergy alerts and drug–drug interaction alerts. These systems can support a bundled approach to AMS, including antimicrobial restriction, dosing recommendations, rule-based alerts and order sets for disease conditions. One study has demonstrated reductions in mortality, length of stay and readmissions for patients admitted with community-acquired pneumonia using an evidence-based order set.[28] The systems have the capacity to include automated stop orders or review prompts for medicines. Electronic order systems for pathology can also integrate decision support prompts.

Poorly implemented e-prescribing without associated decision support (for example, error checking) may be associated with patient harm.[31-33] Many resources are usually required to modify eCDSS content provided by commercial vendors for local implementation.[34] In a study of 10 e-prescribing systems in the United States, aspects of system safety that would negatively affect antimicrobial prescribing included[35-37]:

- Large numbers of medicines and dosing combinations
- Dangerous autocomplete directions that displaced or contradicted the original intended orders
- Failure to transmit medication discontinuation orders from computerised physician order entry to outpatient pharmacies
- Inconsistent design, implementation and firing of the clinical decision support, leading to very high rates of override (more than 90%) for many alerts
- Off-the-shelf commercial medication databases that were poorly designed to meet the needs of sites, leading to extensive local customisation that was difficult to maintain with software releases.

Sophisticated EMM environments can incorporate algorithms to force or prevent any aspect of the electronic workflow, and to customise alerts and reporting functions for the AMS team. However, such modifications or customisations require considerable time investments from the health service organisation in terms of IT and content expertise. The extra time might not be factored in at the time of the original implementation.

In Australia, where third-party antimicrobial approval systems are already embedded within AMS programs, AMS is conducted within the EMM environment to generate the workflow to support these systems. This might include forcing an approved indication and approval number for restricted antimicrobials. Other teams have developed custom-made solutions – such as post-prescription review tools that interface with the hospital e-prescribing system – to support their AMS service.

4.2.5 Advanced decision support systems

Advanced decision support systems use complex logic, mathematical modelling and case-based probabilities to provide patient-specific recommendations. There are very few reports of advanced decision support systems that support antimicrobial prescribing and that have been successfully implemented outside the originating institution.

The Antimicrobial Assistant, developed by the informatics group at the Latter Day Saints hospital in Utah, was an early leader in antimicrobial decision support.[38] The system used predictive models, and its impact was described in several publications relating to AMS, infection control surveillance, surgical prophylaxis and adverse drug events.

Another eCDSS for empirical antimicrobial therapy uses a causal probabilistic network. The system uses the available data within the first few hours of infection presentation to predict sites of infection and specific pathogens. In a cluster-randomised trial across three wards in three countries (Israel, Denmark and Germany), the system was shown to improve appropriateness of empirical antimicrobial therapy and improve patient outcomes.[39-41]

Machine learning, natural language processing and text mining are promising technologies to support AMS; they allow the use of free text in electronic healthcare records, pathology or radiology reports, and prescriptions. These systems use supervised learning to establish a knowledge base of classification rules. A text-mining tool for predicting pulmonary invasive fungal infection from computed tomography chest reports was more effective than traditional manual methods and led to earlier detection in the validation dataset.[42] A Canadian eCDSS was augmented with machine-learning capabilities to identify inappropriate prescriptions, such as dose and dosing frequency adjustments, discontinuation of therapy, early intravenous-to-oral switching, and a redundant antimicrobial spectrum.[43]

eCDSSs have a potential role in the detection and management of sepsis in hospitals with fully implemented electronic healthcare records (including patient observations). An automated, real-time surveillance algorithm was developed that aggregated, normalised and analysed patient data from disparate clinical systems and delivered early sepsis alerts to nurses and midwives, and treatment advice to clinicians, using mobile devices and portals. Implementation of the algorithm was associated with a significant reduction in mortality.[44] A recent systematic review of eight studies found that automated sepsis alerts derived from electronic health data may improve care processes, but tend to have poor positive predictive value (ranging from 20.5% to 53.8%; negative predictive value 76.5% to 99.7%), and do not improve mortality or length of stay.[45] However, a systematic review does not capture the important qualitative evaluation required to fully understand the impact of an eCDSS, and why some systems were not associated with improved outcomes despite improved care processes.

4.2.6 Implementing electronic clinical decision support systems for antimicrobial stewardship

Implementing eCDSSs requires an assessment of the organisation's needs and capacity, compared with the capabilities of the new system. It is also vital to recognise that IT systems for AMS are not standalone systems and that AMS activities should be integrated with other IT systems.

Although few studies have looked at the reasons that eCDSSs may or may not be effective[46,47], the features of an eCDSS that are likely to improve effectiveness include speed, simplicity of use, integration with workflow, monitoring and feedback.[48] There are also many barriers and facilitators for implementation and uptake of these systems.[25,49]

Ensuring effective integration of eCDSSs with clinical workflow requires consideration of organisational, cultural and technological factors. For example, an evaluation of an Australian web-based AMS management tool identified differences in uptake and adoption of the tool between the junior and senior medical workforce, and this was correlated with awareness of AMS.[18,50]

Readiness assessment

Organisations implementing eCDSSs need to consider a broad range of local issues, and different users need to be involved in making informed decisions.

Five system planning and design processes are essential before procuring and implementing a new system:

1. Technical readiness – understanding the integration requirements, and access to IT infrastructure; this includes availability of IT workforce members to support
   - data extraction and processing (for example, Health Level 7 [HL7])
   - databases and servers
   - local security requirements.

   Data security is essential, particularly with the increasing use of wireless, mobile and cloud technologies, and appropriate data governance policies need to be established in advance of system implementation
2. Financial and human resources – including appropriate project support (often an AMS pharmacist or ID specialist) with allocated time for AMS activities
3. Skills training – considering training needs and previous experience of the project team and end users.

   Training of the project leads in the new system, followed by a train-the-trainer approach, may be appropriate. Visits to demonstration sites that have a particular system in place are also recommended
4. Process readiness – including project planning, system implementation and evaluation planning
5. Administrative readiness – including executive support and high-level clinical champions.

Effective system planning will ensure that AMS team members are formally engaged in the scoping, functional specification and implementation of an eCDSS, including approval systems, electronic surveillance systems, e-prescribing systems and electronic healthcare record implementation. All elements of the system that are relevant to AMS should be reviewed to ensure that they meet the needs of the AMS program and end users, and the hospital more generally.

Cultural factors

Cultural factors can have a marked effect on the successful implementation of new IT systems. In a hospital where ID physicians or microbiologists have not previously played a prominent consultative role, the workforce will face more barriers than in hospitals with existing telephone- or paper-based approval systems. Any barriers to acceptance need to be identified during the planning phase of the project and managed during implementation. Importantly, management of the change process – including local champions or project leaders, and an organisation that supports innovation, incentives and participation – is a key determinant in system uptake.[51]

Sites with successful eCDSSs report a common set of factors:

- Strong leadership with a clear long-term commitment
- A commitment to improving clinical processes by enlisting clinician support
- Involving the clinicians in all stages of the development process.

A well-planned and well-timed communication strategy using the intranet, grand rounds, unit meetings and posters in preparation for the go-live date is important. The strategies used need to meet the institution's particular needs, goals and culture.[52]

4.2.7 Electronic clinical decision support in primary care

The use of general practice prescribing software is almost universal in Australia: 80–90% of general practitioners and 65% of community pharmacists use one of six prescribing systems, and one of three dispensing systems. The National Prescribing Service evaluated general practitioner prescribing systems to establish which features were available to support safety and quality in prescribing.[53] A panel of 12 experts in medicine, informatics or pharmacy identified 114 features across several domains that were tested in each of the systems. The decision support features were the most variable and, on average, the most poorly implemented. Features relating to recording patient data and selecting medicines were better implemented.

The report was published in 2011, but remains highly relevant for the key safety and quality issues relating to AMS. In particular, it found the following[54]:

1. The systems had limited access to evidence-based medicine and therapeutic information.

   No system provided access to independent (that is, not developed by the pharmaceutical industry) resources such as *Therapeutic Guidelines: Antibiotic*[6] and the *Australian Medicines Handbook*.[55] Many medication prompts contained information sponsored by pharmaceutical companies, which may not be immediately apparent to the prescriber

2. There was variable decision support for prescribing.

   Drug–drug interactions, medicines in pregnancy and allergy alerts were the most commonly implemented eCDSS features. All but one system relied on commercial medication databases, with limited opportunity for modification

3. Linking the prescription with the indication was optional.

   Mandatory indication documentation is required for quality improvement activities such as comparing individuals' prescribing with best-practice guidelines.

4. Clinical reporting was variable.

   The ability to report back to the clinician was limited.

General practices can, however, set up their practice systems to maximise the opportunity for improved antimicrobial prescribing, by:

- Subscribing to the electronic version of *Therapeutic Guidelines: Antibiotic*[6]
- Turning off automatic repeats
- Ensuring that indications and allergies are captured in the healthcare record for future patient visits.

Most published reports of eCDSSs in general practice relate to conventional algorithms integrated into electronic healthcare records or on an electronic device, which support antimicrobial prescribing for specific syndromes such as urinary tract and respiratory tract infections.[56-63] A systematic review of these systems found that eCDSSs that provided automatic decision support were more effective than those that required information to be initiated by the provider.[64]

The My Health Record system in Australia is an electronic summary of an individual's key health information drawn from their existing healthcare records and is designed to be integrated into existing local clinical systems. The system aims to give healthcare organisations access to patient information such as medication records, test results, discharge summaries, allergies and immunisations. Once it is widely rolled out, this program should provide increased opportunities for clinical decision support. Although the adoption of the My Health Record system has been slow (4.78 million users as of July 2017), a move to an opt-out clause and the introduction of the e-health Practice Incentives Program will increase its use. The ability for the system to interface with hospital electronic healthcare record systems would further improve communication between the community and hospital sectors.

4.3 Data collection and reporting

Antimicrobial approval systems, infection surveillance and EMM systems are all important data sources that can help to identify patients who require post-prescription review. They are also sources of data about antimicrobial use that can be used for institutional auditing and reporting purposes (see Chapter 6: 'Measuring performance and evaluating antimicrobial stewardship programs').

Approved linkages between institutional datasets are important to enable the monitoring and surveillance of both intended (improved patient outcomes and reduced AMR) and unintended consequences of AMS programs. Many hospitals' pathology or pharmacy databases do not allow for the data aggregation required to support such activities. Data from pathology systems can, however, contribute to local, state, territory and national data collections, as well as produce local antibiograms. Hospital pharmacy systems can generate reports on antimicrobial use and costs for monitoring and evaluation purposes.

A major barrier to effective reporting and surveillance of AMS interventions is the functionality of systems interoperability and the heterogeneity of messaging standards (especially HL7). National approaches to AMS will be improved by the standardisation of clinical data systems, semantic interoperability, the use of standard terminologies, messaging standards (such as HL7, particularly for microbiology data) and the use of unified patient healthcare record numbers.

There have been several improvements to the systems that support local, state, territory and national hospital data collection for the National Antimicrobial Prescribing Survey and the National Antimicrobial Utilisation Surveillance Program. The AURA project has established a coordinated approach to national surveillance and reporting for AMS, AMR and patient outcomes. This work will continue to improve data quality and consistency through the alignment of data definitions, the ability to improve the interoperability of systems and the potential for appropriate data linkage.

Table 4.2: Situations in which telehealth can be used to support antimicrobial stewardship strategies

AMS strategy	Telehealth options
Pre-authorisation (individual patient ID consultations, AMS ward rounds)	• Videoconferencing, Skype • Remote access to electronic healthcare records; electronic medication management systems; and pathology, microbiology, teleradiology results • Remote access to AMS electronic decision support systems
Post-prescription review (AMS ward rounds)	• Videoconferencing, Skype • Remote access to electronic healthcare records; electronic medication management systems; and pathology, microbiology, teleradiology, telepathology results • Scanning medication charts and sending to an off-site pharmacy for review
Education	• Online education programs • Webinars

AMS = antimicrobial stewardship; ID = infectious diseases

4.4 Telehealth

The International Organization for Standardization defines telehealth as the 'use of telecommunication techniques for the purpose of providing telemedicine, medical education and health education over a distance'.[65] Telehealth involves using different telecommunication technologies to support a model of service delivery in which not all clinical input is available on site. All telehealth must be underpinned by an appropriate service model and may include:

- Live, audio and video interactive links for clinical consultations and education
- Storage of digital images, video, audio and clinical data for secure transmission and use in remote clinics
- Teleradiology and telepathology for remote reporting and clinical advice for diagnostic tests
- Telehealth services and equipment to monitor people's health in their homes.

R

Telehealth can improve access to services and specialty care, especially for people living in rural and remote areas. Rural and remote health services are often leaders in the use of telehealth across a range of clinical areas, including support for AMS activities – for example, the use of low-cost videoconferencing systems to conduct individual patient reviews with an ID specialist, or virtual AMS ward rounds with a remote ID physician, clinical microbiologist or pharmacist. Examples of the types of telehealth that can be used to support AMS activities are listed in Table 4.2.

Health service planning needs to incorporate telehealth into AMS program delivery, and consider the following questions:

- What is the scope of services to be provided through telehealth, and what workforce is required to support these services?
- What key antimicrobials, indications or microbiology results will require consultation?
- Have formal arrangements been established for when and how advice on prescribing is to be sought and documented?
- Have ongoing arrangements been established to ensure continuity of service provision – for example, for leave?
- Have protocols been established for documenting consultations and decisions?
- How will external access be provided to on-site IT systems such as electronic healthcare records, AMS clinical decision support, and pathology, microbiology and radiology systems?
- What processes and systems are required to ensure the confidentiality and security of patient records?
- Will education form part of the telehealth service? How will clinicians be involved in educating and upskilling the local workforce?
- How will other technology, such as clinical decision support software or electronic healthcare records, be used and supported at both sites?

Models for providing AMS by telehealth include regular weekly AMS case conferences and virtual AMS bedside rounds, and prescriptions being reviewed remotely before being dispensed. Australian models have included an ID physician or clinical microbiologist who has remote access to the hospital computer system and teleconferencing, with an on-site AMS pharmacist who attends the bedside and reviews the patient's paper medication chart. The pharmacist then documents the agreed recommendation about antimicrobial use in the patient's notes. See Case study 4.3 for an Australian example.

Case study 4.3: Using telehealth for antimicrobial stewardship

Hospital B is a 250-bed public hospital in a regional town. It has an electronic antimicrobial approval system that was designed in-house and facilitates pre-prescription authorisation of restricted antimicrobials according to nominated indications, but does not have on-site infectious diseases (ID) physicians or a microbiology service. It had no system for escalating concerns about prescribing and no opportunities for post-prescription review. The AMS program was overseen by the infection control service; however, they did not feel equipped to manage the AMS program without more support, especially in the intensive care unit.

A successful business case was developed for contracting AMS services from a large major-city teaching hospital to support the local program. A comprehensive service agreement was achieved that included:

- Monthly visits by an ID physician
- Attendance by the ID physician at the AMS committee and infection prevention meetings (using teleconference facilities or on site)
- Access to policies and guidelines developed at the Principal Referral Hospital that could be customised for local use
- Involvement in audit activities, including analysis of data and preparation of reports
- Monthly on-site ID outpatient service, funded under a Medicare fee-for-service arrangement.

The AMS team developed a new model of care in which the ID physician conducts weekly AMS ward rounds using teleconference facilities. The AMS pharmacist triages a list of patients for post-prescription review, based on the pre-prescription approval list. The ID physician has remote access to the hospital's information technology (IT) system, and can view investigations and results, as well as nursing or midwifery handover notes. If required, they can phone to discuss patients with the resident doctors. The local clinicians discuss the cases with the AMS pharmacist at the bedside, with the ID physician joining through teleconference facilities. The resulting advice is documented electronically using an IT product that enables the AMS pharmacist to view the ID physician's typed recommendations and send them to the electronic healthcare record. The AMS ward rounds also involve regular contact with intensive care clinicians, using teleconference facilities, to provide advice about their patients.

The local AMS pharmacist and infection control practitioner felt better supported when they were able to discuss concerns with the ID physician first. Consistent advice was delivered by the ID physician, and the local team gained valuable knowledge. The pharmacist and infection prevention practitioners attended training courses in AMS to develop their skills. The program has been very well received by the workforce, and preliminary data suggest an immediate increase in the appropriateness of antimicrobial prescribing.

Resources

- Third-party antimicrobial approval systems: The Guidance Group, eASY medication stewardship, IDEA³S
- Third-party eCDSSs: TheraDoc, TREAT

Mobile apps providing prescribing information and guidelines

Australian

- Therapeutic Guidelines Limited: e-TG complete (Therapeutic Guidelines complete)

International

- Imperial College London: Imperial Antibiotic Prescribing Policy app
- Sanford Guide: Sanford Guide online
- Johns Hopkins Medicine: Johns Hopkins antibiotics guide
- Horizon Strategic Partners (UK): MicroGuide (supports local customisation)
- Emergency Medicine Residents Association (US): 2017 EMRA Antibiotic Guide
- Wolters Kluwer Health (US): UpToDate online
- Börm Bruckmeier Publishing, LLC Medica: Antibiotics pocket
- Spectrum Mobile Health Inc: Spectrum – localized antimicrobial stewardship
- Infection Control Branch, Centre for Health Protection, Department Of Health (Hong Kong): Impact

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