AUSTRALIAN COMMISSION
ON SAFETY AND QUALITY IN HEALTH CARE

AURA
Antimicrobial Use and Resistance in Australia

AURA 2021

Fourth Australian report on antimicrobial use and resistance in human health

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Summary

Antimicrobial resistance (AMR) continues to be one of the most significant challenges that healthcare services face in Australia, and around the world. The Antimicrobial Use and Resistance in Australia (AURA) Surveillance System collects, reviews and analyses AMR and antimicrobial use (AU) data, monitoring patterns and trends, and regularly reporting on AU and AMR across Australia. Local and national data on AMR and AU are available for all levels of the Australian healthcare system, across the acute care and community sectors, and for the public and private sectors.

AURA 2021 is the fourth in a series of national reports developed by the Australian Commission on Safety and Quality in Health Care (the Commission) to enhance AMR prevention and containment strategies. These reports and the data captured through the AURA Surveillance System support effective clinical practice, policy decisions, and prioritisation of public health action.

It is projected that 10,430 people in Australia will die between 2015 and 2050 as a result of AMR.[1]

AURA 2021 reports against each component of the AURA Surveillance System; highlights current areas of improvement and concern; and, suggests areas for action.

AMR occurs when a microorganism develops resistance to an antimicrobial that previously provided an effective treatment, resulting in:

- A reduced number of antimicrobials available to treat infections
- Increased treatment times and costs
- Increased potential for hospitalisation for conditions usually managed in the community
- Increased morbidity and mortality.

Highlights

Chapter 3 – Antimicrobial use and appropriateness – includes the following important findings on AU and appropriateness of prescribing, highlighting a number of areas of concern and opportunities for improvements in antimicrobial stewardship (AMS):

- While there has been a continuing gradual decline in community AU up to 2019, more than 10 million people in Australia (40.3%) had at least one antimicrobial dispensed under the Pharmaceutical Benefits Scheme (PBS) or the Repatriation Pharmaceutical Benefits Scheme (RPBS) in 2019. This is much higher than most European countries and Canada. This is in addition to people who received antimicrobials during a stay in hospital
- There has been a continuing gradual increase in the volume of hospital AU,

which is higher than any European country and Canada

- There has been no improvement, over time, in overall appropriateness of antimicrobial prescribing in hospitals and aged care services. Appropriateness varies widely across hospital peer groups, and there have been improvements in some and deterioration in others
- Improvements have occurred in hospitals since 2013 in documentation of indication and review or stop date, and the duration of administration of surgical antimicrobial prophylaxis
- A very high percentage of patients from participating NPS MedicineInsight general practices continue to be prescribed antimicrobials for conditions for which there is no evidence of benefit. For example, for acute bronchitis (81.5%) and acute sinusitis (80.1 %).

Antimicrobial prescriptions continue to remain high, compared with European countries; Australia ranks seventh highest among European countries in its community use of antibiotics.

An urgent re-focusing by all prescribers to align with national and state and territory guidelines for antimicrobial prescribing, where developed, is necessary.

Chapter 4 – Antimicrobial resistance – provides detailed data for each of the AURA Surveillance System Priority Organisms, including the main types of infections that result from these organisms, the important antimicrobials used for treatment, and changing resistance patterns over the past five years. Important findings include the following:

- In gram-negative pathogens, it is of serious concern that resistances continue to increase to common agents used for treatment in *Escherichia coli*, which is the most common cause of urinary tract infections (UTIs) and septicaemia in the community in otherwise healthy people. Resistance to ciprofloxacin and other fluoroquinolones continues to rise in isolates from community-onset infections, despite restriction of access to these agents on the PBS. As a result, the availability of reliable oral antimicrobials for conditions such as UTIs is substantially reduced, and this can result in increased hospital admissions for intravenous treatment.

  It is noted that PBS/RPBS data underestimate the level of total dispensing in the community, due to non-PBS prescribing or dispensing of antimicrobials ('private scripts'); the Commission will work with the Australian Government Department of Health to further examine this issue.

- Carbapenem resistance in *Enterobacterales* remains uncommon, and rates of resistance in *Enterobacterales* to most antimicrobials were lower in the community than in hospitals. However, rates in aged care homes were often as high as, or higher than, rates in hospitals.

Chapter 6 – Focus areas – includes specific information on AMR and AU not previously included in AURA reports that is of particular current interest. The information includes:

- The dramatic reduction seen in antimicrobial PBS dispensing through 2020 during the COVID-19 pandemic, which may be an opportunity to target inappropriate AU in the community and sustain a lower volume of AU in the future

- An expanded range of resistance data to include *Clostridioides difficile*
- Improved geographic coverage through the inclusion of data from far north Australia.

AURA 2021 also includes a number of case studies that demonstrate how AURA data can be used to support improved clinical practice and quality improvement action, improve patient care, and reduce the risk of AMR.

Chapter 7 – Conclusions and future developments – discusses key areas for action, including the following:

- Prioritisation of important resistant organisms for notification

  The AURA Surveillance System is a collaboration between the Commission and many organisations that provide AMR and AU data on a voluntary basis, along with the program partners that collect, analyse and report on these data. The voluntary contribution of AMR data has been successful during the establishment phase of the AURA Surveillance System, and has created a large national dataset that includes all states and territories, the public and private sectors, and hospital and community settings. However, it does not yet provide a complete picture of AMR in Australia.

  To complement the existing approaches, there are opportunities to consider a range of state, territory and national processes to enhance surveillance and response strategies through a mandatory, nationally consistent approach to detection and reporting of critical antimicrobial-resistant organisms.

  Mechanisms currently used at state and territory, and national levels (such as the National Health Security Agreement) should be considered to establish nationally consistent resistance surveillance definitions, response protocols and notification of key priority organisms. This process could prioritise carbapenemase-producing *Enterobacterales* (CPE), which has been identified as a priority in a number of states and territories.

  As a further measure, a requirement could be considered for all laboratories receiving payments through the Medical Benefits Schedule for susceptibility testing to provide resistance data to Australian Passive AMR Surveillance (APAS).

- Urgent improvement strategies for antimicrobial prescribing and use

  As a priority patient safety issue, action must be taken at organisational and practitioner levels to address the lack of improvement in the appropriateness of antimicrobial prescribing, particularly in the hospital setting. The Commission has recently strengthened the requirements of the National Safety and Quality Health Service (NSQHS) Standards for health service organisations to demonstrate that there has been review of antimicrobial prescribing and use, and that surveillance data on AMR have been used to support appropriate prescribing.

  The Commission will work with the Aged Care Quality and Safety Commission and the Royal Australian College of General Practitioners to promote improved antimicrobial prescribing across all sectors to reduce patient harm and AMR.

- Improved access to resistance data

  AURA 2021 data provide increased capacity to identify patterns and trends in resistance in the priority organisms for Australia in acute care, residential aged care services and the community. These data continue to inform targeted responses to specific resistances in specific settings. The Commission will consult further with clinical and technical experts to provide this resistance information in the most accessible form while the One Health Surveillance System is developed.

Overview

The systematic use of surveillance data is vital to the development and implementation of successful prevention and response strategies; to reduce the impact of AMR; improve the appropriateness of antimicrobial prescribing; and, reduce patient harm.

The contribution of the AURA Surveillance System to the expansion in the breadth and depth of Australian AMR and AU data, since 2013, has allowed a more comprehensive understanding of resistance, providing examples of both improvements in, and worsening of, AMR in specific organisms.

The AURA national reports have consolidated various AMR datasets, and the Commission continues to work with stakeholders to inform policy and practice change. A key area of action is provision of data to support regular review and update of national guidelines for Australian prescribers, such as those produced by Therapeutic Guidelines Limited, as well as local antimicrobial prescribing guidelines and formulary management.

AURA Surveillance System and the Australian Commission on Safety and Quality in Health Care

The AURA Surveillance System is now a well-established, nationally coordinated system as a result of implementation of a comprehensive and cohesive strategy, which was developed, and is managed, using a partnership approach. The Australian Government Department of Health is currently undertaking consultation on structural changes needed to develop the One Health Surveillance System, which has resulted in changes to the coordination role for the Commission's AURA team. However, the Commission will continue to undertake a number of roles to support human health AMR and AU surveillance, along with its lead roles in patient safety and quality, infection prevention and control, and AMS.

Improvements continue to be made across the AURA Surveillance System. For example, both the National Antimicrobial Utilisation Surveillance Program (NAUSP) and the National Antimicrobial Prescribing Survey (NAPS) have been enhanced to increase geographic and peer group representativeness of contributing hospitals, and to streamline data collection and analysis processes. The Commission has continued to develop and expand the scope of AURA, as demonstrated by the inclusion of data in Chapter 6 from the HOTspots surveillance program, which monitors AMR in far north Australia, and the inclusion of data on *C. difficile*.

Other areas of the Commission's work also support the use of AURA data to improve safety and quality. The Preventing and Controlling Infections Standard is one of eight NSQHS Standards. As part of an update in 2021, this standard requires health service organisations to monitor patterns of healthcare-associated infections, AU and AMR, and use these data to guide AMS practices, and meet infection prevention and control requirements. New actions were added to the standard that strengthen the requirements for reporting to clinicians and governing bodies on areas of action for AMR, and to improve appropriateness of prescribing by compliance with guidelines, as well as monitor AU performance over time. These additions are intended to ensure the use of surveillance data for improvement action.

Antimicrobial use and appropriateness of prescribing in hospitals

In 2019, AU in hospitals that participated in NAUSP increased by 2.8% compared with 2018. The usage rate increased from 848.2 defined daily doses (DDDs) per

1,000 occupied bed days (OBDs) in 2015, to 883.0 DDDs per 1,000 OBDs in 2019. The greatest increases occurred in South Australia (4.2%), Western Australia (3.9%) and Tasmania (3.8%).

> In hospitals, AU is increasing, and inappropriate prescribing levels are static.

On a DDD per 1,000 people basis, AU in Australian hospitals appears to be higher than in any European country, and is nearly four times that of the European country with the lowest AU (the Netherlands). It is noted that the Australian value is based on NAUSP data; participation in NAUSP includes many larger hospitals where there may be higher use than the national average, due to higher case complexity.

From 2015 to 2019, there were improvements in three important indicators of appropriateness of antimicrobial prescribing in hospitals: documentation of indication, documentation of review or stop date, and the proportion of surgical prophylaxis given for greater than 24 hours.

The overall appropriateness of prescribing across all hospital peer groups that participated in NAPS was 75.8% in 2019. This has essentially remained static since 2013. However, both participation rates and appropriateness varied between peer groups, with improvements in some and deterioration in others.

Hospital data showed inappropriate prescribing of several broad-spectrum antimicrobials in 2019, particularly cefalexin, cefazolin, azithromycin and amoxicillin–clavulanic acid. The rate of inappropriateness for ceftriaxone prescribing was the most notable change between 2018 and 2019, increasing from 24.9% to 29.0%.

The three indications with the most inappropriate prescribing did not change from 2018 to 2019: chronic obstructive pulmonary disease (COPD), surgical prophylaxis and non-surgical wounds. The trends for COPD require urgent intervention, as noncompliance with guidelines continues to rise and the level of appropriate prescribing has declined. The Commission is collaborating with Lung Foundation Australia and the Thoracic Society of Australia and New Zealand to promote appropriate prescribing and adherence to national guidelines.

The trends for COPD require urgent intervention, as noncompliance with guidelines continues to rise and the level of appropriate prescribing has declined.

For surgical prophylaxis, antimicrobial prescribing was audited as appropriate in 56.7% of all surgical episodes audited for the Surgical NAPS in 2019. For procedural prophylaxis, the main issues were documentation of antimicrobial administration time and incision time. For post-procedural prophylaxis, the main problems were incorrect duration, dose and frequency of administration. The Commission is continuing to collaborate with the Royal Australasian College of Surgeons and relevant specialty groups to improve prescribing of antimicrobials for surgical prophylaxis.

The Commission developed the Priority Antibacterial List for Australian use to categorise antibacterials according to their potential to contribute to the development of AMR: Access – Curb – Contain.

AURA 2019 identified priorities for action in relation to AU, including the volume and appropriateness of prescribing of amoxicillin–clavulanic acid, cefalexin and other broad-spectrum antibiotics. In response, in 2020, the Commission developed the Priority Antibacterial List, based on a system developed by the World Health Organization to categorise antibacterials according to their potential to contribute to the development of AMR. This resource groups antibacterials into three categories: Access, Curb and Contain. Access antibacterials should be used ahead of Curb and Contain antibacterials, wherever possible, to preserve the Curb and Contain categories for use only when clinically necessary. The Priority Antibacterial List complements AU data and enables Australian hospitals to monitor and regulate their use of Curb and Contain antibacterials as part of their AMS programs.

In the primary care setting, AU is decreasing, but many common conditions are still being treated inappropriately.

Surveillance of AU data has shown a positive trend in overall AU in the Australian community, with a decline since 2017, across all states and territories. Between 2015 and 2019, there was a gradual annual decline in the rate of antibiotic dispensing, and a 14.8% decrease in the age-adjusted rate of prescriptions per 1,000 people under the PBS/RPBS. In 2019, 40.3% of the Australian population had at least one antimicrobial dispensed under the PBS/RPBS. This was a slight increase compared with 40.0% in 2018. The mostly commonly supplied antibiotics under the PBS/RPBS continue to be cefalexin, amoxicillin and amoxicillin–clavulanic acid; this is of concern because cefalexin and amoxicillin–clavulanic acid are first-line agents for very few conditions.

The COVID-19 pandemic has had a dramatic impact on dispensing rates, an experience that has also been reported in other countries. During 2020, Australia experienced substantial decreases (between 22% and 49%) in dispensing for several antimicrobials, including amoxicillin, cefalexin and doxycycline. This suggests a decrease in dispensing for seasonal respiratory infections, which coincided with pandemic control measures such as hand hygiene and physical distancing. It indicates that there are opportunities to intervene to sustain these lower levels of AU for conditions for which antimicrobials are not generally recommended. The Commission will work with clinicians, state and territory governments, and the Australian Government to explore strategies to improve appropriateness of prescribing, particularly for upper respiratory tract infections, and sustain infection prevention and control activities.

During 2020, Australia experienced substantial decreases (between 22% and 49%) in dispensing for several antimicrobials, including amoxicillin, cefalexin and doxycycline, which indicates opportunities to intervene to sustain these lower levels of AU for conditions for which antimicrobials are not generally recommended.

Antimicrobials continue to be overprescribed compared with national guideline recommendations. For example, a very high percentage of patients from participating MedicineInsight practices were prescribed antimicrobials for conditions for which there is no evidence of benefit, including acute bronchitis (81.5% of patients with this condition) and acute sinusitis (80.1% of patients with this condition). Antimicrobial prescribing also remains high compared with European countries: Australia ranks seventh highest among European countries in its community use of antibiotics. The Commission will increase its work with Therapeutic Guidelines Limited to provide data to inform changes to the guidelines, where indicated, and communicate with prescribers about current and emerging AMR and the implications for prescribing practice.

Dispensing rates vary by local area. In some cases, the area with the lowest dispensing rate is near to, or contiguous with, the area with the highest dispensing rate. Differences between the regions with the lowest and highest dispensing rates are up to four-fold. This suggests that local physician preference is a major influence on AU.

Dispensing rates also vary across age groups. In 2019, the rate was highest for those aged over 65 years, followed by those in the 2–4-year age group. The lowest rate of antibiotic dispensing was observed for the 10–19-year age group. For participating MedicineInsight practices, children aged 0–4 years were most commonly prescribed amoxicillin, and people aged 90–94 years were most commonly prescribed cefalexin. This reflects the infection types most commonly seen in these age groups.

Approximately 50% of all antibiotic prescriptions were ordered with repeats. Of these repeats, approximately half were filled within 10 days of the original prescription. Much of this prolonged use is likely to be unnecessary and increase the risk of the patient acquiring resistant pathogens. To encourage prescribers to issue repeat prescriptions for antibiotics only when clinically indicated, PBS policy changes in April 2020 reduced the number of repeat prescriptions permissible for the five most commonly dispensed antibiotics (amoxicillin, amoxicillin–clavulanic acid, cefalexin, doxycycline and roxithromycin).

In residential aged care services, levels of inappropriate AU remain high.

Restrictions on PBS-listed antimicrobials may be increasing private prescription rates for some agents. For example, both azithromycin and ciprofloxacin are listed as ‘restricted’ or ‘authority required’, and a steady rise was seen in the proportion of private prescriptions for these agents from 2010 to 2019. It is important to understand the potential unintended impacts of restrictions in the PBS/RPBS, as they may affect AU surveillance, and AMR prevention and control efforts. The Commission considers that a case can be made for capturing data on all antimicrobial prescriptions at the time of dispensing, and will work with the Department of Health and other stakeholders to investigate the feasibility of identifying the volume of dispensing not currently captured by surveillance.

Residential aged care services are an important community setting for monitoring AU and AMR, because of the higher levels of infections, prescribing and antimicrobial-resistant organisms. For some organisms, rates of AMR in aged care homes are as high as, or higher than, rates in hospitals.

It is concerning that, from 2017 to 2019, there were no significant improvements in

AU in residential aged care services, and the proportion of residents prescribed antimicrobials increased slightly. The 2019 Aged Care NAPS (AC NAPS) has repeatedly identified the same resident safety issues in relation to AU as surveys since 2015. These include prolonged duration of AU, high rates of PRN ('as needed') prescriptions for antimicrobials, and high rates of topical AU, particularly for PRN administration for conditions where antimicrobials are not usually indicated.

The top five known indications for prescribing antimicrobials for aged care residents between 2016 and 2019 were cystitis; skin, soft tissue or mucosal infection; pneumonia; wound infection (non-surgical); and tinea. Many of these conditions can be prevented by managing hydration and providing good basic hygiene, rather than prescribing antimicrobials. Options for improving the care of residents in relation to these issues will be considered through liaison with the Aged Care Quality and Safety Commission.

Topical antimicrobials accounted for almost one-third (30.4%) of all prescriptions and almost 90% of PRN prescriptions in residential aged care. In response to this, the Commission developed a fact sheet on topical antimicrobial use. Cefalexin, topical clotrimazole, amoxicillin–clavulanic acid, trimethoprim and doxycycline were the most commonly prescribed antimicrobials.

Almost 1 in 6 (15.0%) antimicrobials were prescribed for PRN administration in residential aged care. This approach may reduce clinical review of antimicrobial choice at the time of onset of infection, and delay decisions about treatment duration, leading to extended duration of treatment. In addition, approximately 20% of antimicrobial prescriptions in residential aged care services in 2019 were for prophylaxis. This is concerning because there are relatively few indications for AU as prophylaxis in the aged care setting.

Understanding the reason for an antimicrobial prescription is vital to assessing appropriateness in any setting, and to inform quality improvement activities. For a number of AURA programs, no indication was recorded for a large proportion of prescriptions. For example, no indication was recorded for approximately 25% of prescriptions for services that contributed to AC NAPS in 2019. However, there was an improvement in documentation of antimicrobial review or stop dates for residents of these services (64.7%, compared with 58.9% in 2018).

Strategies are required to address reported barriers to improvement in AU in residential aged care services, including difficulties in diagnosis of infections, staffing issues, off-site laboratory services and family expectations. The Commission will continue to work with the Aged Care Quality and Safety Commission to promote antimicrobial prescribing improvement programs informed by the AC NAPS findings, in addition to ongoing surveillance of infections and AU in residential aged care services. Recent work in this area has included the Commission's antimicrobial consumer fact sheet and the inclusion of a specific chapter in *Antimicrobial Stewardship in Australian Health Care*.[2]

AMR is increasing for some priority organisms, including *Escherichia coli*, typhoidal *Salmonella* and *Staphylococcus aureus*.

Antimicrobial resistance

National rates of resistance for many priority organisms have not changed substantially from those reported in AURA 2019. AURA

reports on organisms that are high priorities for human health with sufficient data available to provide valid reporting.

In a few cases, rates of resistance have decreased. For example, in *Neisseria meningitidis*, the number of notifiable cases has decreased since 2017. Reduced susceptibility to benzylpenicillin has declined from 44.9% in 2017 to 21.0% in 2019, with full resistance to benzylpenicillin now found in less than 1% of isolates. In *N. gonorrhoeae*, rates of azithromycin resistance have declined since 2017, with resistance at 4.6% in 2019. However, the total number of notifiable cases has increased. This highlights the importance of ongoing public health messages regarding sexually transmitted infections.

However, rates of resistance are increasing for several organisms and are of concern:

- In *E. coli*, where resistances to common agents used for treatment continue to increase, resistance to ciprofloxacin and other fluoroquinolones continued to rise. These changes indicate potential increasing treatment failures and greater reliance on last-line treatments such as carbapenems, as oral options are not feasible
- Rates of resistance to fluoroquinolones in *E. coli* and *Klebsiella pneumoniae* are low in Australia compared with most European countries, but increased significantly from 2015 to 2019. Australia has slowly risen in rank in rates of resistance to third-generation cephalosporins in *E. coli* over the past decade, and now ranks towards the middle
- In *Enterococcus faecium*, the overall rates of vancomycin resistance are declining nationally, but are still above 40%. Rates of resistance to vancomycin in *E. faecium* were higher than all European countries except Cyprus, Greece and Poland in 2019
- In *Salmonella*, ciprofloxacin resistance in typhoidal species (*Salmonella* Typhi and *Salmonella* Paratyphi) exceeded 78% in 2019, confirming that ciprofloxacin should no longer be relied on for empirical treatment
- In *Staphylococcus aureus*, the epidemiology of methicillin resistance continues to evolve. Clones that were previously dominant are being replaced by other clones, and community-associated methicillin-resistant *S. aureus* has become prominent everywhere, but especially in remote and very remote regions. This demonstrates a need for a renewed focus on infection prevention and control in both community and acute settings
- In *Shigella sonnei*, resistance to ceftriaxone, ciprofloxacin and ampicillin increased rapidly over the period 2017–2019
- In *Streptococcus agalactiae*, resistance to erythromycin and clindamycin has steadily increased to around 33% in 2019
- In *Streptococcus pyogenes*, macrolide resistance has doubled since 2017 to 9% in 2019, reducing the utility of these second-line agents.

Critical antimicrobial resistances and the National Alert System for Critical Antimicrobial Resistances (CARAlert)

Since its establishment in 2016, the National Alert System for Critical Antimicrobial Resistances (CARAlert) has created a national repository of data on the relatively rare, but growing, occurrence of critical antimicrobial resistances (CARs) in Australian health services and the community, as well as an almost real-time system for alerting health service organisations to the occurrence of CARs. CARAlert complements state and territory monitoring and notification arrangements for CARs, where they exist, and provides data that can be used to inform local infection prevention and control, screening

and public health strategies to respond to outbreaks of CARs.

CARAlert has identified carbapenemase-producing Enterobacterales *and multidrug-resistant* Shigella *as the most frequently reported critical antimicrobial resistances.*

Data and analyses from CARAlert and APAS provide a national picture of CARs and multidrug-resistant organisms across healthcare and aged care settings. The Commission is continuing to collaborate with relevant experts to enhance CARAlert as new resistances are identified.

In 2020, the most commonly reported CAR was CPE. CARs reported from aged care settings were predominantly CPE or daptomycin-nonsusceptible *S. aureus*, and there was a small increase in the number of CARs reported from aged care homes between 2019 and 2020. Variation between states and territories in reports of CPE indicates the need for local decisions about containment priorities.

There were large increases in multidrug-resistant *Shigella* species from 2018 to 2019. However, there was a sharp fall in the monthly number of CARs reported from April 2020 onwards, notably of multidrug-resistant *Shigella* species. This fall correlated with the introduction of COVID-19 restrictions throughout Australia.

HOTspots

AURA 2021 includes resistance data from across northern Australia for the first time, as a result of collaboration with HOTspots, which monitors AMR in the far north of Australia. The HOTspots program collects data from participating pathology services and is hosted by the Menzies School of Health Research. HOTspots shows that resistance rates of some important pathogens are higher in the far north region than in other parts of Australia. Higher rates of antimicrobial prescribing and poor housing conditions in northern Australia, especially in remote communities, are likely to be important determinants of AMR rates in this part of the country.

AMR rates in northern Australia are often higher than national rates, or increasing.

For 2019, rates of resistance varied across regions:

- Rates of resistance to fluoroquinolones in *E. coli* were similar to national figures, but rates of resistance to third-generation cephalosporins (ceftriaxone or cefotaxime) were higher in northern Australia. Rates of both these resistances increased over the period 2015–2019
- Methicillin-resistant *S. aureus* is prevalent in northern Australia, although rates of resistance are stable
- Erythromycin-resistant *S. pyogenes* remained at a low prevalence (<2%) in far north Queensland from 2015 to 2017, but has increased to 8.0% in 2019. Rates of resistance to erythromycin and tetracycline in *S. pneumoniae* have been falling in far north Western Australian but remained stable in far north Queensland over 2015–2019. However, erythromycin resistance rates were still high across the three regions.

Inclusion of HOTspots resistance data is an important development in incorporating data from across Australia and broadening the representativeness of the data, particularly by including passive AMR surveillance data from

the Northern Territory for the first time. The Commission and HOTspots will continue to work together to develop focused reports of resistance in northern Australia.

Resistance in *Clostridioides difficile*

AURA 2021 also includes data from the first five years (2013–2018) of the *C. difficile* Antimicrobial Resistance Surveillance study, highlighting the importance of *C. difficile* infection (CDI) surveillance in Australia, given that CDI causes life-threatening diarrhoea and is the leading healthcare-related gastrointestinal infection in the world.

As an AURA priority organism, *Clostridioides difficile* is included for monitoring through passive surveillance and will be prioritised for additional surveillance if a signal emerges. The Commission will continue to work with experts and stakeholders to ensure effective monitoring and response, as required.

The AURA Surveillance System has included genomics data in a number of reports and technical papers from the Australian Group on Antimicrobial Resistance since 2013. A number of CARAlert confirming laboratories are able to provide whole-genome sequencing data on CARs such as CPE. These data complement the phenotypic antimicrobial susceptibility data, and greatly increase the utility of the data from these programs. Such information is increasingly important in identifying AMR prevention and control strategies, and is critical to enhancing the capacity of these surveillance programs to describe trends and to monitor the emergence and spread of AMR. The Commission will continue to use genomics data and promote standardisation of whole-genome sequencing procedures to ensure that reliable AMR data are available for surveillance and clinical purposes.

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Chapter 1
Introduction

Key messages

- Antimicrobial resistance (AMR) continues to be an increasing risk to patient safety because it reduces the number of antimicrobials available to treat infections. AMR increases morbidity and mortality associated with infections caused by multidrug-resistant organisms. AMR may limit future capacity to perform medical procedures such as organ transplantation, cancer chemotherapy, diabetes management and major surgery, because of a lack of effective antimicrobials.
- The Australian Commission on Safety and Quality in Health Care established the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System in 2014. This has enabled national coordination of data collection, analyses and public reporting.
- This improved understanding of local and national patterns and trends in antimicrobial use (AU) and AMR across Australia provides clinicians, policymakers and health system managers with a breadth and depth of information that were not previously available to inform clinical policy and practice.
- Comprehensive, coordinated and effective surveillance of AMR and AU enables effective strategies to be developed to prevent and control AMR at the local level, by all states and territories and by the private sector.
- In 2020, the Australian Commission on Safety and Quality in Health Care worked with the Australian Group on Antimicrobial Resistance to prepare aggregated resistance data for submission to the World Health Organization Global Antimicrobial Resistance Surveillance System. Data for six out of eight potential priority pathogens and two of the four priority specimens were submitted.
- AURA 2021 is the fourth report of its type on AMR and AU in Australia. It includes data about organisms that have been determined to be a priority for Australia, the volume of AU, the appropriateness of antimicrobial prescribing, key emerging issues for AMR, and a comparison of Australia's situation with other countries.
- During 2020, in response to COVID-19, Australia experienced substantial decreases (between 22% and 49%) in PBS dispensing for several antimicrobials, including amoxicillin, cefalexin and doxycycline.

Antimicrobial resistance (AMR) continues to be one of the biggest challenges internationally to the provision of safe, high-quality health services. The depth of information about antimicrobial use (AU) and AMR continues to grow in this fourth national Antimicrobial Use and Resistance in Australia (AURA) report. This chapter provides the background and current context for this important public health and public policy challenge. The chapter also outlines the current Australian strategic context and the contribution of the AURA Surveillance System to the response to AMR.

1.1 Background

Effective surveillance and monitoring are essential to determine the burden of AMR, and to inform response, prevention and control strategies.

In 2013, the Australian Government Department of Health (the Department) engaged the Australian Commission on Safety and Quality in Health Care (the Commission) to set up a nationally coordinated system for surveillance of AMR and AU for human health. At that time, a small number of AMR surveillance programs were operating independently, with varying levels of geographic representativeness, but there was no nationally integrated approach to surveillance. In addition, minimal data were available on AU, which is a key driver of AMR.

The establishment of the AURA Surveillance System provided the opportunity and means for a comprehensive, nationally coordinated approach to AMR surveillance, and for integrating data on the volume and appropriateness of AU. The Commission collaborated with existing surveillance programs, the states and territories, and private health service organisations to develop the national system and provide strategic direction to the development of AURA.

About the Commission

Australian governments and health service organisations are committed to improving the safety and quality of health care, and the Commission is central to this process. In 2006, the Council of Australian Governments (COAG) established the Commission to lead and coordinate national improvements in the safety and quality of health care. The Commission's permanent status was confirmed under the *National Health and Hospitals Network Act 2011*, and its role was codified in the *National Health Reform Act 2011*. The Commission's governance structure is determined by these Acts. The Commission commenced as an independent statutory authority on 1 July 2011, funded jointly by the Australian Government and state and territory governments on a cost-sharing basis.

The Commission's purpose is to lead and coordinate national improvements in the safety and quality of health care. This contributes to better health outcomes and experiences for all patients and consumers, and improved value and sustainability in the health system. Within this overarching purpose, the Commission aims to ensure that people are kept safe when they receive health care and that they receive the care they should.

The Commission works in partnership with patients, consumers, clinicians, managers, policymakers and health service organisations to achieve a sustainable, safe and high-quality health system.

National Safety and Quality Health Service Standards

To protect the public from harm and improve the quality of health service provision, the Commission developed the National Safety and Quality Health Service (NSQHS) Standards[1,2] in collaboration with the states and territories, clinical experts, patients and

consumers. The NSQHS Standards provide a quality assurance mechanism that tests whether relevant systems are in place to ensure that expected standards of safety and quality are met. They provide a nationally consistent statement about the standard of care that consumers can expect from their health service organisations.

There are eight NSQHS Standards, which cover clinical governance, partnering with consumers, preventing and controlling infection, medication safety, comprehensive care, communicating for safety, blood management, and recognising and responding to acute deterioration.

The Preventing and Controlling Infection Standard was reissued in 2021 to incorporate lessons learned from the response to COVID-19. The revised standard better supports health service organisations to prevent, control and respond to infections that cause outbreaks, epidemics or pandemics, in addition to healthcare-associated infections (HAIs). This standard requires health service organisations to monitor patterns of HAIs, AMR and AU, and use this information to guide antimicrobial stewardship (AMS) practices and meet infection prevention and control requirements. Data from the AURA Surveillance System directly support this standard. The Commission has developed a number of national programs that focus on prevention and control of HAIs, and quality improvement through AMS activities.

About the AURA Surveillance System

The AURA Surveillance System provides essential information to inform strategies for preventing and containing AMR in human health, and improving AU across the acute and community healthcare settings. Funding for the AURA Surveillance System during the period covered by AURA 2021 was provided by the Department, and state and territory health departments.

The role of the AURA Surveillance System is described in Box 1.1. The Commission's AURA National Coordination Unit (NCU) developed the system after consulting stakeholders about the requirements for an effective national system and reviewing the capacity of existing surveillance systems. The system was implemented by partnering with existing AMR and AU surveillance programs, and establishing extra programs, as required. Contracts were established with several partners to specify data requirements, and enable development of a comprehensive picture of patterns and trends in AU and AMR. Collaboration continues with a variety of stakeholders to build and improve surveillance infrastructure, and to coordinate data collection, analysis and reporting on AMR and AU. Elements of the AURA framework are described in Figure 2.1 in Chapter 2.

Improvements to the AURA Surveillance System

The Commission's overall strategic objective in conducting AURA is to develop and sustain a comprehensive, representative and robust surveillance system. Substantial effort is invested to continue to increase participation and to deal with gaps in surveillance, either geographically or for clinical and community settings. This fourth national report provides details on several areas where the power of AURA data has grown.

When gaps are identified that require new systems, or enhancements to existing systems, the Commission takes action to respond. New systems developed by the Commission for AURA include the National Alert System for Critical Antimicrobial Resistances (CARAlert) in 2016, and the Australian Passive AMR Surveillance (APAS) system in 2015. There has been continual

Box 1.1: Role of the AURA Surveillance System

The Antimicrobial Use and Resistance in Australia (AURA) Surveillance System, conducted by the Commission:

- Provides coordinated, effective and integrated surveillance and reporting of antimicrobial use (AU) and antimicrobial resistance (AMR) in Australia
- Continues to improve quality, coverage and utility of data collections on AU and AMR
- Provides increasingly detailed analysis across data collections, including analysis of relationships between AU and AMR, at a system level
- Provides systematic, coordinated and centralised national reporting on AU and AMR
- Ensures currency of data collections through the systematic and timely identification of the emergence of critical antimicrobial resistances
- Provides a means for rapidly consulting and communicating with states, territories and a variety of stakeholders to further improve the system and its reporting capabilities, and to continue to inform strategies for AMR prevention and control, and antimicrobial stewardship
- Promotes action in response to issues highlighted through the analysis and reporting of data, and assessment of the clinical implications of trends at local, state and territory, and national levels.

growth in the coverage and volume of data in both these systems.

CARAlert combines the information on critical antimicrobial resistances (CARs) that laboratories currently provide to clinicians with a system to inform health service program and system managers. This allows timely responses at the local and state and territory levels, if required, which supplement local data and response systems.

The Commission established APAS with the support of Queensland Health, which enabled access to the OrgTRx system as the information technology infrastructure. APAS collects information provided by laboratories to clinicians, and analyses and reports on de-identified patient-level AMR data contributed by 10 public and private pathology services across Australia. These laboratories detect AMR in isolates referred from public and private hospitals, aged care homes and community settings. Initially, data were captured from January 2015 from all contributing laboratories; historical data have now also been incorporated from four of these laboratories. Each of these laboratories has variable population coverage, ranging from all public facilities in Queensland, South Australia, Western Australia and the Australian Capital Territory, to one public health service in Victoria that provides care to one-quarter of Melbourne's population. APAS includes more than 70 million AMR records from 2005 to 2020.

The Commission continues to take a systematic approach to improving data representativeness, collection, analytics and accessibility by identifying gaps and targeting those areas for expansion. The AURA NCU also consults with stakeholders about further reports and analyses that would inform policy and practice. Since 2014, AURA publications have reported on increasingly comprehensive and complex aspects of AU and AMR in

public and private hospital, aged care and community settings across Australia. Data from AURA, and commentary on analyses of these data, have been provided to clinicians, policy and program developers, health service managers and executives, state and territory governments, and the Australian Government to inform policy and clinical practice, and support containment of AMR. The Commission also uses AURA data to identify priorities for quality improvement programs, and develop resources for infection prevention and control, and AMS.

Alignment with national strategies

In 2019, the Australian Government released Australia's second strategy on AMR, *Australia's National Antimicrobial Resistance Strategy: 2020 and Beyond* (the 2020 AMR Strategy).[3] This strategy builds on the first strategy from 2015 to address AMR using a One Health approach, encompassing food production, the environment, and other classes of antimicrobials such as antifungals and antivirals. The AURA Surveillance System provides the national response to the human health aspects of this One Health approach.

The AURA Surveillance System and the NSQHS Standards (especially the Preventing and Controlling Infection Standard) support safe and effective health care, and the following objectives of the 2020 AMR Strategy:

- Objective 2 – Prevention and control of infections and the spread of resistance
- Objective 3 – Greater engagement in the combat against resistance
- Objective 4 – Appropriate usage and stewardship practices
- Objective 5 – Integrated surveillance and response to resistance and usage.

Partners and contributors

The AURA NCU continued to work with the AURA Surveillance System foundation partners, in liaison with the Department, during the period covered by this report, to ensure both continuity and growth in the scope and representativeness of data. These partners include:

- Australian Group on Antimicrobial Resistance (AGAR)
- National Antimicrobial Prescribing Survey
- National Antimicrobial Utilisation Surveillance Program
- Queensland Health OrgTRx system, which is the technology platform for APAS.

In addition, data and reports are collated from:

- The National Neisseria Network, on *Neisseria gonorrhoeae* and *N. meningitidis*
- The National Notifiable Diseases Surveillance System, on *Mycobacterium tuberculosis*
- The Pharmaceutical Benefits Scheme (PBS) and the Repatriation Pharmaceutical Benefits Scheme (RPBS)
- The NPS MedicineWise MedicineInsight program
- Sullivan Nicolaides Pathology, on rates of AMR from the community and private hospital settings
- CARAlert (see Chapter 5 for more information about CARAlert).

Each of the historical partner programs provides valuable data on AU and AMR that cover selected organisms or antimicrobials from the community and hospitals. The programs use several methods, sampling techniques and sources, and have largely been set up to provide data at the local or state and territory levels for specific purposes. The coverage, capture and content of these data have varied over time.

However, each of these programs operates within the framework of AURA to provide an integrated and coordinated picture of AU and AMR in Australia that continues to improve as a result of increased participation and representativeness. Important functions of the AURA Surveillance System include coordinating data from across the public and private hospital, aged care and primary care settings; and engaging with providers to support the use of AURA data and reports to improve clinical practice, and prevent and contain AMR.

Important functions of the AURA Surveillance System include providing strategic direction; coordinating and supporting data collection from across the public and private hospital, aged care and primary care settings; and engaging with providers to support the use of AURA data and reports to improve clinical practice, and prevent and contain antimicrobial resistance.

To increase the breadth of resistance data from more remote geographical areas, the Commission has worked with the HOTspots project, which is part of HOT North, a research program funded by the National Health and Medical Research Council that aims to optimise disease surveillance. One of the key research elements is AMR surveillance in northern Australia.

Rates of many bacterial infections in northern Australia exceed rates in other parts of Australia. By working together with HOTspots and including these important data in AURA 2021, a broader picture of resistance across Australia can be gained. This provides further critical information to clinicians, laboratory scientists, microbiologists, public health authorities and policymakers.

From 1 January 2021, the Department assumed the overall coordination role for the AURA Surveillance System. This structural change is part of the move to a One Health Surveillance System.

AURA data and reporting

Several detailed reports on AMR and AU have been published by the AURA NCU since 2014, in addition to three comprehensive national reports in 2016, 2017 and 2019.[4-6] The patterns and trends identified in AURA reports guide improvements in infection control, AMS and antimicrobial prescribing practices. The key findings of these publications are incorporated in this report.

The AURA Surveillance System has created capacity to compare AU and AMR in Australia with data from some other countries, as described in Chapters 3 and 6. These types of comparisons are important for benchmarking. Comparable data on the volume of AU in the community are only available from European countries and Canada. However, national data on appropriateness of AU in community settings, which is a feature of AURA, are not yet available for any other countries or regions. Resistance rates for selected pathogens can only be compared with European countries at present, as Europe is the only region that regularly releases comparable data.

AURA Surveillance System data were part of the World Health Organization Global Antimicrobial Resistance Surveillance System (GLASS) for the first time in 2020, following a change in the GLASS requirements to allow receipt of aggregated data, without a denominator.[7]

In addition to gonococcal data submitted by the National Neisseria Network, data from AGAR 2019 Sepsis Outcome programs

were submitted on five pathogens from blood (*Staphylococcus aureus*, *Klebsiella pneumoniae*, *Escherichia coli*, *Acinetobacter* species and *Salmonella* species). Work is in progress to include APAS data in the 2021 GLASS submission.

1.2 Australian healthcare system: governance and context

Governance of the Australian healthcare system is a shared responsibility of the Australian Government and state and territory governments.[8] Their roles include funding, policy development, regulation and service delivery. In May 2020, the governance role formerly facilitated by the COAG Health Council and its advisory body, the Australian Health Ministers' Advisory Council (AHMAC) was superseded by a new set of arrangements led by a National Federation Reform Council (NFRC), with National Cabinet at the centre of the NFRC.[9] As a result, the COAG Health Council and AHMAC were replaced with (respectively) the National Cabinet Reform Committee (Health) and the Health Chief Executive Forum.

The Australian healthcare system is multifaceted. Services are provided by both the public and private sectors, and in institutional and community settings. Healthcare providers include individual clinicians such as doctors, nurses and allied health professionals, and organisational entities such as hospitals, primary care services, and government and non-government agencies.

State and territory governments license and regulate private hospitals that are operated by the private or not-for-profit sectors. All pathology laboratories must meet standards and requirements set by the National Pathology Accreditation Advisory Council to be accredited providers of services that are eligible for a Medicare rebate. The National Association of Testing Authorities assesses laboratories against these standards.

The Australian, state and territory governments each contribute funding to public hospitals. Public hospitals are managed by state and territory governments through Local Hospital Networks and Local Health Districts.

A suite of other services, including population health programs, community health services, health and medical research, and Aboriginal and Torres Strait Islander health services, are funded and delivered by combinations of the Australian Government and state and territory governments. The role of local government in health service delivery varies between states and territories.

Medicare is the Australian Government–funded universal health insurance scheme that provides access to free or subsidised healthcare services for the Australian population. It provides free hospital services for public patients in public hospitals, subsidises private patients for hospital services, and provides benefits for out-of-hospital medical services such as consultations with general practitioners (GPs) or specialists. The Australian Government also funds Primary Health Networks. GPs are important providers of health care in community settings, and most antimicrobial prescriptions in community settings are written by GPs.

The Australian Government's PBS and RPBS provide subsidised access to many medicines for all Australians. Under the PBS/RPBS, patient contributions towards medication costs at pharmacies are capped, and there is a Safety Net scheme to protect people with high medication needs.

1.3 Importance of antimicrobial resistance

AMR occurs when a microorganism develops resistance to an antimicrobial that was previously an effective treatment. As a result, infections caused by the resistant organism may need to be treated with other antimicrobials, which may have more severe side effects, be more expensive or take longer to work. People with infections caused by more resistant bacteria spend longer times in hospitals, and their infections take longer to resolve. In some severe cases, resistant organisms may not be able to be treated by currently available antimicrobials, and more people may die as a result.

International evidence consistently demonstrates the growing effect that AMR is having on human health, and studies confirm that increasing numbers of infections in health service organisations and in the community are caused by resistant pathogens. The Organisation for Economic Co-operation and Development (OECD) has estimated that, on average, 290 people die each year in Australia from infections caused by eight resistant bacteria. Between 2015 and 2050, it is estimated that 10,430 people will die as a result of AMR.[10]

Estimating the economic impact of AMR is complicated by the limited availability of data that allow comparative analyses. Most analyses of the costs of AMR in Australia are based on international data, such as the data produced by the OECD. The most recent OECD estimate is that, between 2015 and 2050, AMR will cost the health systems of the United States, Canada and Australia combined approximately $74 billion in United States dollar purchasing power parity.[10] An analysis undertaken in 2014 projected a continued rise in resistance by 2050 that would lead to 10 million people dying every year and a reduction of 2–3.5% in gross domestic product.[11] The safety of medical procedures will be affected across all countries surveyed by the OECD – between 44,000 and 439,000 additional postoperative infections will occur as a result of reduced effectiveness of antimicrobials.[11]

1.4 Importance of surveillance

Comprehensive and coordinated surveillance is a critical requirement of efforts to control AMR. The information generated through the AURA Surveillance System informs and supports national, state and territory, and local strategies to prevent and contain AMR. Successive international and Australian reports on AMR have identified the effective coordination of national surveillance as a foundation for reducing the adverse effects of AMR. Slowing the rate of increase in resistance, preparing for and responding to new and emerging threats, and ensuring that antimicrobials are used appropriately are all components of the Commission's work, informed by AURA Surveillance System data, to ensure the safety and quality of health care in Australia. Broader health system benefits will also be gained through reduced length of stay in hospitals and more efficient use of bed capacity.

Use of surveillance data can result in earlier detection of, and response to, CARs and may reduce overall population impact in an outbreak. The Commission's leadership in developing an AMR outbreak response model, in collaboration with states and territories and the Department, will be supported by AURA Surveillance System data.

Readier access to relevant data on AMR and AU will more effectively inform policy decisions, such as development or revision of antimicrobial prescribing guidelines. It will also help identify priorities for public health action, such as education campaigns

or regulatory measures. For example, the AURA NCU has worked with the developers of *Therapeutic Guidelines: Antibiotic* to provide a variety of AURA Surveillance System data to inform review of antimicrobial treatment protocols.

A lack of surveillance, or poor or ineffective reporting, can lead to misdirected and inefficient policies and programs, along with poor use of resources through inappropriate or ineffective therapies. Importantly, these deficits can also lead to increased morbidity and mortality for patients.

Reporting the information gained from an effective surveillance program to policymakers and clinicians will have positive effects at all levels of the health system. At a policy level, programs will be better targeted at the areas of greatest need, improving their effect and efficiency. At a patient care level, information that is robust and accessible may contribute to more effective prescribing, creating the potential for better health outcomes and reduced healthcare costs.

Reporting the information gained from an effective surveillance program to policymakers and clinicians will have positive effects at all levels of the health system.

1.5 AURA 2021 report

AURA 2021 is the fourth national AURA report. It builds on three national reports from 2016, 2017 and 2019. AURA 2021 provides more detail than previous reports about the key AMR issues for Australia, with a greater breadth of data on the most frequently used antimicrobials and a designated group of priority organisms. The report includes data and analyses on patterns and trends:

- For antimicrobial prescribing and dispensing in hospitals and the community
- For the appropriateness of antimicrobial prescribing
- For resistance in priority organisms to key antimicrobials in acute care, aged care homes and the community
- To provide evidence to inform state and territory AMR prevention and containment strategies.

AURA 2021 highlights some issues for AU and AMR in Australia, comparisons with other countries, and a preliminary analysis of the impact of COVID-19 on community AU.

This report integrates data from many programs and organisations, and reflects participation from all states and territories, and the private sector. Details on the data sources and methods for individual collections are included in Chapter 2 and Appendix 1.

The Commission continues to engage new participants and partners to strengthen the integrity and utility of the AURA Surveillance System. The Commission's AURA team will continue to work with each of the partner programs, the states and territories, the Australian Government, the private sector and clinicians, within the new structural arrangements, to ensure that participation continues to grow, and that data are increasingly consistent and comparable. Data will also be analysed from medical, scientific and epidemiological perspectives to inform response strategies. The Commission's governance arrangements, clinician networks, and relationships with consumers and governments enable information to be reported in formats that will be most useful to these diverse audiences.

The Commission thanks each of the organisations and networks that collaborate

with it to contribute to the overall value and effectiveness of the AURA Surveillance System, and to the many reports that support AMR prevention and containment strategies across Australia. The Commission continues to actively encourage greater participation and use of the surveillance data by all those involved in health service delivery.

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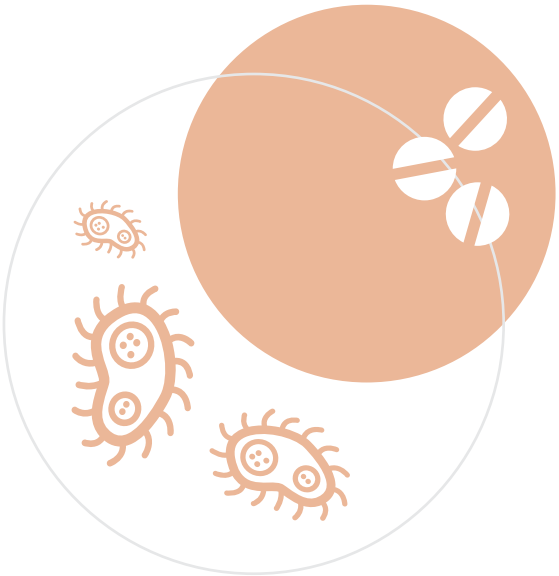

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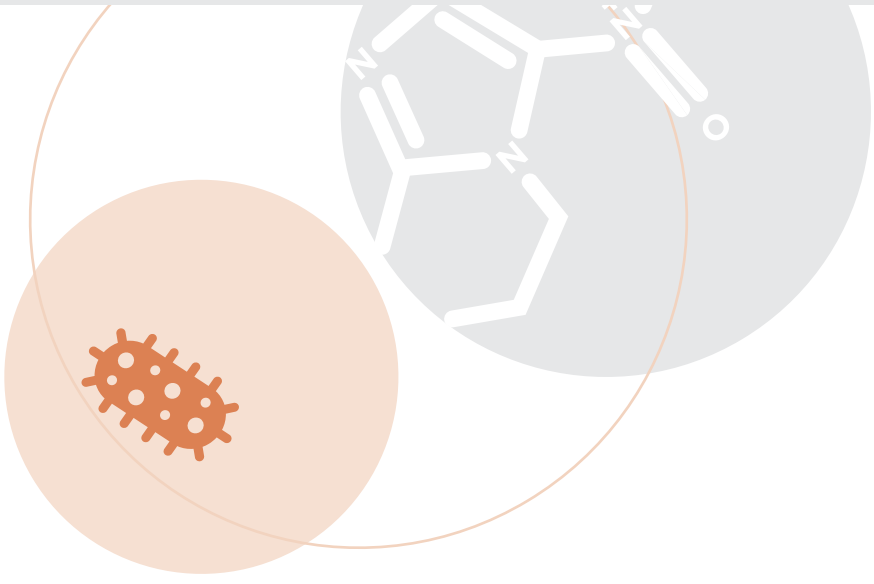
Chapter 2
Data sources and methods

Key messages

- The Antimicrobial Use and Resistance in Australia (AURA) Surveillance System is Australia's national surveillance system. It captures data on antimicrobial use (AU) and antimicrobial resistance (AMR) from hospital and community settings using both passive and targeted systems.
- The Australian Commission on Safety and Quality in Health Care (the Commission) has managed the AURA Surveillance System since it established the system in 2014.
- Data on AU and appropriateness of prescribing are sourced from the National Antimicrobial Prescribing Survey, the National Antimicrobial Utilisation Surveillance Program, the NPS MedicineWise MedicineInsight program, the Pharmaceutical Benefits Scheme and the Repatriation Pharmaceutical Benefits Scheme.
- Data on AMR are sourced from the Australian Group on Antimicrobial Resistance, Australian Passive AMR Surveillance, the National Neisseria Network, the National Notifiable Diseases Surveillance System, Sullivan Nicolaides Pathology and the National Alert System for Critical Antimicrobial Resistances.



The Australian Commission on Safety and Quality in Health Care (the Commission) has a longstanding and well-established approach to working collaboratively with the states and territories, clinicians, the private sector, consumers and a range of stakeholders to improve the safety and quality of health care. The Commission's Antimicrobial Use and Resistance in Australia (AURA) National Coordination Unit (NCU) has used this approach to establish and develop the AURA Surveillance System as a voluntary system, as there is no requirement for organisations to participate or provide data.

The AURA NCU continued to work in collaboration with many organisations and programs to specify the data and information required to provide a comprehensive dataset, and to coordinate all elements of the AURA Surveillance System to achieve effective performance over the period covered by this report.

The overall objective of the AURA Surveillance System is to maximise geographic coverage – coverage of both the community and acute sectors, and across the private and public sectors – to achieve greater representativeness. Participation in each of the surveillance components is progressively increasing to continually improve the utility of the system. The collection methods, analyses and documentation of any limitations of the use of the data will also continue to be refined. Effective coordination, timely analysis and accurate reporting by the Commission continue to inform strategies for local, state and territory, and national health systems. Opportunities to enhance the AURA Surveillance System continue to be identified to further improve the capacity to prevent and contain antimicrobial resistance (AMR).

This chapter describes the types and sources of data used in the AURA Surveillance System.

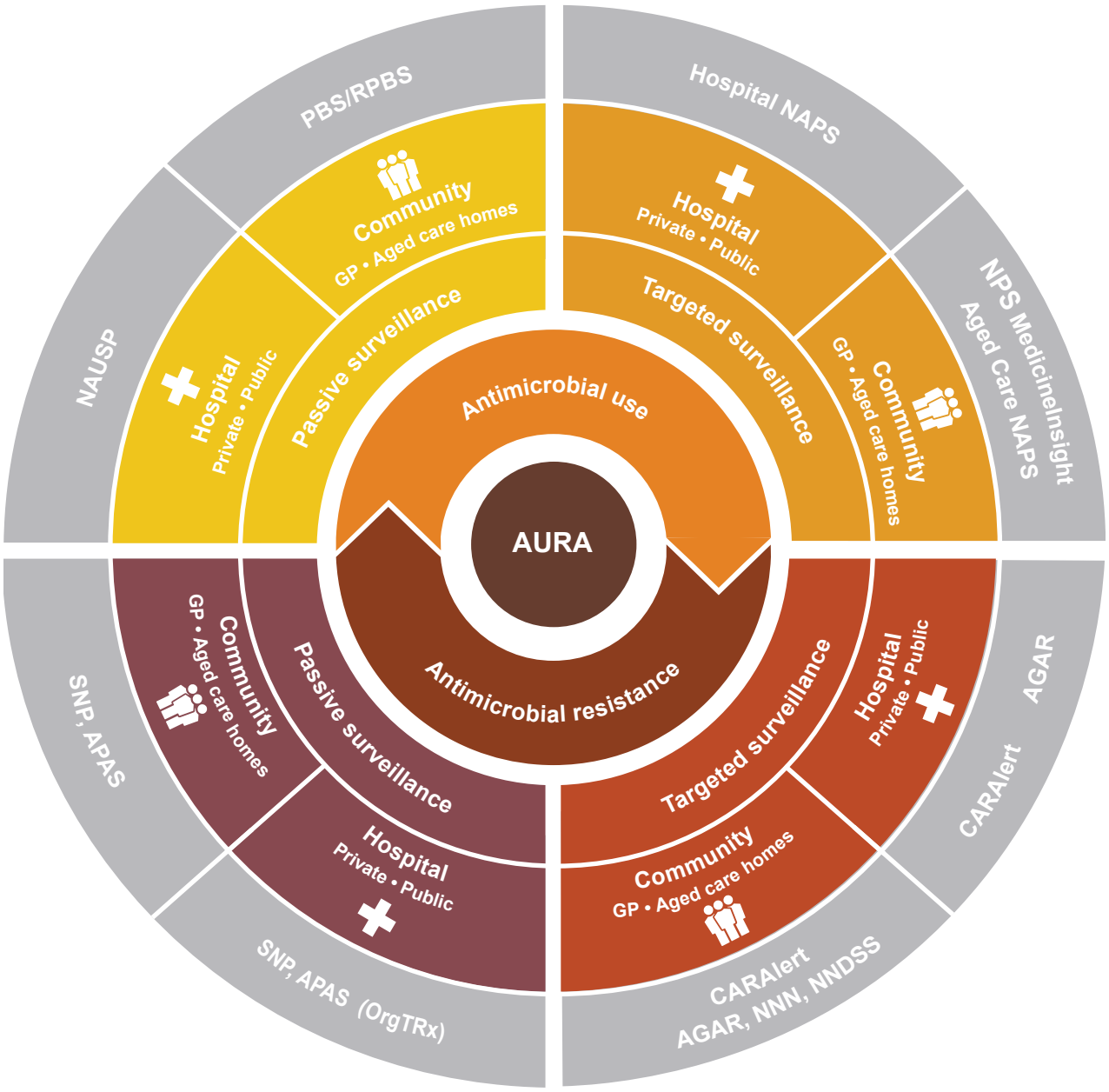
2.1 Types of data and information collected under the AURA Surveillance System

The framework for, and the components of, the AURA Surveillance System are shown in Figure 2.1, along with data sources. This report includes available and validated data, predominantly from 2018 and 2019. However, to review patterns of use, NPS MedicineWise MedicineInsight program data on antimicrobial use (AU) in the community, and Pharmaceutical Benefits Scheme (PBS) data from between 2015 and 2019, are included. Data from the National Alert System for Critical Antimicrobial Resistances (CARAlert) from 2020 are also included.

AURA uses a combination of passive and targeted surveillance to achieve comprehensive and effective surveillance, and to support timely and appropriate response strategies. Passive surveillance is the use of data that are already collected for other purposes to identify patterns and trends in AMR and AU. Targeted surveillance is where the primary purpose of collecting data is to identify trends and patterns in AMR and AU.

Surveillance data are collected from the hospital and community sectors (Figure 2.1). Table 2.1 summarises the data sources, the type of surveillance undertaken, the types of data sourced, and the settings and coverage of data included in AURA 2021. Further detail on the data sources for this report, including details of collection methods, are in Appendix 1.

Figure 2.1: The AURA Surveillance System



AGAR = Australian Group on Antimicrobial Resistance; APAS = Australian Passive AMR Surveillance; CARAlert = National Alert System for Critical Antimicrobial Resistances; GP = general practitioner; NAPS = National Antimicrobial Prescribing Survey; NAUSP = National Antimicrobial Utilisation Surveillance Program; NNDSS = National Notifiable Diseases Surveillance System; NNN = National Neisseria Network; PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme; SNP = Sullivan Nicolaides Pathology

Table 2.1: Data sources for the AURA 2021 report

Subject and type of surveillance	Data source	Type of data	Setting	Coverage
 Antimicrobial use Targeted Community	MedicineInsight	Appropriateness of prescribing, prescribing patterns	Australian general practices	All states and territories 2015: 393 general practices, 1,865,688 patients 2016: 405 general practices, 1,926,591 patients 2017: 410 general practices, 1,988,760 patients 2018: 411 general practices, 2,030,045 patients 2019: 412 general practices, 2,081,855 patients
	Aged Care National Antimicrobial Prescribing Survey	Appropriateness of prescribing, prescribing volume, infections	Australian aged care homes and multi-purpose services	All states and territories since 2018 2016: 287 facilities 2017: 292 facilities 2018: 407 facilities 2019: 568 facilities
 Antimicrobial use Targeted Hospital	Hospital National Antimicrobial Prescribing Survey	Appropriateness of prescribing, prescribing volume	Australian public and private hospitals	All states and territories, public and private hospitals 2016: 325 hospitals (229 public, 91 private)* 2017: 314 hospitals (228 public, 86 private) 2018: 326 hospitals (233 public, 93 private) 2019: 377 hospitals (268 public, 109 private)
	Surgical National Antimicrobial Prescribing Survey	Appropriateness of prescribing, prescribing volume	Australian public and private hospitals	All states and territories, public and private hospitals 2017: 106 hospitals (56 public, 50 private) 2018: 112 hospitals (64 public, 48 private) 2019: 144 hospitals (74 public, 70 private)

continues

Table 2.1: *continued*

Subject and type of surveillance	Data source	Type of data	Setting	Coverage
 Antimicrobial use Passive Community	Pharmaceutical Benefits Scheme and Repatriation Pharmaceutical Benefits Scheme	Dispensed volume, trends	Australian general practices and community health services	National 2016: 27,324,648 prescriptions for all antibiotics 2017: 26,553,451 prescriptions for all antibiotics 2018: 26,229,366 prescriptions for all antibiotics 2019: 26,669,561 prescriptions for all antibiotics
 Antimicrobial use Passive Hospital	National Antimicrobial Utilisation Surveillance Program	Dispensed volume	Australian public and private hospitals	All states and territories, public and private hospitals 2016: 169 hospitals (143 public, 26 private), including all Principal Referral Hospitals 2017: 191 hospitals (155 public, 36 private), including all Principal Referral Hospitals 2018: 212 hospitals (169 public, 43 private), including all Principal Referral Hospitals 2019: 219 hospitals (170 public, 49 private), including all Principal Referral Hospitals

continues

Table 2.1: *continued*

Subject and type of surveillance	Data source	Type of data	Setting	Coverage
 Antimicrobial resistance Targeted Community	Australian Group on Antimicrobial Resistance	Rates of resistance, 30-day all-cause mortality	Australian public and private hospitals (community onset)	All states and territories 2016: 28 laboratories servicing 32 hospitals and their communities 2017: 29 laboratories servicing 36 hospitals and their communities 2018: 29 laboratories servicing 36 hospitals and their communities 2019: 29 laboratories servicing 39 hospitals and their communities
	CARAlert	Rates of resistance for priority organisms	Australian general practices, aged care homes, community health services and hospital non-admitted care services	National 28 confirming laboratories
	National Notifiable Diseases Surveillance System	Rates of resistance and trends for *Mycobacterium tuberculosis*	Australian general practices, community health services and hospital non-admitted care services	National 5 reference laboratories
	National Neisseria Network	Rates of resistance and trends for *Neisseria gonorrhoeae* and *N. meningitidis*	Australian general practices, community health services and hospital non-admitted care services	National 9 reference laboratories

continues

Table 2.1: *continued*

Subject and type of surveillance	Data source	Type of data	Setting	Coverage
 Antimicrobial resistance Targeted Hospital	Australian Group on Antimicrobial Resistance	Rates of resistance, 30-day all-cause mortality	Australian public and private hospitals (hospital onset)	National 2016: 28 laboratories servicing 32 hospitals 2017: 29 laboratories servicing 36 hospitals 2018: 29 laboratories servicing 36 hospitals and their communities 2019: 29 laboratories servicing 39 hospitals and their communities
	CARAlert	Rates of resistance for priority organisms	Australian public and private hospitals	National 28 confirming laboratories
 Antimicrobial resistance Passive Community	Australian Passive AMR Surveillance	Rates of resistance	Community and aged care homes	Each of the laboratory services provides access to a range of resistance testing for primary care and non-admitted hospital patients. Laboratories estimated that testing for the community sector represents 30–85% of their workload
	Sullivan Nicolaides Pathology	Rates of resistance	Community and aged care homes	Queensland and northern New South Wales
 Antimicrobial resistance Passive Hospital	Australian Passive AMR Surveillance	Rates of resistance	Australian Capital Territory, New South Wales, Queensland, South Australia, Tasmania, Victoria, Western Australia	All Queensland public hospitals; Mater Pathology Brisbane (selected private hospitals, Queensland); all public hospitals and private hospitals in South Australia; selected public hospitals and health services in the Australian Capital Territory, New South Wales, Tasmania, Victoria and Western Australia
	Sullivan Nicolaides Pathology	Rates of resistance	Queensland and northern New South Wales	Queensland and northern New South Wales

AMR = antimicrobial resistance; CARAlert = National Alert System for Critical Antimicrobial Resistances

* For the 2016 Hospital National Antimicrobial Prescribing Survey (NAPS) report, analyses were included for 320 hospitals (229 public and 91 private) that contributed data during the data collection period of 1 March 2016 to 2 February 2017.[1] In 2017, the Hospital NAPS data collection period was the calendar year 1 January 2017 to 31 December 2017. The National Centre for Antimicrobial Stewardship reanalysed data for 2016 and 2017 for the 2017 Hospital NAPS report, based on the calendar year in which the data were collected; the analyses included 325 hospitals that contributed data between 1 January 2016 and 31 December 2016 (234 public and 91 private).[2]

2.2 Sources of data for antimicrobial use and appropriateness of prescribing

Chapter 3 describes patterns and trends in AU and appropriateness of prescribing, based on data collected by four programs:

1. **National Antimicrobial Prescribing Survey (NAPS)**
   NAPS is a voluntary online audit performed annually by hospitals and aged care homes to assess antimicrobial prescribing practices and appropriateness of prescribing. National data are reported annually. Participating hospitals and aged care homes can interrogate their own data and undertake benchmarking using the audit tool. The methodology for the Hospital NAPS has varied each year since 2013 when the audit was piloted, so results are not directly comparable from year to year.
2. **National Antimicrobial Utilisation Surveillance Program (NAUSP)**
   NAUSP is a voluntary continuous data collection program conducted by hospitals using their dispensing systems to monitor the volume of AU. Participating hospitals can interrogate data and generate reports on local practice at any time. NAUSP analyses and reports on AU data every six months for states and territories, and hospital peer groups; this further supports opportunities for benchmarking.
3. **NPS MedicineWise MedicineInsight program**
   MedicineInsight is a large general practice dataset, originally established to support quality improvement in Australian primary care and post-market surveillance of medicines. MedicineInsight consists of monthly longitudinal, de-identified, whole-of-practice data extracted from the clinical information systems of consenting general practices across Australia. The program aims to support quality improvement by providing local data to general practices. The data can be benchmarked at local, regional and national levels. Participating practices are offered customised quality improvement activities that support alignment with best practice and identify key areas for improvement.
4. **Pharmaceutical Benefits Scheme (PBS) and Repatriation Pharmaceutical Benefits Scheme (RPBS)**
   Data on antimicrobials dispensed under the PBS and RPBS are analysed for AURA reports. For AURA 2021, these data were obtained from the Australian Government Department of Human Services.

The AURA NCU has established effective working relationships with each of these programs and organisations to specify the data to be included in the surveillance, as part of AURA. Together, these data sources reflect AU and the appropriateness of prescribing in public and private hospitals, and in the community across Australia. Publishing these data and analyses, and working with the states and territories to highlight trends and patterns of use, will inform local, and state and territory antimicrobial stewardship programs, and direct more effective strategies to improve prescribing.

2.3 Sources of data for antimicrobial resistance

Chapter 4 describes rates of resistance for priority organisms and trends over time, based on data collected by six programs:

1. **Australian Group on Antimicrobial Resistance (AGAR)**
   AGAR collects, analyses and reports on data on priority organisms, including *Enterobacterales*, *Enterococcus* species, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Acinetobacter* species.

Data are reported nationally for three AGAR programs every year, both individually and in an amalgam report prepared by the AURA NCU in collaboration with AGAR.

2. **National Alert System for Critical Antimicrobial Resistances (CARAlert)**
   CARAlert collects surveillance data on nationally agreed priority organisms that are resistant to last-line antimicrobial agents, and provides timely information to states and territories to support response action.
3. **Australian Passive AMR Surveillance (APAS)**
   APAS was established in collaboration with Queensland Health, and uses the OrgTRx system to collect, analyse and report on AMR data from hospitals and private pathology services. Participants include Pathology Queensland; ACT Pathology (Australian Capital Territory); Monash Health (Victoria); New South Wales (NSW) Health Pathology laboratories that provide services to the Hunter New England, Illawarra Shoalhaven, Mid North Coast, Northern NSW, South Eastern Sydney, South Western Sydney and Sydney Local Health Districts, and the Sydney Children's Hospitals Network (Randwick); SA Pathology (South Australia); Royal Hobart Hospital (Tasmania); PathWest Laboratory Medicine (Western Australia); and Mater Pathology Brisbane (Queensland). APAS participants have timely access to their own data, enabling local reports to be generated to better understand local patterns of resistance. The Commission continues to work with all state and territory health authorities and several private pathology services to achieve nationwide participation in APAS and enhance national surveillance coverage.
4. **National Neisseria Network (NNN)**
   The NNN conducts the national laboratory surveillance programs for *Neisseria gonorrhoeae* and *N. meningitidis*. Data from the NNN programs are published in the journal *Communicable Diseases Intelligence*.
5. **National Notifiable Diseases Surveillance System (NNDSS)**
   The NNDSS collects data on *Mycobacterium tuberculosis*. Data are published in the journal *Communicable Diseases Intelligence*. The Australian Mycobacterium Reference Laboratory Network provides antimicrobial susceptibility data on *M. tuberculosis* isolates to state and territory public health units for inclusion in the NNDSS.
6. **Sullivan Nicolaides Pathology (SNP)**
   SNP collects data on organisms in the community, acute facilities and aged care homes in Queensland and northern NSW. SNP has worked collaboratively with the AURA NCU to provide AMR reports since the AURA Surveillance System began.

Further detail on each of these data sources is provided in Appendix 1.

Chapter 5 includes reporting on critical antimicrobial resistances collected through CARAlert.

2.4 Considerations for interpreting the data

The AURA Surveillance System continues to expand the breadth of AMR and AU surveillance data for the hospital and community sectors. Although the AURA reports have improved access to a range of data not previously available, such as resistance data for populations across Australia, several considerations should be noted in interpreting the data.

Further information on data sources and interpretation is available in Appendix 1.

Percentages and other data relating to 2015–2017 may have changed compared with previous reports as more data have become available.

To improve the understanding of AMR in remote areas, the AURA NCU has collaborated with the HOTspots program. Highlights are reported in Chapter 6 of this report.

With continued maturation of the datasets available through AURA, long-term trend analyses are available for some programs, including NAUSP and APAS. However, there are not yet enough longitudinal data to perform time-series analyses for all components of AURA. Comparisons across years can be made within this report, but continual enhancements and changes to the data sources may affect comparisons between different reports.

The AURA NCU continues to work with health service organisations, and states and territories to expand the range of data provided, but participation in the AURA Surveillance System remains voluntary.

Denominator data

Denominator data are not available for all the AURA partner programs for several reasons, and the most appropriate choice of denominator depends on the intended purpose of the analyses. For example, estimates of the proportion resistant for each species are used to determine the probability of failure with primary treatment and inform guidelines about primary therapeutic choices, whereas estimates of the burden of resistance, overall and by syndrome, are used to determine the extent of the problem.

In hospitals, laboratory information systems and patient information systems are usually separate. Laboratory information systems, PBS data and general practice desktop software each collect specific data from various sources, and important privacy considerations relate to any proposal for data linkage. Similarly, the PBS database is separate from the Medicare Benefits Schedule database, with the same privacy considerations related to data linkage. As a result, the AURA NCU considers each data request and analysis based on individual requirements and in consultation with the program leads, and includes the most appropriate assumptions and qualifications with the results of analyses.

Finally, the populations served by individual hospitals, networks and laboratories cannot be precisely defined. A Principal Referral Hospital may provide a full range of services to a reasonably well-defined ‘local’ geographical catchment population of around 1 million people, but will also provide additional, more highly specialised services to an entire state, and potentially the whole of Australia. Similarly, a population of 5 million people in the community may be served by five different laboratory services, with the populations served by each laboratory being quite different.

Antimicrobial resistance

AMR data have expanded across all components of AURA, particularly throughout 2019. Data from the community sector, including aged care homes, are more limited, and the AURA NCU will continue to focus on this sector to increase the volume and breadth of resistance data captured for future AURA reports.

Passive surveillance data on AMR in public and private hospitals are gathered by APAS through voluntary agreements with Local

Hospital Networks and Local Health Districts or the states and territories, and selected private sector pathology services. For 2018 and 2019, the coverage is as shown in Table 2.1, and has now grown to more than 75 million records.

There are also variations in testing practice. For example, many hospital patients have susceptibility testing performed if a specimen is accessible. In contrast, few community patients have susceptibility testing performed, even if a specimen is accessible.

Antimicrobial use

Prescribing data presented in this report are an indication of the volume and appropriateness of prescribing. Prescribing data can differ from dispensing data because not all prescriptions are dispensed.

The proportion of prescriptions written in the community that are captured by the PBS and RPBS is estimated[3] to be more than 90%, although the exact percentage is not known. The PBS and RPBS also capture public hospital outpatient and discharge prescriptions in all states and territories except NSW. The PBS and RPBS do not capture data on private prescriptions, or from the majority of Aboriginal and Torres Strait Islander health services.

Both NAPS and NAUSP rely on voluntary contribution of data through agreements with the states and territories, and the private sector. The number of contributors to each program has steadily increased each year.

The NPS MedicineWise MedicineInsight program also relies on voluntary participation and submission of data from general practices. Practices are enrolled in the MedicineInsight program using opportunistic, non-random sampling methods. As such, the proportion of enrolled practices within Australian jurisdictions varies, and comparisons between states and territories should be interpreted carefully. The number of enrolled practices contributing data month-to-month also varies. However, this generally arises due to technical or logistical reasons and can be considered to be random.

Enhancements to the MedicineInsight data warehouse since AURA 2019 may result in variations in the number of conditions and prescriptions identified in this report compared with AURA 2019. Comparisons of data between years should therefore only be made within this report.

2.5 Data governance

The Commission's Data Governance Framework provides guidance on data acquisition, maintenance, sharing and permissions, reporting and publication.

The framework provides the basis for developing and implementing data management policies, and provides guidance for all the data collections managed and coordinated by the Commission, including the AURA Surveillance System. The framework covers:

- Key data governance concepts, including collection, handling and reporting of data in compliance with legislative, regulatory and policy requirements
- Commission structures and roles to support good data management practices
- Key data management principles
- An overview of policies, guidelines and procedures, including integrated data management.

As part of its partnership approach and contracting arrangements, the AURA Surveillance System has established protocols to ensure the integrity and security of the data it uses. These arrangements also ensure that data conform to appropriate standards

of data management and quality, and that data are used in accordance with appropriate approvals.

The entities that manage the data collections are the data custodians, and are responsible for:

- Approving access to, and use of, data collections
- Ensuring that data collections are protected from unauthorised access, alteration or loss
- Advising data users on use of the data, including any caveats
- Ensuring compliance with relevant legislation and policies regarding administration, quality assurance, and data access and release.

The data collections and systems that now form the AURA Surveillance System were originally established for different purposes, such as health service quality improvement, research or statistical analysis.

The Commission's data governance arrangements apply to all data requested, collected or funded by the Commission. As a result, each AURA data custodian is required to ensure that data management policies, guidelines and procedures are in place for data collection, including for:

- Data governance
- Data development
- Data acquisition, storage and management
- Data security
- Data quality management
- Data processing
- Data disclosure and reporting
- Metadata management.

The Commission continues to work with each of its partners and contracted suppliers of data and reports to improve standardisation of data definitions, comparability of data items, development of new data items, and analytical methodologies. The Commission will also continue to identify opportunities to reduce duplication of, and effort associated with, data systems and provision of data by health services, and to increase the utility of the systems.

References

1. National Centre for Antimicrobial Stewardship, Australian Commission on Safety and Quality in Health Care. Antimicrobial prescribing practice in Australian hospitals: results of the 2016 Hospital National Antimicrobial Prescribing Survey. Sydney: ACSQHC; 2018 (accessed May 2021).
2. National Centre for Antimicrobial Stewardship, Australian Commission on Safety and Quality in Health Care. Antimicrobial prescribing practice in Australian hospitals: results of the 2017 Hospital National Antimicrobial Prescribing Survey. Sydney: ACSQHC; 2018 (accessed May 2021).
3. Drug Utilisation Sub Committee. Antibiotics: PBS/RPBS utilisation, Oct 2014 and Feb 2015 [Internet]. Canberra: Australian Government Department of Health; 2015 [updated 2015 May 29; cited 2021 Mar 4].

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Chapter 3
Antimicrobial use and appropriateness

Key findings

Hospitals

- In 2019, the total-hospital antibiotic use in hospitals that participated in the National Antimicrobial Utilisation Surveillance Program increased by 2.8% in comparison with the previous year. The usage rate increased from 848.2 defined daily doses (DDDs) per 1,000 occupied bed days (OBDs) in 2015 to 883.0 DDDs per 1,000 OBDs in 2019.
- The Priority Antibacterial List is a categorisation system used to stratify antibiotics according to preferred use to contain antimicrobial resistance in human health in Australia. This tool enables Australian hospitals to benchmark their use of antibiotics against other similar hospitals and to monitor their use over time. There is variability between states and territories and peer groups in the use of antibacterials with a higher risk of contributing to the development of antimicrobial resistance.
- The overall appropriateness of prescribing across all peer groups that participated in the National Antimicrobial Prescribing Survey (NAPS) was 75.8% in 2019. Overall appropriateness of prescribing has essentially remained static since 2013. However, appropriateness varied widely between peer groups, with improvements in some and deterioration in others.
- The Surgical NAPS demonstrated that documentation of antimicrobial administration time and incision time were the main issues for procedural surgical prophylaxis. For post-procedural surgical prophylaxis, the main issues were incorrect duration, dose and frequency of administration.
- Inappropriate topical antimicrobial use for surgical prophylaxis was identified by the Surgical NAPS. In 2019, 75.5% of topical antimicrobials used in procedural prophylaxis were deemed inappropriate, and 65.2% used in post-procedural prophylaxis were deemed inappropriate.

Community: primary care

- In 2019, 40.3% (*n* = 10,227,693) of the Australian population had at least one antimicrobial dispensed under the Pharmaceutical Benefits Scheme (PBS) or the Repatriation Pharmaceutical Benefits Scheme (RPBS).

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- Between 2015 and 2019, there was a gradual annual decline in the rate of antibiotic dispensing and a 14.8% decrease in the age-standardised rate of PBS/RPBS prescriptions per 1,000 people.
- The most commonly supplied antibiotics under the PBS/RPBS continue to be cefalexin, amoxicillin and amoxicillin–clavulanic acid.
- In patients aged less than 65 years, the highest rate of dispensing was for children aged 2–4 years.
- Approximately 50% of all antibiotic prescriptions were ordered with repeats; of those repeats, approximately half were filled within 10 days of the original prescription.
- The rate of systemic antimicrobial prescribing in participating MedicineInsight practices has steadily declined since 2010. However, antimicrobials continue to be overprescribed compared with guideline recommendations.
- In 2019, 31.2% of patients from participating MedicineInsight practices were prescribed systemic antimicrobials.
- A very high percentage of patients from participating MedicineInsight practices were prescribed antimicrobials for conditions for which there is no evidence of benefit, including acute bronchitis (81.5% of patients with this condition recorded) and sinusitis (80.1% of patients with this condition recorded).
- Differences in prescribing were found among age groups in participating MedicineInsight practices. Children aged 0–4 years were most commonly prescribed amoxicillin, and people aged 90–94 years were most commonly prescribed cefalexin. The most common indications for cefalexin prescribing were skin and wound infections, and urinary tract infections.

Community: residential aged care services

- Approximately 20% of antimicrobial prescriptions in residential aged care services that participated in the Aged Care National Antimicrobial Prescribing Survey (AC NAPS) were for prophylaxis. This is concerning because there are relatively few indications for antimicrobial use as prophylaxis in the aged care setting.
- Topical antimicrobials accounted for almost one-third (30.4%) of all prescriptions and almost 90% of PRN (as required) prescriptions. The most commonly prescribed antimicrobial was clotrimazole (74.1%).
- Almost 1 in 6 (15.0%) antimicrobials for residents of services that contributed to AC NAPS were prescribed for PRN administration. This may reduce clinical review of antimicrobial choice at the time of onset of infection, and delay decisions about treatment duration, leading to extended duration of treatment.
- Although there is variation from year to year in the cohort of AC NAPS contributors, there is no indication that the overall safety of antimicrobial use in services that contribute to AC NAPS has improved since 2015. However, there was an improvement in documentation of antimicrobial review or stop dates for residents of services that contributed to AC NAPS in 2019 (64.7%, compared with 58.9% in 2018).

continues

- The most common clinical indications for antimicrobial prescriptions were cystitis; skin, soft tissue or mucosal infections; pneumonia; tinea; and non-surgical wound infections. Many of these conditions can be prevented by managing hydration and providing good basic hygiene, rather than prescribing antimicrobials.
- Cefalexin, topical clotrimazole, amoxicillin–clavulanic acid, trimethoprim and doxycycline were the most commonly prescribed antimicrobials. Narrower-spectrum agents (for example, amoxicillin) are recommended over cefalexin or amoxicillin–clavulanic acid for many infections because they are less likely to promote antimicrobial resistance.

Inappropriate antimicrobial use (AU) can promote antimicrobial resistance (AMR) in individuals and the community. Surveillance of AU and appropriateness of prescribing are essential to inform AMR prevention and containment strategies.

This chapter provides analysis of data on AU, dispensing and appropriateness of prescribing in public and private hospitals, and in the community.

3.1 Antimicrobial use in hospitals

Two long-term surveillance programs provide data to the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System on the volume of antimicrobials dispensed, and the appropriateness of antimicrobial prescribing, in Australian public and private hospitals. These are the National Antimicrobial Utilisation Surveillance Program (NAUSP), which is conducted by SA Health, and the National Antimicrobial Prescribing Survey (NAPS), which is conducted by the National Centre for Antimicrobial Stewardship (NCAS). Together, these programs help health service organisations monitor the quantity and quality of their AU, and identify focus areas for their antimicrobial stewardship (AMS) programs. This assists them to meet the requirements of the Preventing and Controlling Infections Standard of the National Safety and Quality Health Service Standards. Both NAPS and NAUSP have been improved since they were incorporated into the AURA Surveillance System; geographic and peer group representativeness of hospitals that contribute data have been increased, and data collection and analysis processes have been streamlined.

Highlights of analyses of data on the volume of AU from the 2017–18 Biennial Supplement NAUSP report[1] and from the 2019 NAUSP report[2] have been summarised for AURA 2021. Hospitals contribute data on AU in adult acute-care settings to NAUSP on a voluntary basis. In 2018, 212 acute-care hospitals (169 public and 43 private) participated in NAUSP across Australia. In 2019, 219 acute-care hospitals (170 public and 49 private) participated in NAUSP. All Principal Referral Hospitals and 92% (98/106) of Public Acute Group A and Public Acute Group B hospitals participated in NAUSP in 2019.

AURA 2021 includes historical comparisons of data between and within states and territories, and comparisons of AU rates between hospital peer groups for selected classes of antimicrobials. Rates are expressed as defined daily doses (DDDs) per 1,000 occupied bed days (OBDs). Hospitals are classified into peer groups according to the November 2015 criteria of the Australian Institute of Health and Welfare.[3]

Highlights of analyses of data on appropriateness of antimicrobial prescribing in Australian hospitals from the 2018[4] and 2019[5] Hospital NAPS reports have been summarised for AURA 2021. There were 324 public and private hospital participants in the 2018 Hospital NAPS, and 377 participants in the 2019 Hospital NAPS. AURA 2021 also includes highlights of analyses of data on appropriateness of surgical antimicrobial prescribing in Australian hospitals from the 2019 Surgical NAPS report.[6]

Volume of use in hospitals

Total annual usage rates

NAUSP participation rates have increased since 2013 (Table 3.1), which has increased the representativeness and value of the data. Both public and private facilities from all states and territories contribute to NAUSP.

The annual total-hospital systemic antibiotic usage rate reported by NAUSP contributor hospitals has increased from 848.2 DDDs per 1,000 OBDs in 2015 to 883.0 DDDs per 1,000 OBDs in 2019. There was an increase of 2.8% in the total-hospital aggregate usage rate between 2018 and 2019 (Figure 3.1).

Antibiotic usage rates by state and territory

Figure 3.2 illustrates total-hospital antibiotic use for NAUSP contributors nationally and by state and territory in 2018 and 2019. Aggregate usage rates for 2019 were higher than rates in 2018 for every state and territory. The greatest increases occurred in South Australia (SA; 4.2%), Western Australia (WA; 3.9%) and Tasmania (3.8%).

Antimicrobial, antibacterial or antibiotic?

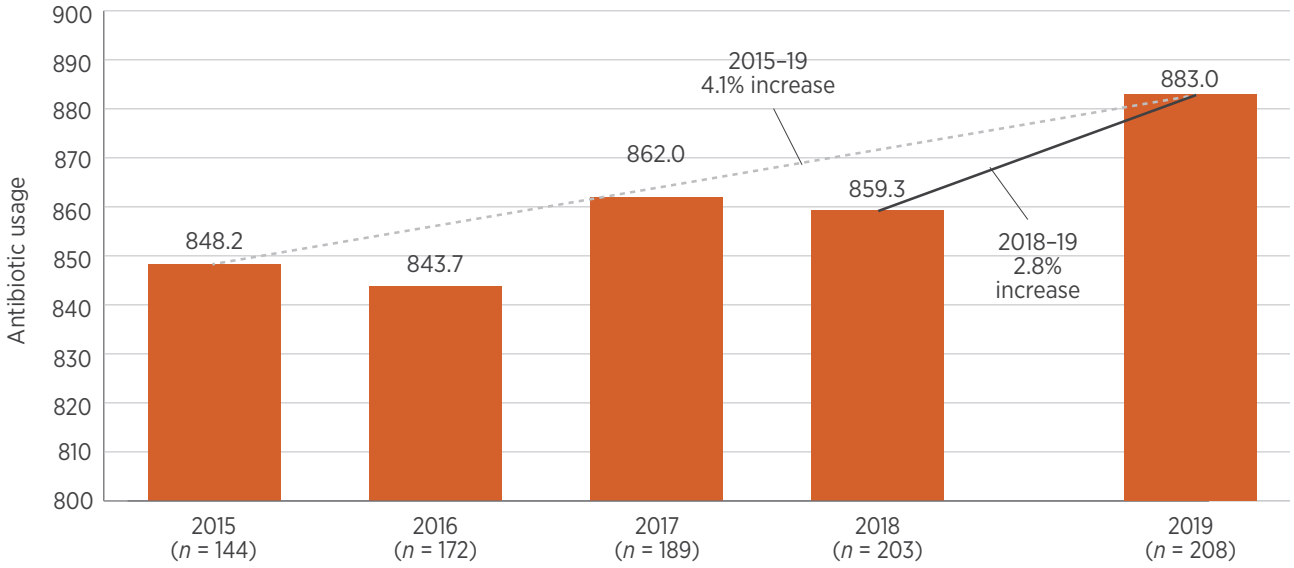
Confusion can arise about the terms antimicrobial, antibacterial and antibiotic. Antimicrobials include all antibiotics, antifungals, antivirals and antiparasitic agents. The terms antibacterial and antibiotic have the same meaning. In this chapter, except in relation to the Priority Antibacterial List, the term antibiotic is used to refer to antibacterials; the term antimicrobial is used unless the data being discussed relate specifically to antibiotics.

Table 3.1: NAUSP participation by public hospitals (by peer group) and private hospitals, 2015–2019

Year ending	Principal Referral Hospitals	Public Acute Group A Hospitals	Public Acute Group B Hospitals	Public Acute Group C Hospitals	All private hospitals	Specialist Women's Hospitals	Total
2015	30	55	36	13	19	4	157
2016	30	56	37	16	26	4	169
2017	30	58	37	26	36	4	191
2018	31	60	40	33	43	4	211
2019	31	60	38	38	49	4	220

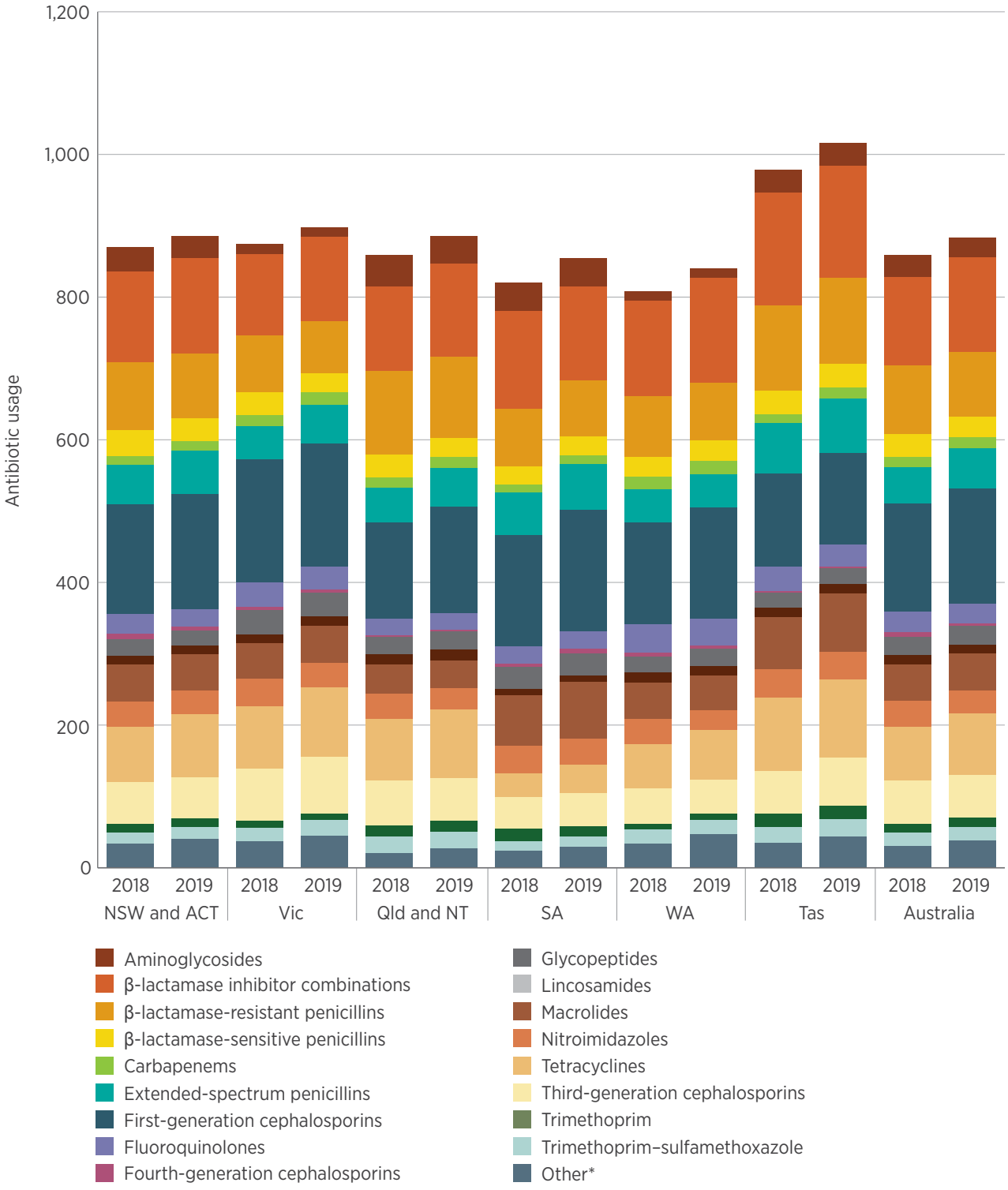
NAUSP = National Antimicrobial Utilisation Surveillance Program
Note: This table shows the number of hospitals registered to participate in NAUSP. Not all participating hospitals were able to provide validated data for the analyses in this report. Numbers shown may differ from those previously reported due to hospitals merging, closing or withdrawing from the program. In some instances where hospitals have been restructured, they have been reassigned to a new peer group, which may differ from the peer group published by the Australian Institute of Health and Welfare.
Source: NAUSP[2]

Figure 3.1: Annual total-hospital systemic antibiotic usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, 2015–2019



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Note: Rates (DDD/1,000 OBD) may vary slightly from previous reports as a result of retrospective usage data adjustments, the number of hospitals contributing to aggregate data and changes to DDD values assigned by the World Health Organization. Data on alimentary antibiotics were not collected by NAUSP before 2017.
Source: NAUSP[2]

Figure 3.2: Aggregate total-hospital antibiotic usage rates (DDD/1,000 OBD) by class in NAUSP contributor hospitals, by state and territory, 2018–2019



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

* Alimentary antibiotics, amphenicols, combinations for eradication of *Helicobacter pylori*, intermediate-acting sulfonamides, monobactams, nitrofurans, fosfomycin, linezolid, daptomycin, polymyxins, rifamycins, second-generation cephalosporins, steroids, streptogramins, streptomycins

Source: NAUSP[2]

The Priority Antibacterial List for Antimicrobial Resistance Containment (Priority Antibacterial List) was developed by the Australian Commission on Safety and Quality in Health Care (the Commission) in 2020 as a tool to support AMS (Table 3.2), in response to the action included in AURA 2019 to promote better compliance with treatment recommendations and improve all aspects of prescribing broad-spectrum antibacterials.[7] The Priority Antibacterial List aims to promote improved prescribing and reduce the total quantity of antibacterial use. It can be used for analysis of AU in terms of preferred or optimal prescribing choices, and to support analyses of usage surveillance data. The Priority Antibacterial List may also be used for local AMS programs in both hospital and community settings.

Using the Priority Antibacterial List provides additional information, which complements usage volume data for trend analyses. For example, the volume of use measured in DDDs per 1,000 OBDs may not change over time, but the proportionate use of restricted antimicrobials may change.

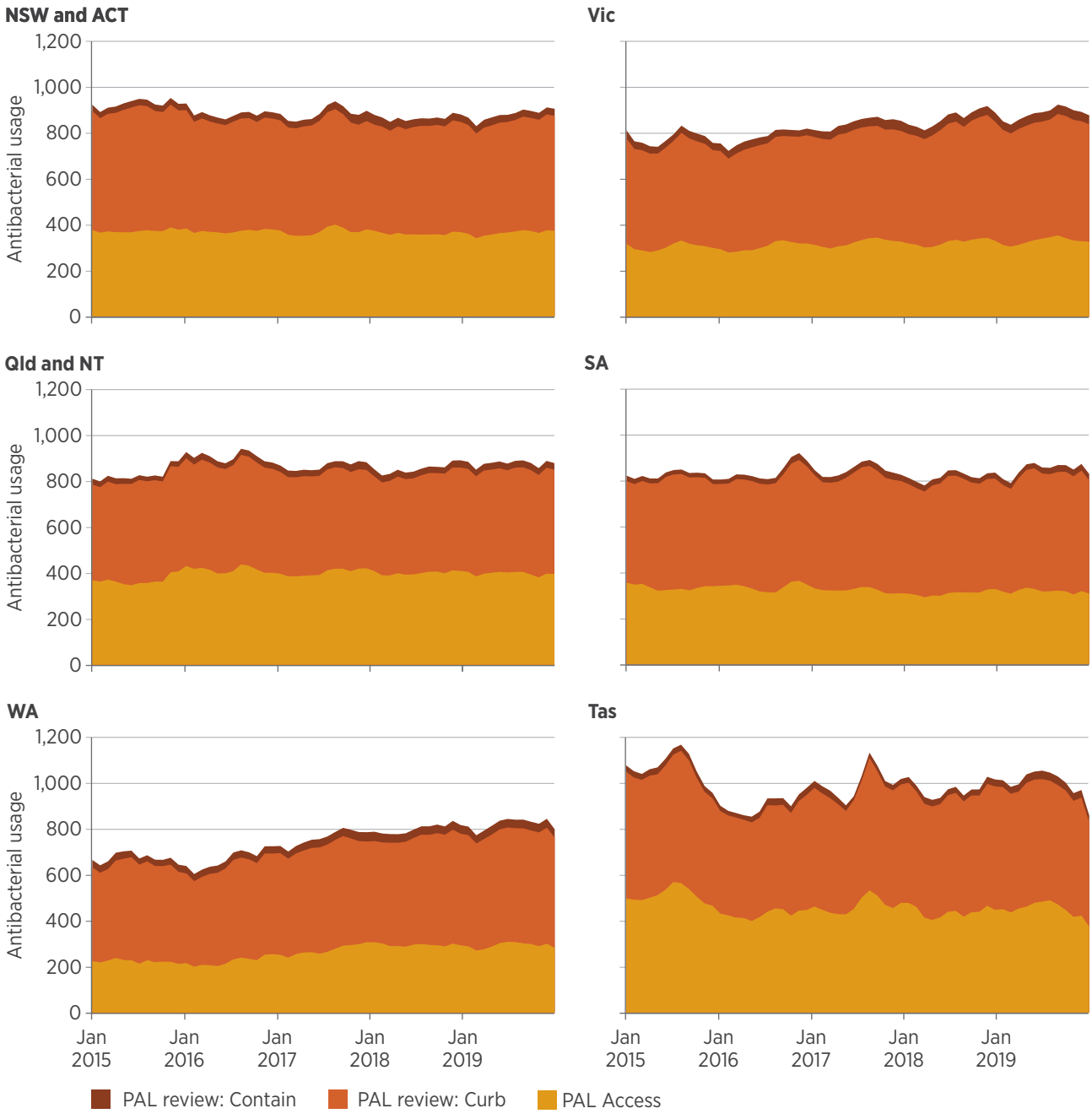
Figure 3.3 illustrates the trend in total-hospital antibacterial use from 2015 to 2019, according to the Priority Antibacterial List categories (Access, Curb, Contain) for NAUSP contributor hospitals, by state and territory. Table 3.3 shows the number of hospitals contributing to these data, by state and month.

Table 3.2: Priority Antibacterial List categories

Category		Inclusion criteria
Access		Includes: • Antibacterials that are recommended as first-line agents for common infections and have low potential for AMR or HAI • Antibacterials not recommended as first-line agents for common infections but with low AMR potential
Review	Curb	Includes: • Antibacterials recommended as first-line agents for common bacterial infections, despite a high AMR potential • Antibacterials not recommended as first-line agents but with moderate to high AMR or HAI potential • Antibacterials only recommended as first-line agents for prophylaxis, as opposed to treatment
	Contain	Includes antibacterials with high AMR or HAI potential that are not recommended as first-line agents for common bacterial infections

AMR = antimicrobial resistance; HAI = healthcare-associated infection

Figure 3.3: Aggregate antibacterial usage rates (DDD/1,000 OBD) by Priority Antibacterial List category in NAUSP contributor hospitals, by state and territory, 2015–2019



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day; PAL = Priority Antibacterial List
Source: NAUSP[2]

Table 3.3: Number of NAUSP contributor hospitals by state, 2018 and 2019

State or territory	Jan 2018	Feb 2018	Mar 2018	Apr 2018	May 2018	Jun 2018	Jul 2018	Aug 2018	Sep 2018	Oct 2018	Nov 2018	Dec 2018
NSW & ACT	69	69	69	68	68	68	68	66	66	66	67	67
Vic	31	33	33	33	33	34	34	35	35	35	34	34
Qld & NT	46	46	46	46	46	46	46	46	47	47	47	47
SA	22	22	22	21	21	22	21	20	20	20	20	20
WA	24	24	24	24	24	25	27	26	25	25	26	26
Tas	6	6	6	6	6	6	6	6	6	6	6	6

State or territory	Jan 2019	Feb 2019	Mar 2019	Apr 2019	May 2019	Jun 2019	Jul 2019	Aug 2019	Sep 2019	Oct 2019	Nov 2019	Dec 2019
NSW & ACT	70	69	69	69	69	69	71	71	72	73	73	73
Vic	35	35	35	36	35	35	37	36	36	36	36	37
Qld & NT	49	49	49	49	49	49	49	49	49	49	49	49
SA	20	20	20	20	20	20	21	21	22	22	23	23
WA	28	28	28	28	28	28	28	27	27	27	27	27
Tas	5	5	5	5	5	5	5	5	5	5	5	5

NAUSP = National Antimicrobial Utilisation Surveillance Program

On average, for all three Priority Antibacterial List categories combined, the monthly usage rate was lowest in WA (7.0% lower than the national average in 2019), as illustrated in Figure 3.3. However, in 2019, WA reported the highest proportion of use of antibacterials in the Curb category. On average, between 2015 and 2019, 60.4% of antibacterial use in WA was in the Curb category. It is important to note that cefazolin, a first-line antibiotic for surgical antimicrobial prophylaxis, is included in the Curb category, and in many hospitals this is affecting the relative frequency of Priority Antibacterial List classes. Although the reported monthly total use of antibacterials included in the Priority Antibacterial List in Tasmanian hospitals was the highest nationally, Tasmania had the highest proportion of use in the Access category. The average monthly proportion of use that fell into the Access category over the five-year period from 2015 to 2019 was 46.4% in Tasmania, compared with 35.0% in WA.

From information to action

Topical antibacterial use in Australian hospitals: opportunities for stewardship interventions

Very few clinical situations require treatment with topical antibacterial agents.[1] Routine post-procedural application of topical antibacterials for surgical antimicrobial prophylaxis is not recommended due to the increased risk of the development of antimicrobial resistance.

Despite a lack of evidence, antibacterial ointments and creams are often used for topical prophylaxis of surgical wounds. Except for some ophthalmic surgical procedures, postoperative topical antibacterial use should be strongly discouraged. It should also not be a substitute for appropriate preoperative skin preparation, good surgical technique and postoperative dressing management.

Recent evidence indicates high rates of inappropriate topical antimicrobial use in the surgical setting. Just over three-quarters (76%) of topical antibacterial prescriptions audited for the 2019 Surgical National Antimicrobial Prescribing Survey were deemed inappropriate.[2] When used in plastic and reconstructive procedures, chloramphenicol was assessed as inappropriately prescribed in 75% of cases.

Figure A shows the inpatient usage rates of chloramphenicol 1% ointment and mupirocin 2% ointment in 2019. These are based on pharmacy dispensing data that were submitted to the National Antimicrobial Utilisation Surveillance Program by 214 Australian hospitals.[3] Usage rates are compared between states and territories, and between the hospital and intensive care settings.

Reported annual inpatient usage rates for chloramphenicol and mupirocin ointments vary widely in Australian hospitals, with substantial variation in rates of use in the intensive care setting between states and territories.

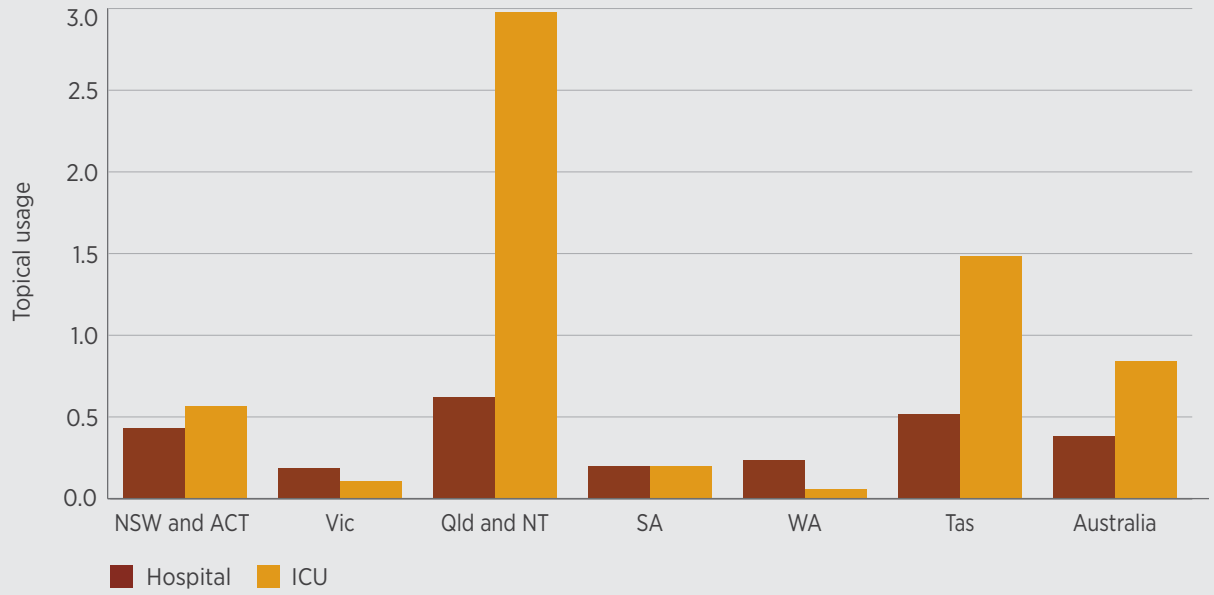
References

1. Therapeutic Guidelines Limited. eTG complete: antibiotic [Internet]. Melbourne: Therapeutic Guidelines Limited; 2021 [cited 2021 May].
2. National Centre for Antimicrobial Stewardship, Australian Commission on Safety and Quality in Health Care. Surgical prophylaxis prescribing in Australian hospitals: results of the 2019 Surgical National Antimicrobial Prescribing Survey. Sydney: ACSQHC; 2020 (accessed May 2021).
3. SA Health, Australian Commission on Safety and Quality in Health Care. National Antimicrobial Utilisation Surveillance Program: 2019 key findings. Sydney: ACSQHC; 2021 (accessed May 2021).

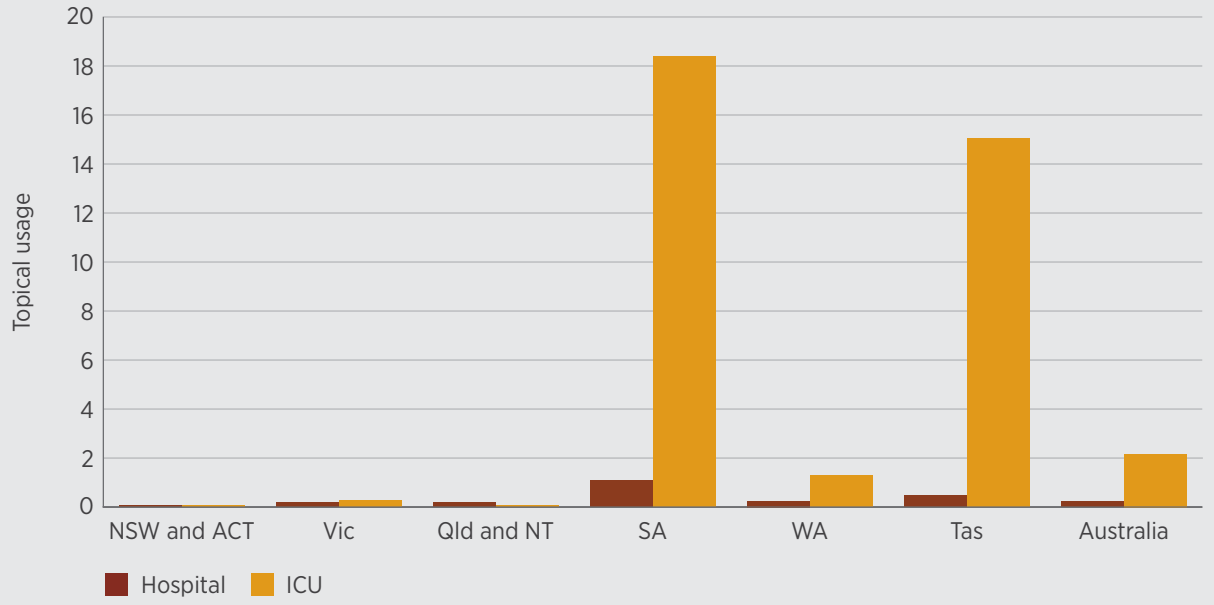
continues

Figure A: Inpatient usage rates (g/1,000 OBD) of chloramphenicol 1% ointment and mupirocin 2% ointment in Australian hospitals and intensive care settings, 2019

Chloramphenicol 1% ointment



Mupirocin 2% ointment



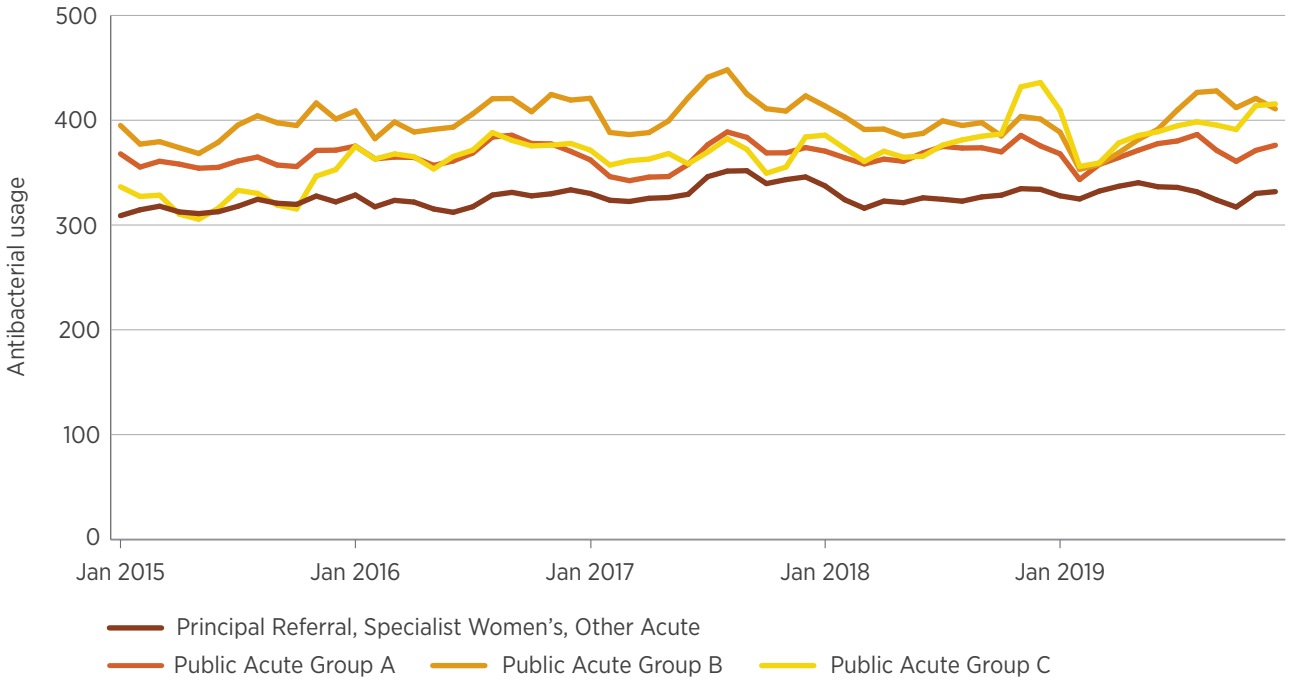
g/1,000 OBD = grams of active ingredient per 1,000 occupied bed days; ICU = intensive care unit
Note: 1 g chloramphenicol = 100 g of 1% ointment (25 × 4 g tubes); 1 g mupirocin = 50 g of 2% ointment (16 × 3 g tubes).
Source: NAUSP[3]

Antibiotic use by hospital peer group

Figures 3.4–3.6 show antibacterial usage rates according to the Priority Antibacterial List categories (Access, Curb, Contain) for NAUSP contributor hospitals, by hospital peer group.

It is evident that Principal Referral Hospitals have the highest use of antibacterials in the Contain category. This could be explained by the casemix and higher acuity of patients in these facilities. Patients requiring treatment with last-line antibiotics are more commonly treated in (or referred to) larger facilities due to the complexity of their care requirements.

Figure 3.4: Aggregate antibacterial usage rates (DDD/1,000 OBD) by Priority Antibacterial List Access category in NAUSP contributor hospitals, by peer group, 2015–2019



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

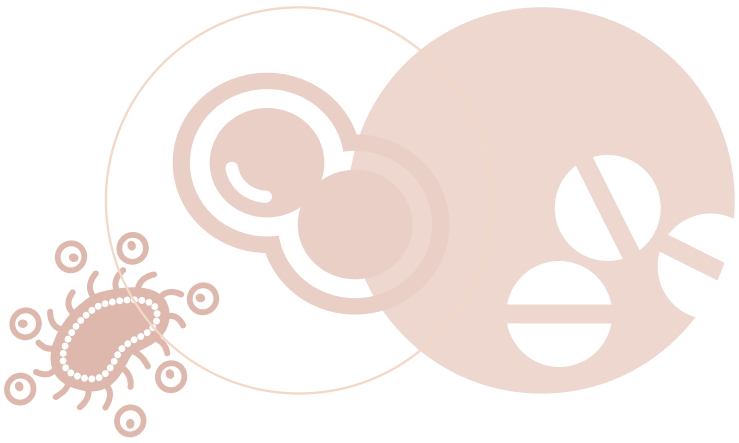
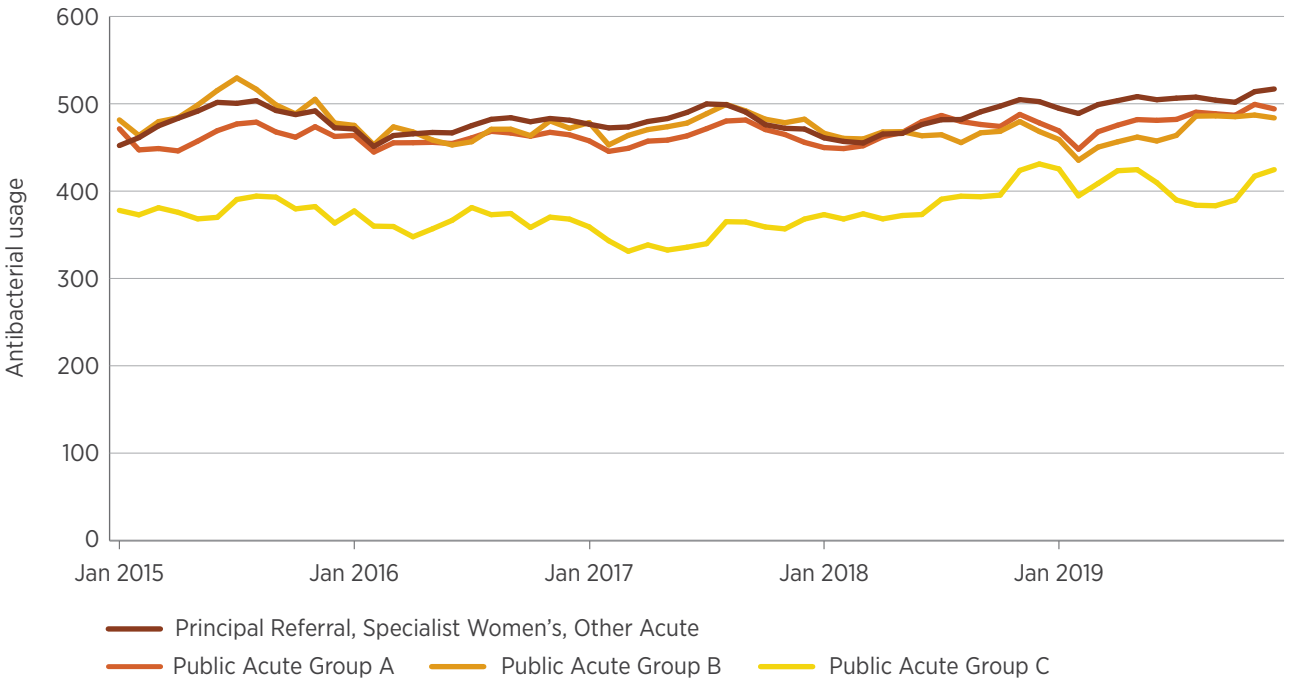
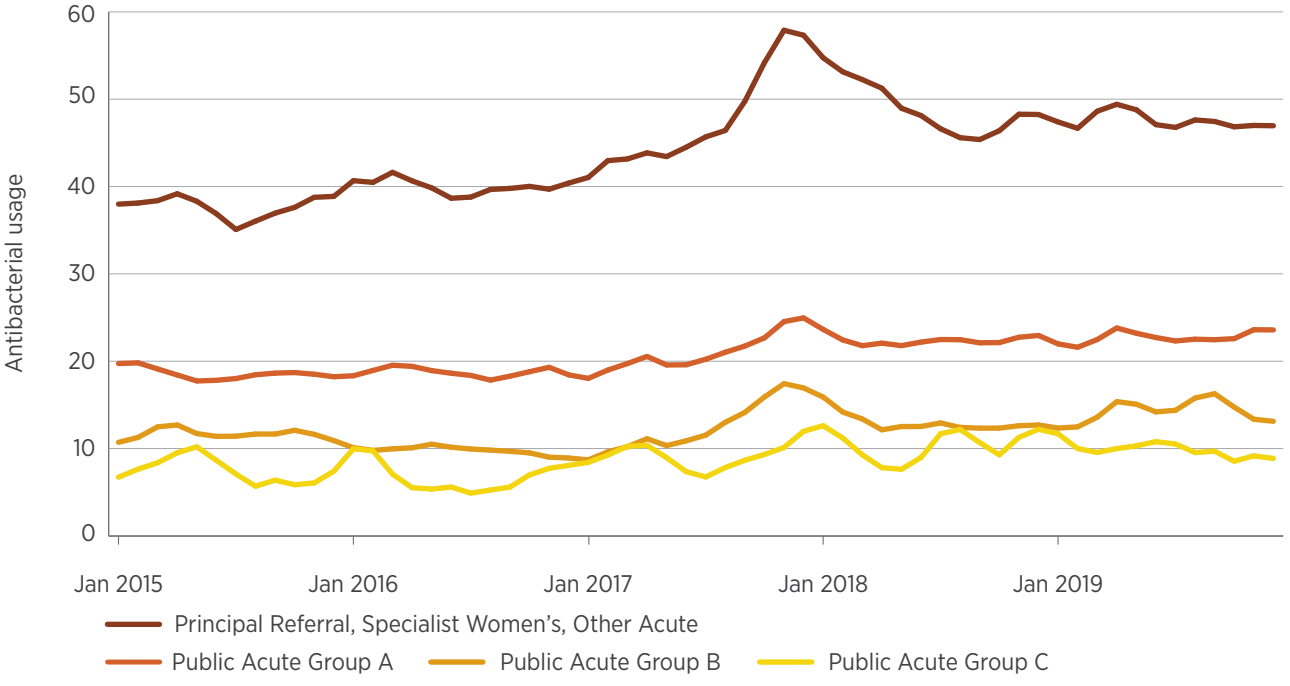


Figure 3.5: Aggregate antibacterial usage rates (DDD/1,000 OBD) by Priority Antibacterial List Curb category in NAUSP contributor hospitals, by peer group, 2015–2019



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Figure 3.6: Aggregate antibacterial usage rates (DDD/1,000 OBD) by Priority Antibacterial List Contain category in NAUSP contributor hospitals, by peer group, 2015–2019



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Appropriateness of prescribing in hospitals

Australian hospitals undertake targeted surveillance of the appropriateness of antimicrobial prescribing using the Hospital NAPS and Surgical NAPS. Table 3.4 shows the growth in the number of hospitals participating in NAPS, and how this affects the numbers of patients and prescriptions recorded.

Australian hospitals must demonstrate that they meet the requirement of the Preventing and Controlling Infections Standard to review antimicrobial prescribing and use. Some choose to do this using the Hospital NAPS and Surgical NAPS.

There have been long-term improvements in three key indicators of appropriateness of antimicrobial prescribing monitored by the Hospital NAPS (Table 3.5):

- Documentation of indication increased to 84.2% in 2019, compared with 70.5% in 2013
- Documentation of review or stop date increased to 48.0% in 2019, compared with 34.8% in 2015 when this indicator was first reported
- The proportion of surgical prophylaxis given for more than 24 hours was 30.0% in 2019, compared with 41.0% in 2013.

Documentation of indication is a requirement described in quality statement 6 of the Antimicrobial Stewardship Clinical Care Standard, which means the reported level of documentation is unacceptably low. It is important to note that the improvement in surgical prophylaxis given for more than 24 hours may be partly attributed to increased participation by private hospitals, including those that provide a higher proportion of day and minor surgeries.

Overall, appropriateness of prescribing has essentially remained static since 2015, and was 75.8% across all peer groups in 2019. It is important to note that there was considerable variation in appropriateness of antimicrobial prescribing across hospital peer groups, some showing improvements and others showing deterioration since 2013 (Figure 3.7). In particular, there appears to have been a decline in rates of appropriateness in the private sector.

Table 3.4: Participation in NAPS, 2013–2019

Year	Prescriptions (*n*)	Patients (*n*)	Hospitals (*n*)
2013	12,800	7,700	151
2014	19,994	12,634	248
2015	22,021	14,389	281
2016*	25,661	17,040	325
2017	26,277	17,366	314
2018	26,714	17,175	324
2019	31,424	19,680	377

NAPS = National Antimicrobial Prescribing Survey

* The data for 2016 are different from those reported in the 2016 Hospital NAPS report. This is because the data collection period changed to calendar years from 2017 to align with other antimicrobial use reports.

Source: Hospital NAPS

Table 3.5: Hospital NAPS key indicators, for assessable prescriptions, 2015–2019

Key indicator	Percentage of total prescriptions				
	2015	2016	2017	2018	2019
Indication documented in medical notes (best practice >95%)	72.0	76.0	77.6	80.2	84.2
Review or stop date documented (best practice >95%)	34.8	38.0	40.7	45.2	48.0
Surgical prophylaxis given for >24 hours (best practice <5%)*	26.8	30.1	30.0	27.9	30.0
Compliant with *Therapeutic Guidelines: Antibiotic* or local guidelines†	70.1	66.0	67.4	67.7	65.3
Appropriate (optimal and adequate)§	76.4	76.1	76.3	77.8	75.8

NAPS = National Antimicrobial Prescribing Survey

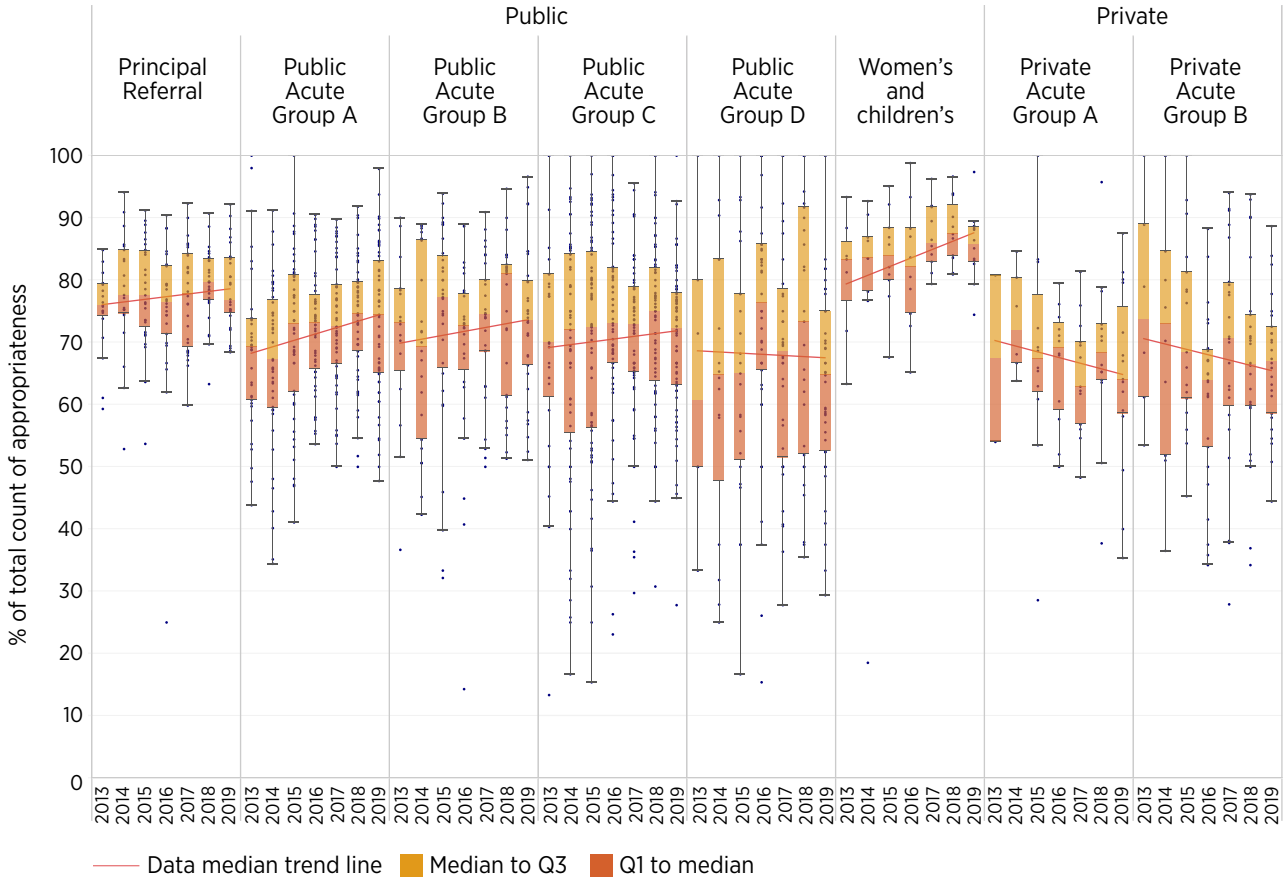
* Where surgical prophylaxis was selected as the indication (*n* = 3,963 in 2019).

† Prescriptions for which compliance was assessable (*n* = 24,989 in 2019). Excludes prescriptions for which guidelines were not available, as well as prescriptions that were 'directed therapy' or 'not assessable'.

§ Prescriptions for which appropriateness was assessable (*n* = 30,228 in 2019). Excludes prescriptions deemed to be 'not assessable'.

Source: Hospital NAPS[5]

Figure 3.7: Appropriateness of prescribing by peer groups in Hospital NAPS contributor hospitals, 2013–2019



NAPS = National Antimicrobial Prescribing Survey

Notes:

1. Whiskers include all data points within 1.5 times the interquartile range (Q3–Q1). All other observed data points are plotted as outliers.
2. Only private Group A and B hospitals were included due to slow initial uptake in that sector.

From information to action

From numbers to networks: using data surveillance to tailor antimicrobial stewardship support for rural hospitals

A number of challenges for health service delivery are common in rural areas of Australia – for example, long distances to higher-level services, and workforce shortages. It is also well documented that health outcomes are impacted for rural and remote residents.

The AURA surveillance data have highlighted the impacts of some of these challenges on antimicrobial stewardship (AMS). Data from the Hospital National Antimicrobial Prescribing Survey (NAPS) show lower appropriateness, and higher use, of antimicrobials in Group D hospitals, compared with tertiary facilities. This indicates that further attention in this area is required. A multifaceted, multidisciplinary program was developed in Queensland, in four rural Hospital and Health Services (HHSs), to address instances of limited on-site AMS capacity.

The program was implemented in January 2017, based on a business case for a sustainability model. The Queensland Statewide Antimicrobial Stewardship Program is a centralised service, and part of a collaborative decision-making process with local clinician champions from the HHS. The program is staffed by AMS pharmacists, infectious diseases physicians, a clinical nurse consultant and a program manager. The activities include 24-hour access to an infectious diseases clinical advice hotline, weekly telehealth rounds and review of Hospital NAPS audits, online education, yearly reporting of antimicrobial use and resistance data, and twice-yearly site visits to promote engagement and involvement in quality improvement activities. Hospital NAPS definitions were used for baseline assessments and to monitor progress after program implementation.

Improvements in appropriateness of antimicrobial prescribing, compliance with guidelines and total antimicrobial use were noted across all four HHSs. One is described here in greater detail. Figure A shows improvement in guideline compliance from 33.7% to 54.1% and appropriateness of prescribing from 49% to 67.5% from 2016 (baseline) to 2018.[1] Respiratory prescribing was identified as an issue of priority, and an assessment focused on this area was conducted in subsequent years. Usage data have shown a decrease in total antibiotic use from 1,528 defined daily doses (DDDs) per 1,000 patient days to 941 DDDs per 1,000 patient days (Figure B).

Key factors contributing to the success of the program include actively engaging stakeholders at the rural sites and using a multifaceted approach. This has allowed adaptation to unique local issues, including differences between sites in disease prevalence, resistance patterns, resource limitations and cultural factors. The program is continuing to facilitate greater participation in the Hospital NAPS to monitor progress, guide quality improvement activities and contribute to national surveillance. Feedback from local clinicians has rated the program as a valuable resource (Figure C).

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Figure A: Hospital NAPS results, 2016–2018

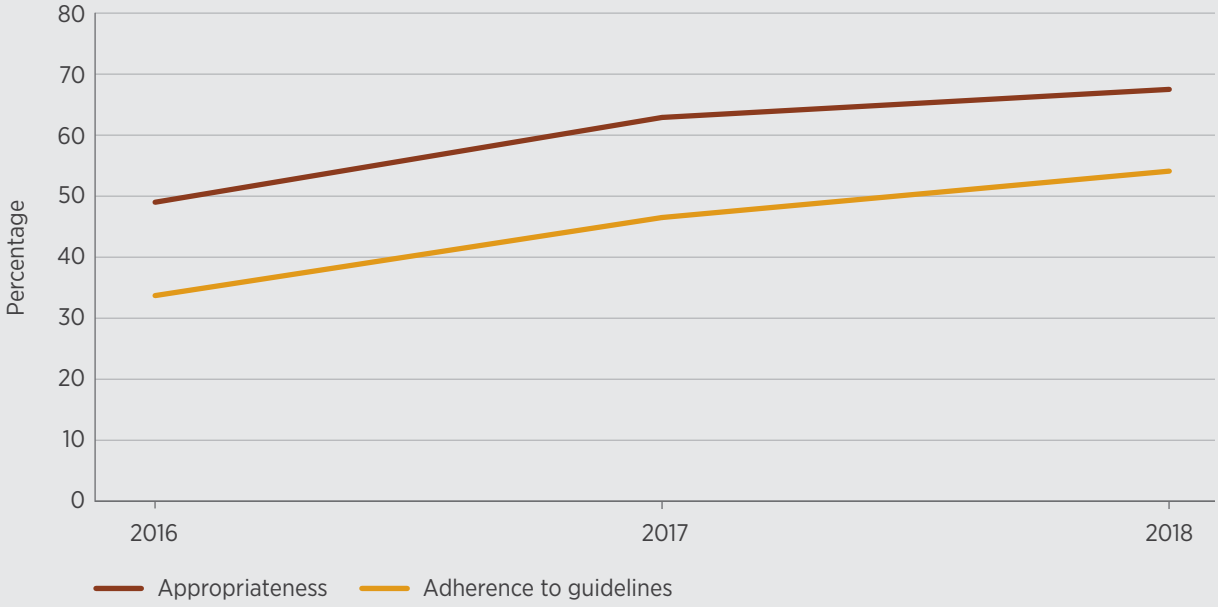

Figure B: Total antibiotic usage (DDD/1,000 patient days), 2016–2020

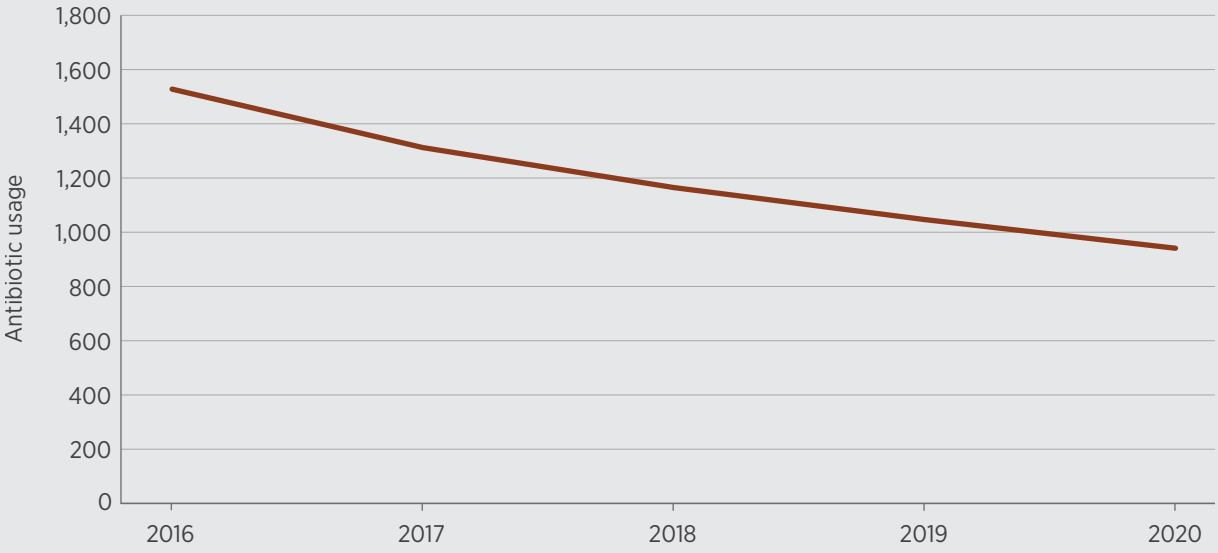

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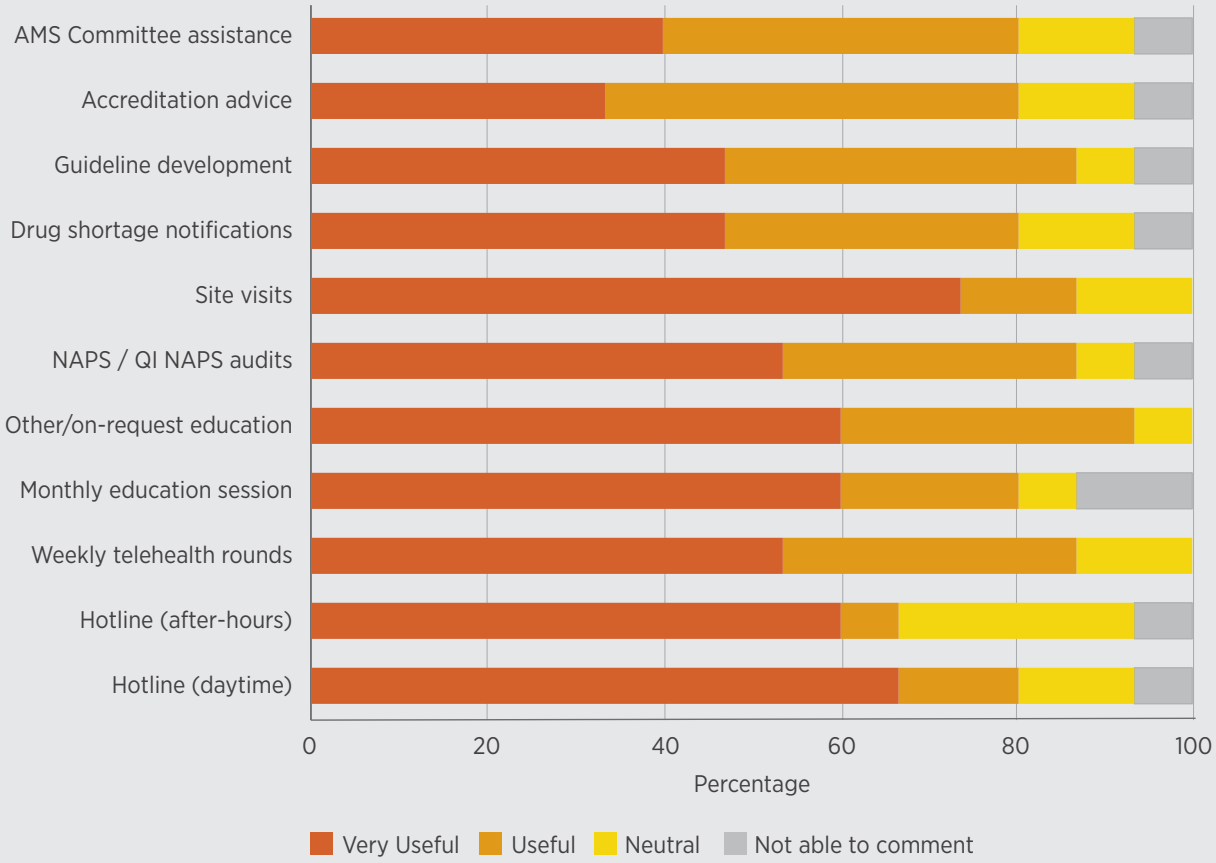
Figure C: Stakeholder feedback



AMS = antimicrobial stewardship; QI NAPS = Quality Improvement National Antimicrobial Prescribing Survey

Reference

1. Avent ML, Walker D, Yarwood T, Malacova E, Brown C, Kariyawasam N, et al. Implementation of a novel antimicrobial stewardship strategy for rural facilities utilising telehealth. Int J Antimicrob Agents 2021;57(6):106346.

From information to action

Using penicillin allergy delabeling in hospitalised patients to improve antibiotic use and appropriateness of prescribing

Penicillin allergies are associated with poor outcomes for both patients and antimicrobial stewardship (AMS). The outcomes can include an increase in:

- The rate of medication error
- Adverse drug reactions
- Length of stay and hospital costs
- Patient mortality
- The use of restricted antibiotics
- Antimicrobial resistance.[1]

Between 5% and 15% of people carry a penicillin allergy 'label'.[1] In the outpatient setting, 83% of antibiotic allergy labels can be removed (or delabeled) following allergy testing.[2] Austin Health and Peter MacCallum Cancer Centre, with funding from Better Care Victoria, created a whole-of-hospital program to find out if delabeling was effective for low-risk penicillin allergies in hospitalised inpatients.[3]

Austin Health identified patients using a custom list generated by the electronic medical record, while Peter MacCallum Cancer Centre used chart-based ward review. A validated antibiotic allergy assessment tool classified patients as low or high risk for their reported antibiotic allergy.[4] Adults with a low-risk penicillin allergy were offered either a single dose of oral penicillin challenge or direct label removal based on history and medication reconciliation (known as direct delabeling).[3] If delabeling occurred, the allergy label was removed in the hospital medical record, and a letter was sent to the patient and their general practitioner detailing the delabeling process.

The goals of the program were to:

- Find out how many patients were delabeled
- Compare hospital antibiotic use before and after delabeling
- Assess the appropriateness of antibiotic prescribing, using the National Antimicrobial Prescribing Survey (NAPS) appropriateness scoring tool.

Between 21 January and 31 August 2019, 1,225 patients with a penicillin allergy were assessed:

- 558 patients were classified as low risk, and 667 were classified as high risk
- 355 patients were delabeled – 194 following a dose of oral penicillin and 161 by direct delabeling.

In the delabeled patients, there was:

- An increase in narrow-spectrum penicillin use
- A reduction in restricted antibiotic use
- Improved appropriateness of antibiotic prescribing.

These findings are shown in Figure A.

Compared with antibiotic use in non-delabeled patients, in delabeled patients there was:

- An increase in narrow-spectrum penicillin use
- An increase in β-lactam/β-lactamase inhibitor use
- A reduction in restricted antibiotic use
- A reduction in inappropriate antibiotic prescriptions.

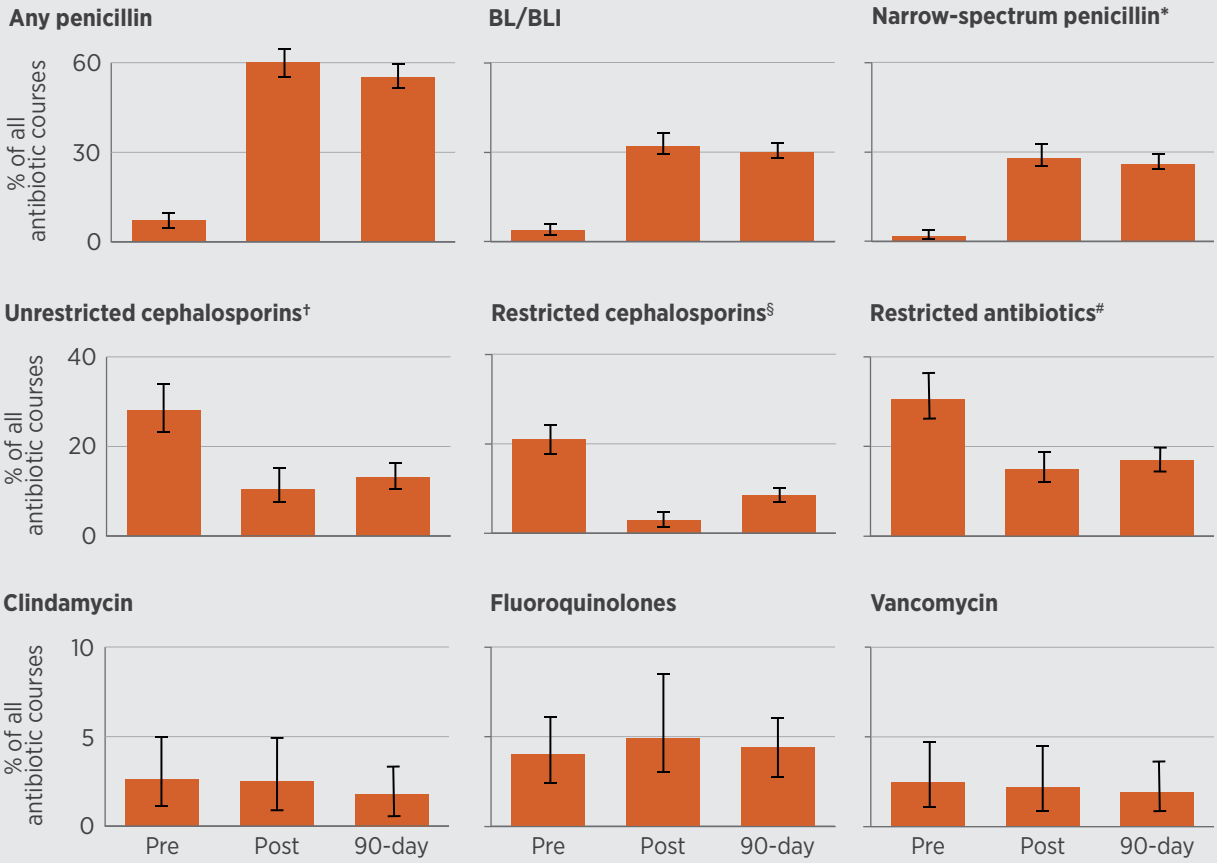
continues

These findings are in Table A.

In this prospective study, the NAPS appropriateness score was used to assess the effect of the penicillin allergy delabeling program. There were improvements in key AMS metrics, including an increased use of preferred antibiotics (following *Therapeutic Guidelines: Antibiotic*)[5] and a decreased use of restricted antibiotics. A follow-up study also showed that patients had a positive opinion of the program.[6]

Because of this success, the inpatient penicillin allergy delabeling program has been approved for ongoing funding at both health centres. The strategy outlined here, and integrated into the existing hospital AMS service, required minimal additional resources and can be scaled up for widespread implementation to improve antibiotic prescribing in patients with a low-risk penicillin allergy label.

Figure A: Antibiotic use in patients before and after delabeling



90-day = 90 days after delabeling; BL/BLI = β-lactam/β-lactamase inhibitor; Post = after delabeling; Pre = before delabelling

* A narrow-spectrum penicillin was defined as one of penicillin VK, penicillin G, flucloxacillin, dicloxacillin, ampicillin or amoxicillin.

† A restricted cephalosporin included a third- or subsequent generation cephalosporin.

§ A restricted antibiotic included lincosamides (i.e. clindamycin, lincomycin), fluoroquinolones (i.e. norfloxacin, ciprofloxacin, moxifloxacin), vancomycin, carbapenems (i.e. ertapenem, meropenem), and third- or subsequent generation cephalosporins (i.e. cefepime, ceftazidime, ceftriaxone).

An unrestricted cephalosporin included a first- or second-generation cephalosporin.

Note: Errors bars represent 95% confidence intervals.

continues

Table A: Antibiotic use in delabeled and non-delabeled patients

	Delabeled (*N* = 355)	Non-delabeled (*N* = 870)	Unadjusted delabeled vs non-delabeled		Propensity score IPTW delabeled vs non-delabeled	
Antibiotic use	***n* (%)**	***n* (%)**	**OR (95% CI)**	***P* value**	**OR (95% CI)**	***P* value**
Before testing vs after testing						
Narrow-spectrum penicillin*	49 (13.8%)	6 (0.7%)	23.06 (9.78, 54.37)	<0.001	13.90 (4.36, 44.30)	<0.001
β-lactam/ β-lactamase inhibitor	61 (17.2%)	16 (1.8%)	11.07 (6.29, 19.51)	<0.001	5.95 (3.21, 11.03)	<0.001
Any penicillin	106 (29.9%)	22 (2.5%)	16.41 (10.15, 26.53)	<0.001	9.02 (5.19, 15.66)	<0.001
Unrestricted cephalosporin†	28 (7.9%)	168 (19.3%)	0.36 (0.23, 0.55)	<0.001	0.45 (0.29, 0.69)	<0.001
Restricted cephalosporin§	9 (2.5%)	85 (9.8%)	0.24 (0.12, 0.48)	<0.001	0.30 (0.15, 0.62)	0.001
Restricted antibiotic#	24 (6.8%)	164 (18.9%)	0.31 (0.20, 0.49)	<0.001	0.38 (0.24, 0.61)	<0.001
Fluoroquinolones	10 (2.8%)	43 (4.9%)	0.56 (0.28, 1.12)	0.102	0.52 (0.25, 1.09)	0.083
Vancomycin	6 (1.7%)	28 (3.2%)	0.52 (0.21, 1.26)	0.146	1.18 (0.46, 3.06)	0.726
Clindamycin	4 (1.1%)	48 (5.5%)	0.20 (0.07, 0.55)	0.002	0.24 (0.09, 0.70)	0.009
Carbapenems	3 (0.8%)	9 (1.0%)	0.82 (0.22, 3.03)	0.76	0.78 (0.19, 3.19)	0.729
Any antibiotic	143 (40.3%)	323 (37.1%)	1.14 (0.89, 1.47)	0.302	0.86 (0.65, 1.13)	0.275
*Appropriateness***						
All inappropriate	24 (6.8%)	94 (10.8%)	0.66 (0.41, 1.06)	0.085	0.47 (0.28, 0.79)	0.004
Some appropriate	15 (4.2%)	108 (12.4%)	0.36 (0.20, 0.63)	<0.001	0.36 (0.20, 0.66)	0.001
All appropriate	104 (29.3%)	121 (13.9%)	2.22 (1.63, 3.01)	<0.001	1.40 (0.99, 1.97)	0.055
Antibiotic not required	212 (59.7%)	547 (62.9%)	Reference	n/a	Reference	n/a

continues

Table A: *continued*

Antibiotic use	Delabeled (*N* = 355) *n* (%)	Non-delabeled (*N* = 870) *n* (%)	Unadjusted delabeled vs non-delabeled OR (95% CI)	*P* value	Propensity score IPTW delabeled vs non-delabeled OR (95% CI)	*P* value
Before testing vs 90 days after testing						
Narrow-spectrum penicillin*	67 (18.9%)	13 (1.5%)	15.34 (8.34, 28.19)	<0.001	10.89 (5.09, 23.31)	<0.001
β-lactam/ β-lactamase inhibitor	81 (22.8%)	25 (2.9%)	9.99 (6.25, 15.97)	<0.001	6.68 (3.94, 11.35)	<0.001
Any penicillin	131 (36.9%)	36 (4.1%)	13.55 (9.11, 20.16)	<0.001	9.13 (5.75, 14.50)	<0.001
Unrestricted cephalosporin†	53 (14.9%)	226 (26.0%)	0.50 (0.36, 0.69)	<0.001	0.60 (0.42, 0.84)	0.003
Restricted cephalosporin§	34 (9.6%)	119 (13.7%)	0.67 (0.45, 1.00)	0.05	0.75 (0.48, 1.15)	0.188
Restricted antibiotic#	48 (13.5%)	217 (24.9%)	0.47 (0.33, 0.66)	<0.001	0.52 (0.36, 0.74)	<0.001
Fluoroquinolones	13 (3.7%)	65 (7.5%)	0.47 (0.26, 0.87)	0.015	0.41 (0.22, 0.77)	0.006
Vancomycin	8 (2.3%)	48 (5.5%)	0.39 (0.18, 0.84)	0.016	0.63 (0.28, 1.41)	0.26
Clindamycin	4 (1.1%)	62 (7.1%)	0.15 (0.05, 0.41)	<0.001	0.17 (0.06, 0.49)	0.001
Carbapenems	4 (1.1%)	18 (2.1%)	0.54 (0.18, 1.61)	0.267	0.40 (0.13, 1.27)	0.122
Any antibiotic	181 (51.0%)	399 (45.9%)	1.23 (0.96, 1.57)	0.103	0.97 (0.74, 1.28)	0.849
*Appropriateness***						
All inappropriate	24 (6.8%)	109 (12.5%)	0.60 (0.37, 0.96)	0.033	0.43 (0.26, 0.72)	0.001
Some appropriate	37 (10.4%)	161 (18.5%)	0.62 (0.42, 0.93)	0.019	0.59 (0.39, 0.90)	0.015
All appropriate	120 (33.8%)	129 (14.8%)	2.52 (1.86, 3.41)	<0.001	1.78 (1.26, 2.50)	0.001
Antibiotic not required	174 (49.0%)	471 (54.1%)	Reference	n/a	Reference	n/a

CI = confidence interval; IPTW = inverse probability of treatment weighting; n/a = not applicable; OR = odds ratio

* A narrow-spectrum penicillin was defined as either penicillin VK, penicillin G, flucloxacillin, dicloxacillin, ampicillin or amoxicillin.

† A restricted antibiotic included lincosamides (i.e. clindamycin, lincomycin), fluoroquinolones (i.e. norfloxacin, ciprofloxacin, moxifloxacin), vancomycin, carbapenems (i.e. ertapenem, meropenem) and third- or subsequent generation cephalosporins (i.e. cefepime, ceftazidime, ceftriaxone).

§ A restricted cephalosporin included a third- or subsequent generation cephalosporin.

An unrestricted cephalosporin included a first- or second-generation cephalosporin.

** Multinomial logistic regression used for analysis; results expressed as relative risk ratio

continues

References

1. Blumenthal KG, Peter JG, Trubiano JA, Phillips EJ. Antibiotic allergy. Lancet 2019;393(10167):183–98.
2. Trubiano JA, Thursky KA, Stewardson AJ, Urbancic K, Worth LJ, Jackson C, et al. Impact of an integrated antibiotic allergy testing program on antimicrobial stewardship: a multicenter evaluation. Clin Infect Dis 2017;65(1):166–74.
3. Chua KYL, Vogrin S, Bury S, Douglas A, Holmes NE, Tan N, et al. The penicillin allergy delabeling program: a multicenter whole-of-hospital health services intervention and comparative effectiveness study. Clin Infect Dis 2020;ciaa653.
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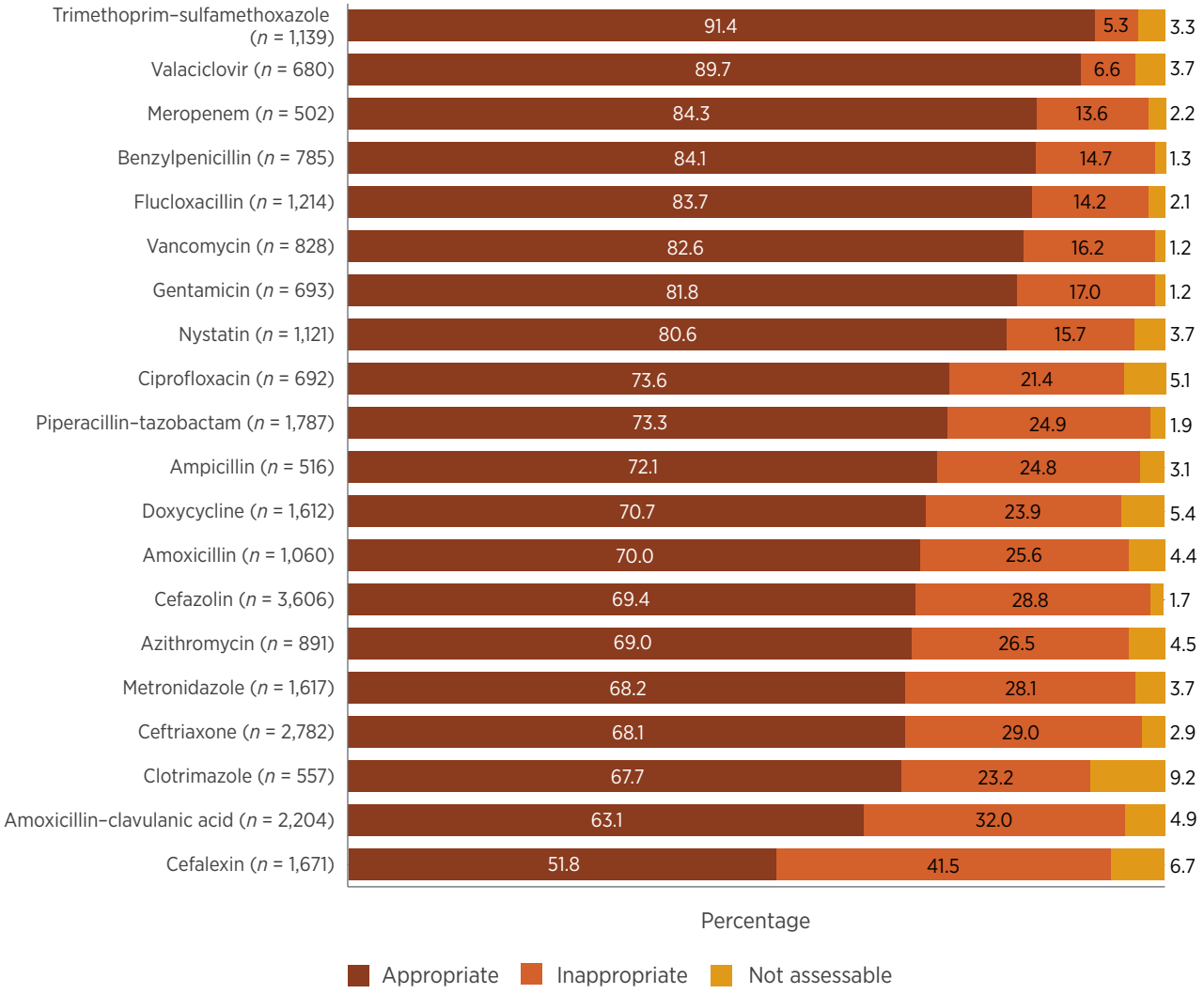
5. Therapeutic Guidelines Limited. eTG complete [Internet]. Melbourne: Therapeutic Guidelines Limited; 2021 [cited 2021 May 13].
6. Wilson A, Trubiano JA, Chua KYL. Patient perspectives on antibiotic allergy delabeling: enablers and barriers. J Allergy Clin Immunol Pract 2020;8(10):3637–9.e5.

In 2019, there was inappropriate prescribing of a number of broad-spectrum antimicrobials, particularly cefalexin, cefazolin, azithromycin and amoxicillin–clavulanic acid (Figure 3.8). The rate of inappropriate prescribing for ceftriaxone was the most notable change between 2018 and 2019, increasing from 24.9% to 29.0%.

Of the top 20 indications, the three with the most inappropriate prescribing did not change from 2018 to 2019: chronic obstructive pulmonary disease (COPD), surgical prophylaxis and non-surgical wounds (Figure 3.9). The indications with the highest rates of appropriate prescribing were also unchanged: gram-positive bacteraemia, osteomyelitis and medical prophylaxis.

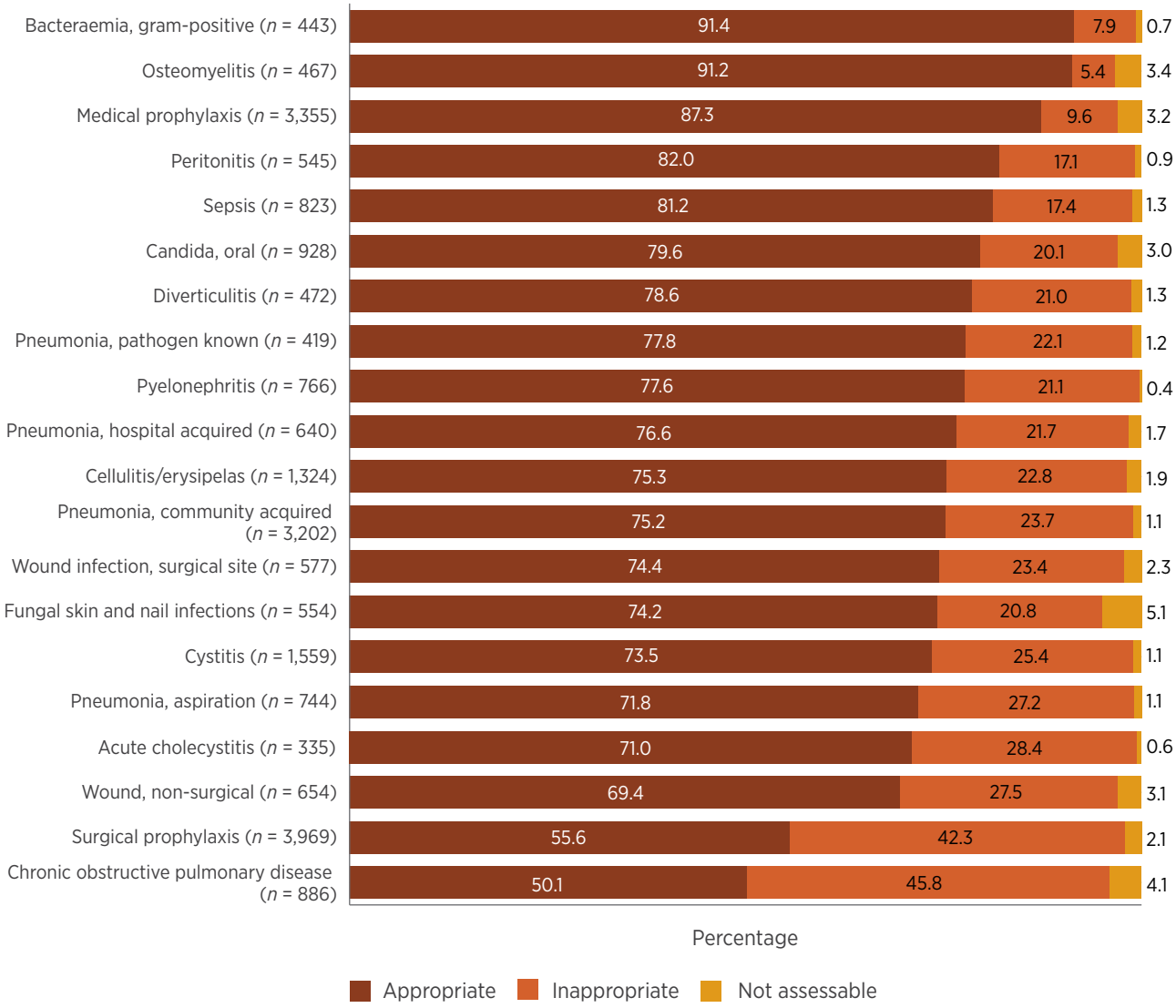
Community-acquired pneumonia and COPD accounted for 10.2% (*n* = 3,202) and 2.8% (*n* = 886), respectively, of all prescriptions reported for the 2019 Hospital NAPS, and both feature in the top 10 most common indications. Figure 3.10 shows that the rate of guideline compliance for community-acquired pneumonia has not improved over time, although the level of appropriateness remains relatively high. The trends for COPD require urgent intervention, as noncompliance with guidelines continues to rise and the level of appropriate prescribing has declined.

Figure 3.8: Appropriateness of prescribing for the most commonly prescribed antimicrobials in Hospital NAPS contributor hospitals, 2019



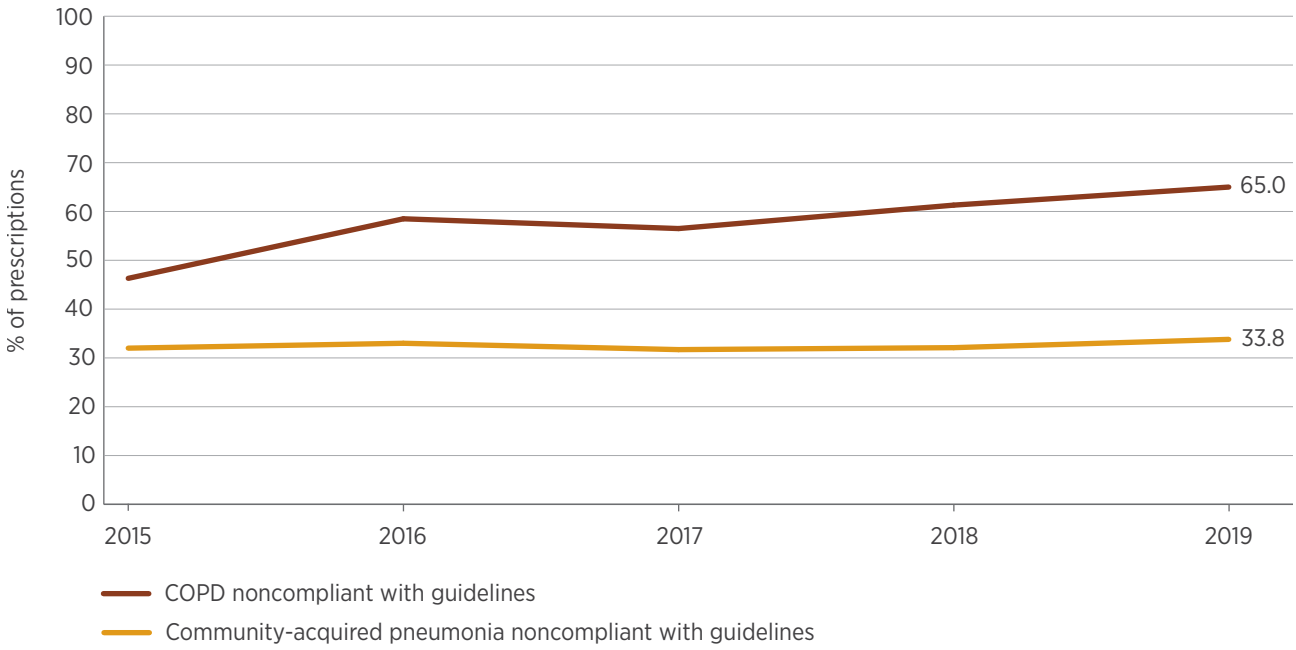
NAPS = National Antimicrobial Prescribing Survey
Source: Hospital NAPS[5]

Figure 3.9: Appropriateness of prescribing for the 20 most common indications in Hospital NAPS contributors, 2019

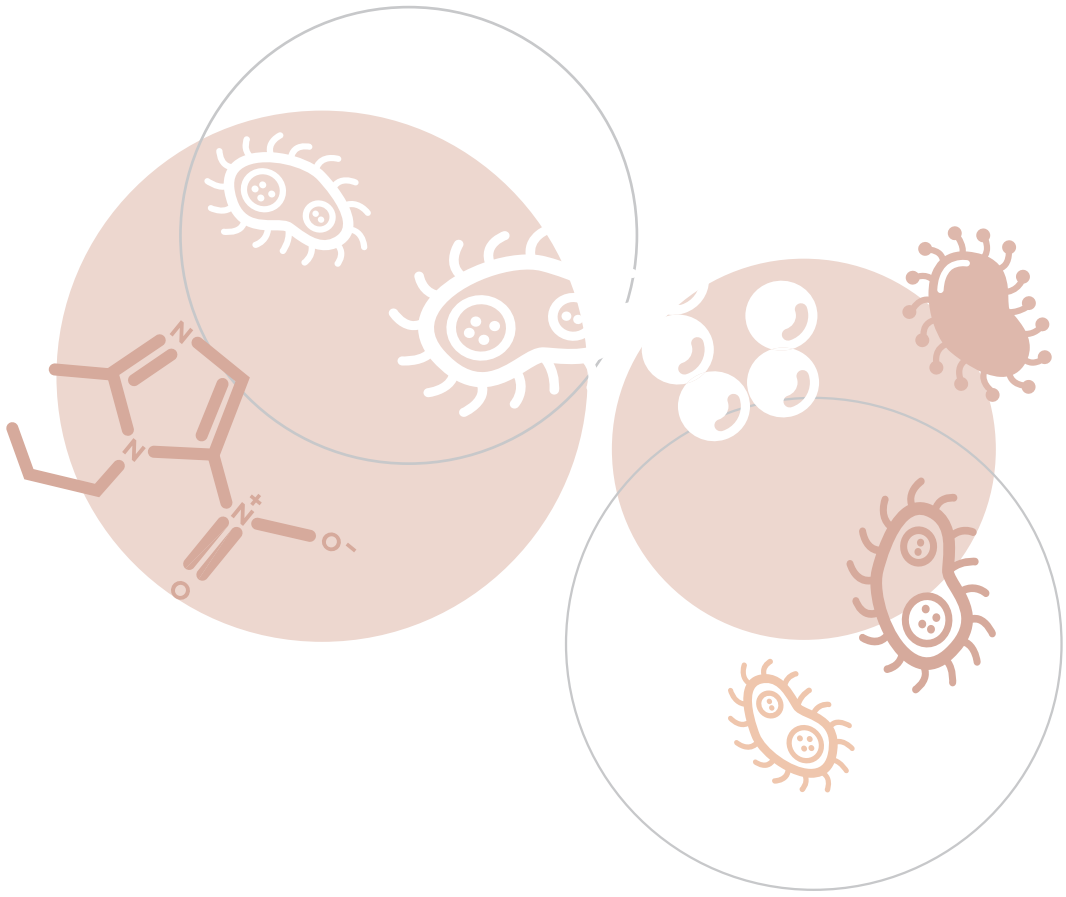


NAPS = National Antimicrobial Prescribing Survey
Source: Hospital NAPS[5]

Figure 3.10: Noncompliance with guidelines for community-acquired pneumonia and COPD prescriptions, 2019



COPD = chronic obstructive pulmonary disease
Note: Excludes prescriptions for which guidelines were not available, as well as prescriptions that were 'directed therapy' or 'not assessable'.



From information to action

Targeting antimicrobial prescribing within the intensive care unit

In 2017, the antimicrobial stewardship (AMS) team at Austin Health reviewed the results of analyses of the data they submitted to the National Antimicrobial Utilisation Surveillance Program (NAUSP) and the National Antimicrobial Prescribing Survey (NAPS), as part of the AURA Surveillance System. They observed a pattern of suboptimal antimicrobial prescribing within the intensive care unit (ICU), including an increase in the use of key restricted antimicrobials, such as vancomycin and meropenem.

Austin Health is a tertiary referral hospital that provides a 29-bed, closed, mixed medical–surgical ICU. Key specialty areas that the ICU manages are acute spinal cord injury; cardiothoracic surgery; neurosurgery; haematology; oncology; and liver, renal and stem cell transplantation services.

According to NAPS data, 57% of antimicrobial prescriptions made within the ICU in 2015 were appropriate, falling to 47% in 2016.[1] Figures from NAUSP also showed an increase in the prescribing of broad-spectrum antimicrobials over the same period (measured as defined daily doses per 1,000 occupied bed days).

To manage this trend in suboptimal antimicrobial prescribing, an AMS-ICU service was introduced in August 2017, with the support of the ICU. This service, operating five days a week, consisted of an AMS pharmacist, an infectious diseases consultant and an infectious diseases registrar joining the ICU staff on the ward and discussing the use of all antimicrobial agents.[2] Although broad-spectrum antimicrobials were targeted, all antimicrobials were identified using electronic prescribing software and discussed with the ICU staff.

Following implementation of this service, the overall appropriateness of antimicrobial prescribing (from NAPS data) increased compared with 2015 and 2016, rising to 77% in 2017 and 70% in 2018.[1] NAUSP data also showed an immediate reduction in the use of ceftriaxone, piperacillin–tazobactam and vancomycin over the same period (Figure A). An ongoing reduction in vancomycin and ciprofloxacin use was also shown.

NAUSP and NAPS data identified areas for improvement within the ICU, and enabled the implementation of a sustainable, targeted AMS service. This service was well received by the ICU and continues to increase AMS engagement in the ICU team.

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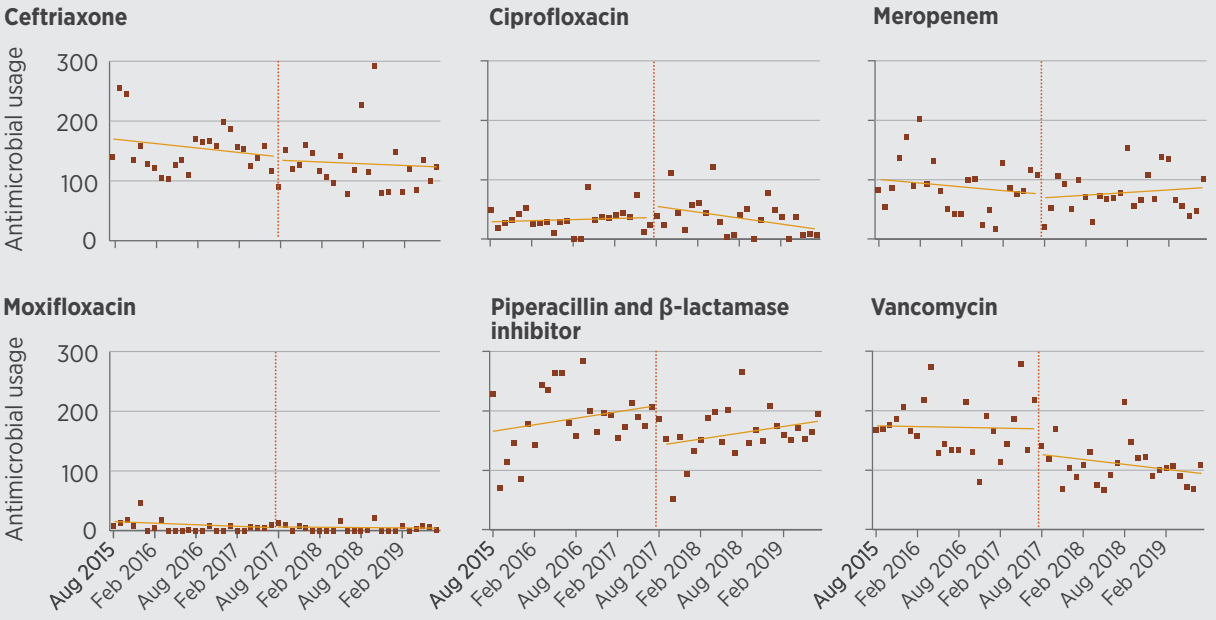
Figure A: Change in antimicrobial use (DDD/1,000 OBD) after ICU-AMS intervention



DDD = defined daily dose; OBD = occupied bed day

Note: Dotted vertical lines represent commencement of intervention. Solid lines represent pre-intervention and post-intervention trends in antimicrobial use, estimated using Poisson segmented regression. The dots on the graph are raw data points.[1]

Source: Based on NAUSP data

References

1. Devchand M, Nolen A, Stewardson AJ, Warrillow SJ, Garrett K, Trubiano JA. Long-term outcomes of an electronic medical record (EMR)–integrated antimicrobial stewardship (AMS) intensive care unit (ICU) ward round. Infect Control Hosp Epidemiol 2021 Mar 18;1–3.
2. Devchand M, Stewardson AJ, Urbancic KF, Khumra S, Mahony AA, Walker S, et al. Outcomes of an electronic medical record (EMR)–driven intensive care unit (ICU)–antimicrobial stewardship (AMS) ward round: assessing the 'five moments of antimicrobial prescribing'. Infect Control Hosp Epidemiol 2019;40(10):1170–5.

From information to action

Virtual clinical pharmacist-led antimicrobial stewardship in rural and remote New South Wales hospitals

In 2020, the Western New South Wales Local Health District introduced a virtual clinical pharmacy service (VCPS) at eight small rural and remote hospitals that did not have routine access to hospital pharmacists. The VCPS uses videoconferencing, electronic medication management and the electronic medical record (eMR) to provide proactive, accessible advice on the quality use of medicines. Before introduction of the VCPS, there were few local antimicrobial stewardship (AMS) activities in place.

As part of a comprehensive clinical pharmacy service, the VCPS provides proactive quality reviews of all prescribed antimicrobials. Noncompliance with guidelines or recommendations for optimising therapy are documented in the patient's health record and communicated to clinicians through the eMR. Urgent issues are addressed over the phone. For consistency in documenting AMS reviews and to assist with data collection, a standardised eMR note template was introduced, based on the National Antimicrobial Prescribing Survey audit tool.

The VCPS began contributing antimicrobial usage data to the National Antimicrobial Utilisation Surveillance Program (NAUSP) in January 2020. This contributed to an increase in the number of Group D public hospitals, including multi-purpose services, contributing to NAUSP.

NAUSP data are analysed, incorporated into monthly reports, and discussed with nursing and executive staff during regular service rounds at each facility. General and targeted antimicrobial education is provided to medical and nursing staff in response to identified antimicrobial use issues. These have included targeted education on AMS to nursing staff and a presentation from an infectious diseases physician on community-acquired pneumonia and appropriate use of ceftriaxone for medical officers.

The VCPS also aims to optimise antimicrobial stock management by providing education and reviewing imprest levels, especially when this is suspected to contribute to undesirable usage trends. Patients also received education on antimicrobials during admission and on discharge.

VCPS education initiatives included:

- Provision of medication lists
- Provision of specific information on quality use of antimicrobials
- Education about use of antimicrobial infusors in the post-acute setting
- Education about clearance of methicillin-resistant *Staphylococcus aureus*
- Education about treatment options for *Clostridioides difficile*.

After nine months (April 2020 to January 2021), 885 patient admissions had been reviewed by the VCPS, resulting in 293 AMS interventions. AMS interventions accounted for 18% of all pharmacist-identified medication-related issues. The most common AMS interventions related to insufficient documentation of duration of

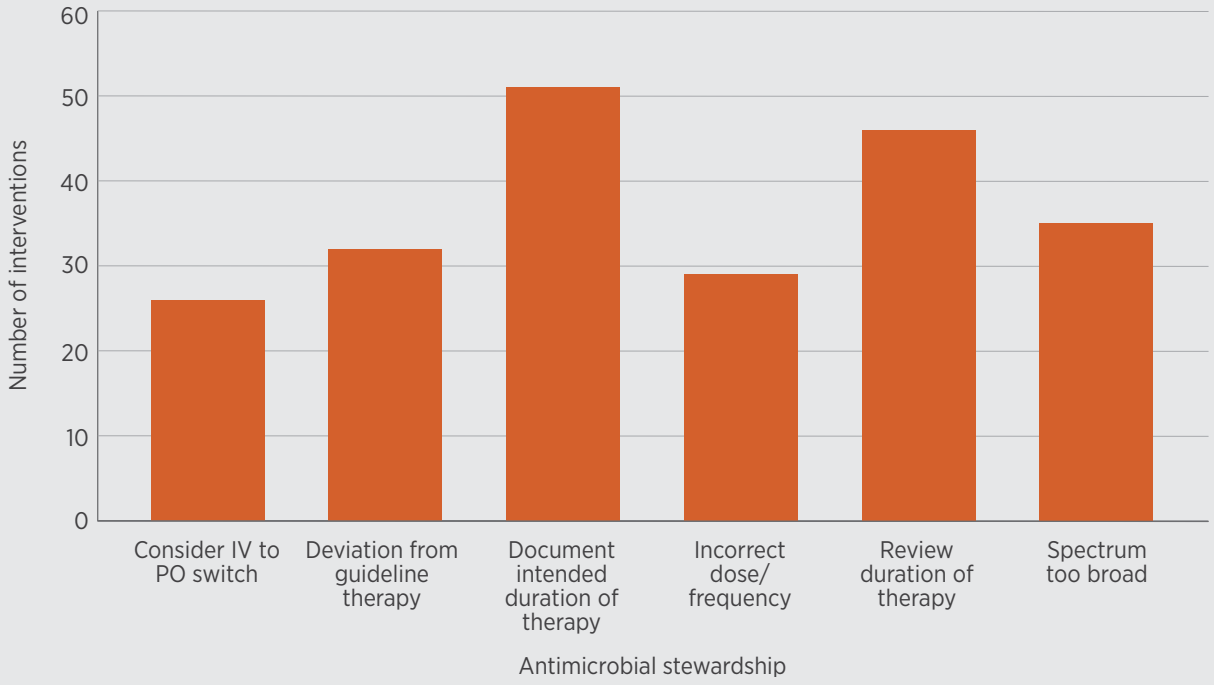
continues

therapy, followed by inappropriate use of broad-spectrum antimicrobials (Figure A). Most AMS interventions (74%) were either accepted or accepted in part by the treating team.

The clinical significance of the interventions was rated on a 5-point scale (minimum, minor, moderate, major and serious). Pharmacists reported 31% of interventions as minimum, 51% as minor and 18% as moderate. Pharmacists self-reported using an intervention tool, and expected 69% of patients to have a positive clinical outcome based on the AMS recommendation.

The prescribing and use of some antimicrobials continues to present challenges in rural settings. However, AMS review and intervention have become standard practice in these facilities. Results from a formal evaluation of the service, with feedback collected from patients and nursing, medical and allied health clinicians, will be published by early 2022.

Figure A: Six most common reasons for AMS interventions, April 2020 to January 2021



IV = intravenous administration; PO = oral administration

Appropriateness of prescribing in hospitals: Surgical National Antimicrobial Prescribing Survey

The Surgical NAPS is an audit tool that allows facilities to review their use of procedural and post-procedural surgical antimicrobial prophylaxis. Procedural antimicrobial prophylaxis is defined as any antimicrobial administered either immediately before or during the procedure for purposes of prophylaxis. Post-procedural antimicrobial prophylaxis is defined as any antimicrobial administered after the surgical procedure for the purposes of surgical prophylaxis. The Surgical NAPS used AU beyond 48 hours as a marker for prolonged post-procedural prophylaxis, whereas the Hospital NAPS used use beyond 24 hours as a marker. From 2019, administration beyond 24 hours and beyond 48 hours were both included in the Surgical NAPS analyses.

In 2019, 6,949 procedural antimicrobial prescriptions and 2,720 post-procedural antimicrobial prophylactic prescriptions were assessed for the Surgical NAPS. Antimicrobial prescribing was assessed as appropriate in 56.7% of all surgical episodes. There were major differences in the reasons for inappropriate prescribing for procedural and post-procedural prophylaxis. The percentage of episodes deemed inappropriate varied by procedure group, ranging from 3.7% for gastrointestinal endoscopic procedures to 76.3% for dentoalveolar surgery. When considering appropriateness for specific procedure groups, it is important that health service organisations consider local factors that may influence prescribing practice – for example, increased surgical loads in these specialties, or high rates of inappropriate prescribing in specific circumstances.

Procedural surgical prophylaxis

There were high rates of suboptimal documentation of the time of antimicrobial administration (77.4%) and of incision (66.1%).

When no antimicrobials were prescribed, guideline compliance (with either *Therapeutic Guidelines: Antibiotic* or local guidelines) was high (85.8%). Compliance with prescribing guidelines was lower when antimicrobials were prescribed (62.7%). The most common reasons for inappropriate procedural prescribing were incorrect timing (37.4%) and incorrect dosage (23.3%).

Inappropriate procedural prescribing was most common for orthopaedic surgery, urological surgery, abdominal surgery, and plastic and reconstructive surgery.

Topical antimicrobials accounted for 2.7% of prescribing, despite the topical route not being recommended as appropriate for procedural surgical antimicrobial prophylaxis. More than three-quarters (75.5%) of prescriptions for topical antimicrobials for procedural prophylaxis were deemed inappropriate.

Post-procedural surgical prophylaxis

When no post-procedural antimicrobials were prescribed, noncompliance with guidelines was infrequent (0.9%). When prescribed, the majority (64.1%) of post-procedural antimicrobial prophylaxis was noncompliant with guidelines. For post-procedural prophylactic prescriptions for which prophylaxis was recommended by guidelines, 42.0% were deemed inappropriate. The majority of inappropriate prescriptions were due to incorrect duration (55.9%). Dose and frequency inconsistencies were the next most common reason (25.5%).

From information to action

Engaging multidisciplinary colleagues to improve prescribing of surgical antimicrobial prophylaxis

Implementing the Surgical National Antimicrobial Prescribing Survey (NAPS) at a Principal Referral Hospital presented some challenges for the antimicrobial stewardship (AMS) team. The barriers that limited the team from regularly collecting data for the Surgical NAPS included the following:

- Auditing paper-based anaesthetic charts was labour-intensive
- Accessing theatres was restricted
- Obtaining surgical case lists was difficult.

The data collected for the 2017 Surgical NAPS, which was conducted over one week for the whole hospital, were of limited usefulness for quality improvement purposes, as insufficient cases were audited from each specialty and procedure type.

In 2018, an anaesthetist and their registrar approached the AMS team to collaborate on a review of four-week snapshots of surgical antimicrobial prophylaxis (SAP). The focus was surgical specialties where possible SAP issues had been identified in the 2017 Surgical NAPS.

The anaesthetist prospectively collected surgery details and data on perioperative antimicrobial use. The AMS team collated that information with data on postoperative antimicrobial use from the hospital's electronic prescribing software. The team submitted the collated data, along with an appropriateness assessment, directly into the Surgical NAPS portal.

This collaborative method substantially reduced the time needed for the AMS team to complete the Surgical NAPS audit:

- It removed the need to review anaesthetics forms and retrospectively enter data into the NAPS portal
- It increased the engagement of the anaesthetics team, as well as their ownership of the appropriateness of SAP
- It allowed real-time review and feedback on SAP prescribing.

These outcomes highlight how a flexible, multidisciplinary, collaborative approach to auditing SAP can use resources more effectively.

The collaborative approach to collecting Surgical NAPS data has now been used for intra-abdominal and urological procedures. Anaesthetists, and general surgery and urology teams, have stated that Surgical NAPS reports are useful in helping them identify where SAP prescribing could be improved. The hospital plans to repeat the collaborative approach of collecting Surgical NAPS data with these departments, monitor progress, and broaden the approach to other surgical specialties.

Inappropriate post-procedural prescribing was most common for orthopaedic surgery, plastic and reconstructive surgery, and otolaryngology head and neck surgery.

Antimicrobials prescribed post-procedurally continued for longer than 24 hours for 61.4% of prescriptions, and 42.8% continued for longer than 48 hours. Three procedure groups accounted for 56.5% of all surgical prophylaxis for up to, or greater than, 48 hours: ophthalmology, plastic and reconstructive surgery, and otolaryngology head and neck surgery.

Topical antimicrobials for ophthalmic procedures may be appropriately prescribed post-procedurally. When these were excluded, almost two-thirds of all topical antimicrobials (65.2%) were deemed inappropriate.

From information to action

Improving appropriateness of prescribing in the perioperative space

The New South Wales Central Coast Local Health District (CCLHD) monitors antimicrobial prophylaxis given to patients who undergo a surgical procedure in the district. It uses data obtained by the antimicrobial stewardship (AMS) team, as well as reports from the National Antimicrobial Prescribing Survey, the National Surgical Quality Improvement Program (NSQIP) and the National Antimicrobial Utilisation Surveillance Program.

Using these data, the CCLHD:

- Reviews the overall appropriateness of surgical prophylaxis prescribing
- Investigates the timing of administering prophylaxis
- Assesses compliance with CCLHD surgical antimicrobial prophylaxis (SAP) guidelines within individual specialties
- Supports investigations of cases of surgical site infection.

In the initial audit in 2019, 42% of patients were found to have received their surgical prophylaxis in the recommended time frame (Figure A). Results of the initial audit were presented to the surgical head of department and anaesthetist meetings, as well as the Drug and Therapeutics Committee, the Infection Prevention and Control Committee, and the AMS Subcommittee. This prompted a review of the SAP guidelines by the surgical and anaesthetic departments, as well as other collaborative quality improvement measures, including:

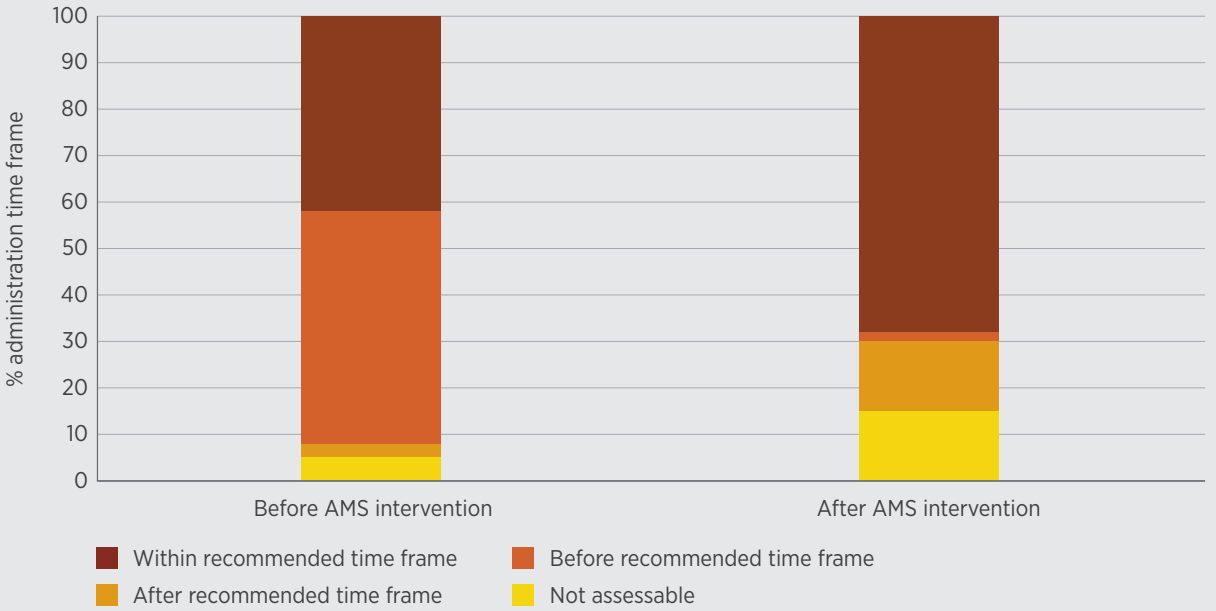
- Display of updated recommendations and procedures in perioperative areas, including in drug storerooms, outside theatres and in common spaces
- Increased education, awareness raising and frequency of reporting by the AMS team to anaesthetists, nursing staff and surgeons
- Review of non-recommended agents on theatre trolleys
- Regular review of, and feedback on, antimicrobial prescribing in an ongoing, collaborative way with the NSQIP.

These departments also received reports of surgical prophylaxis and interventions, and what activities the AMS team has performed in the surgical and perioperative space, every two months. When the audit

continues

was repeated in 2020, after 12 months, the percentage of patients who were documented to have received their surgical prophylaxis within the recommended time frame increased to 68% (Figure A). The CCLHD now performs rolling audits with the NSQIP team and provides ongoing feedback to the surgical and anaesthetic teams.

Figure A: Administration time of initial procedural surgical prophylaxis



3.2 Commentary – acute hospitals

Overall antimicrobial use

The Priority Antibacterial List stratifies antibacterials into three categories to support surveillance of AU in Australia, and enables a focus on antibacterials with a higher risk of contributing to AMR. Access category antibacterials should be prioritised for use over Curb and Contain category antibacterials, if possible, to preserve Curb and Contain categories for use only when clinically necessary. This AMS tool enables Australian hospitals to compare their use of Curb and Contain antibacterials against other similar hospitals, and to monitor their use over time.

Use of the Priority Antibacterial List for analysis of 2019 NAUSP data demonstrated that there was substantial variation in the proportion of Access category antibacterial use between facilities contributing to NAUSP. The proportion of acute hospital use in the Access category ranged from 29.7% to 52.9% for Principal Referral and Specialist Women's hospitals. In hospitals classified as Public Acute Group A, the proportion of use categorised as Curb ranged from 39.9% to 83.8%. These results should be interpreted in the context of the local setting. For example, as cefazolin is included in the Curb category, hospitals with a relatively high proportion of surgical patients may also report a high proportion of Curb antibacterial use.

Although some variation among hospitals can be explained by casemix differences,

analysis using the Priority Antibacterial List provides an alternative method to highlight potentially undesirable trends in use. For example, although Tasmania had the highest reported total AU rate nationally, it also used the highest proportion of antibacterials in the Access category. This demonstrates that a high volume of AU may not always be inappropriate. It is important to remember that AU across all categories has the potential to be either appropriate or inappropriate. Ideally, the majority of AU should be in the Access category, representing antibacterials that are recommended as first-line treatments for infections or where there is low resistance potential.

Caution is required when considering AU measured as DDDs per 1,000 OBDs. The DDD is the average daily adult maintenance dose of a medicine for its main indication (see Appendix 1 for further information). This does not account for variations in patients' characteristics, such as weight or kidney function. Also, for the same antimicrobial, the recommended dose may differ, depending on clinical indications or the severity of infection. When considering aggregated DDD AU data, there may have been higher use of multiple antimicrobials for individual patients, which is clinically appropriate, and may not mean that the number of patients administered antimicrobials has increased.

Appropriateness of prescribing

The Hospital NAPS surveys have demonstrated improvement in documentation of both indications and review dates. Higher rates of appropriate prescribing were associated with indications that typically involve infectious diseases clinicians, such as endocarditis, and with protocol-driven treatments, such as medical prophylaxis.

The increased rate of inappropriateness for ceftriaxone prescribing (from 24.9% to 29.0%) was the most notable change between the 2018 and 2019 Hospital NAPS. One possible explanation is that, for many conditions, the recommended dose of ceftriaxone changed with the release of the new *Therapeutic Guidelines: Antibiotic* in 2019.[8] The new guidelines suggest that 2 g be administered for a number of conditions (for example, sexually acquired pelvic inflammatory disease, peritonitis due to perforated viscus for patients hypersensitive to penicillin, infected pancreatic necrosis for patients hypersensitive to penicillin, and high-severity community-acquired pneumonia), whereas, in previous versions, 1 g was generally recommended. Depending on the patient's circumstances, auditors may have assessed such prescribing as under-dosing, with the potential risk of treatment failure. In accordance with the Hospital NAPS appropriateness definitions, these prescriptions would be considered 'inadequate' and therefore 'inappropriate'.

The variation in appropriateness between peer groups is an ongoing concern, which requires further investigation and targeted AMS strategies.

Surgical prophylaxis

Over the four years that the Surgical NAPS has been conducted, there has been an increase in the appropriateness of procedural prescribing, which may be due to improved timing of administration and dosage of antimicrobials. The Hospital NAPS has also identified an improvement in the proportion of surgical prophylaxis given for more than 24 hours from 41.0% in 2013 down to 30.0% in 2019. This reduction may be partly attributable to increased participation by private facilities, including hospitals that provide a higher proportion of day and minor surgeries. It may also be in response to the focus on surgical prophylaxis hospital AMS programs. The Commission has strongly promoted surgical prophylaxis as a priority

for improvement during that period, and undertaken collaborative work with the Royal Australasian College of Surgeons (RACS) since 2018. The Commission and the RACS have produced a series of co-badged resources promoting appropriate prescribing for surgical prophylaxis.[9]

There are specific patterns of inappropriate prescribing for some surgical specialties, such as prolonged duration of use, or choice of antimicrobials. Although the concepts of appropriate surgical prophylaxis hold true for all specialties, the relative importance of individual factors varies. Targeting specialties with the highest rates of inappropriate prescribing, such as orthopaedic surgery, urological surgery, abdominal surgery, plastic and reconstructive surgery, and otolaryngology head and neck surgery, in collaboration with the RACS and the relevant specialty societies, is a priority for the Commission and its support of AMS programs. Providing tailored and appropriate information for different procedural groups may improve the appropriateness of prescribing.

3.3 Developments and future plans – acute hospitals

The findings regarding AU and appropriateness of prescribing will continue to be communicated to states and territories to facilitate understanding of variation among facilities and considerations for potential targets for AMS programs. The Commission has also been emphasising the role of hospital clinical governance committees in responding to reports about AU and appropriateness of prescribing at facilities. These roles can include, but are not limited to, morbidity and mortality meetings, departmental meetings and grand rounds. To derive the most benefit from surveillance of AU and appropriateness of prescribing, the data must be communicated directly to prescribers, and targeted strategies for speciality groups should be encouraged.

The Commission has been working to facilitate access for state and territory health authorities to NAUSP and Hospital NAPS data for their public hospital contributors to enhance their capacity for system-wide and targeted AMS interventions.

The Commission will continue to collaborate with the RACS and establish relationships with relevant specialty groups to improve prescribing of antimicrobials for surgical prophylaxis.

The Priority Antibacterial List framework will continue to be promoted to health service organisations as a mechanism to assess the appropriateness of AU.

Inappropriate use of amoxicillin–clavulanic acid, especially for the indication of infective exacerbations of COPD, continues to be an ongoing area of concern. It is a highlight area in Chapter 6 of AURA 2021. The Commission is collaborating with COPD-X Guidelines Committee, Lung Foundation Australia, the Thoracic Society of Australia and New Zealand, and Therapeutic Guidelines Limited to address this key area of inappropriate prescribing.

3.4 Antimicrobial use in the community

Data on AU in primary care include dispensing data that are sourced from the Pharmaceutical Benefits Scheme (PBS) and the Repatriation Pharmaceutical Benefits Scheme (RPBS). These are Australian Government schemes that provide all Australians with subsidised access to many medicines.

Data from NPS MedicineWise describe prescribing patterns from participating NPS MedicineInsight practices.

For aged care homes, data are sourced from the Aged Care National Antimicrobial Prescribing Survey (AC NAPS). This is an annual voluntary online audit that aged care homes complete to assess antimicrobial prescribing practices and appropriateness of prescribing.

Pharmaceutical Benefits Scheme and Repatriation Pharmaceutical Benefits Scheme

The principal source of prescribing data in the community in Australia is the PBS/RPBS. Data on all antibacterial prescriptions dispensed under the PBS/RPBS are recorded in a national database. The PBS/RPBS data are estimated to capture more than 90% of all antibacterial prescriptions dispensed in the community. Other prescriptions may be dispensed privately, meaning that the PBS/RPBS does not subsidise the cost of the medicine. A more accurate estimate of the coverage of dispensing through the PBS/RPBS is being explored by the Commission. An indication of the proportion of private prescriptions dispensed in Australia is provided in the MedicineInsight section in this chapter.

For AURA 2021, five years of PBS/RPBS data, from 1 January 2015 to 31 December 2019, were analysed to assess trends. Data include the standard collection of data for the Anatomical Therapeutic Chemical (ATC) Class J01 (systemic antibiotics), which are usually presented internationally. In addition, analyses for AURA 2021 include the following ATC classes of antibacterials:

- A02 – Drugs for acid-related disorders
- A07 – Antidiarrheals, intestinal anti-inflammatory/anti-infective agents
- D06 – Antibiotics and chemotherapeutics for dermatological use
- S01 – Ophthalmologicals
- S02 – Otologicals
- S03 – Ophthalmological and otological preparations.

These additional classes ensure that data on important agents, such as topical fluoroquinolones, were captured to better reflect antibacterial exposure in the community and resistance selection pressure.

Prescription volume

In 2019, 40.3% (*n* = 10,227,693) of the Australian population had at least one antibacterial dispensed under the PBS/RPBS. This was a slight increase compared with 40.0% in 2018.

In 2015, non-J01 antibacterials comprised 8.4% of all prescriptions dispensed (Table 3.6). However, in 2016, chloramphenicol eye drops were rescheduled and became available over the counter without a prescription, resulting in a substantial drop in the total volume of non-J01 prescriptions. The proportion of prescriptions dispensed for non-J01 antibacterials has increased steadily since 2016, and these antibacterials accounted for 3.0% of prescriptions in 2019. There are no volume data available for topical antibacterials that are provided over the counter.

In 2019, 40.3% (n = 10,227,693) of the Australian population had at least one antibacterial dispensed under the PBS/RPBS.

Table 3.6: Volume of PBS/RPBS antibacterial prescriptions dispensed, 2015–2019

Year	All antibacterials (*n*)	J01 antibacterials (*n*)	Non-J01 antibacterials (*n*)	Non-J01 antibacterials (%)
2015	29,264,932	26,813,587	2,451,345	8.4
2016	27,324,648	26,926,933	397,715	1.5
2017	26,553,451	25,924,324	629,127	2.4
2018	26,229,366	25,427,786	801,580	3.1
2019	26,669,561	25,871,075	798,486	3.0

PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Source: Gadzhanova, Roughead[10]

Between 2015 and 2019, there was a gradual decline in the crude and age-standardised rates of antibacterial dispensing (Figure 3.11). In 2019, the age-standardised rate of the number of PBS/RPBS prescriptions per 1,000 people was 14.8% lower than the peak in 2015.

Between 2015 and 2019, there was a gradual decline in the crude and age-standardised rates of antibacterial dispensing.

Rates of supply of antibacterials vary between states and territories (Figure 3.12). The lower rates in the Northern Territory (NT) are likely to reflect access to other sources of antibacterial supply, particularly through Aboriginal and Torres Strait Islander health services, which are not captured in the PBS/RPBS data. Approximately 30% of the NT population is Aboriginal or Torres Strait Islander, compared with approximately 5% or less in other states and territories.[11]

The volume of prescriptions is also available as DDDs per 1,000 people per day for J01 class agents. Although there was a downward trend in the volume of prescriptions dispensed between 2015 and 2018, there was a slight increase in 2019 (Figure 3.13).

Dispensing rates vary by local area (Statistical Area Level 3 – SA3; Table 3.7). In some states and territories, the rates are influenced by the availability of other sources of antibacterial supply, such as Aboriginal and Torres Strait Islander health services. Another noticeable feature is that the area with the lowest dispensing rate is often near to, or contiguous with, the area with the highest dispensing rate. This suggests that local physician preference is a major influence on antibacterial use.

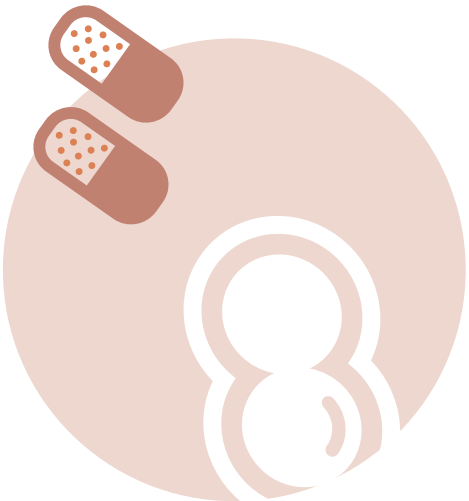
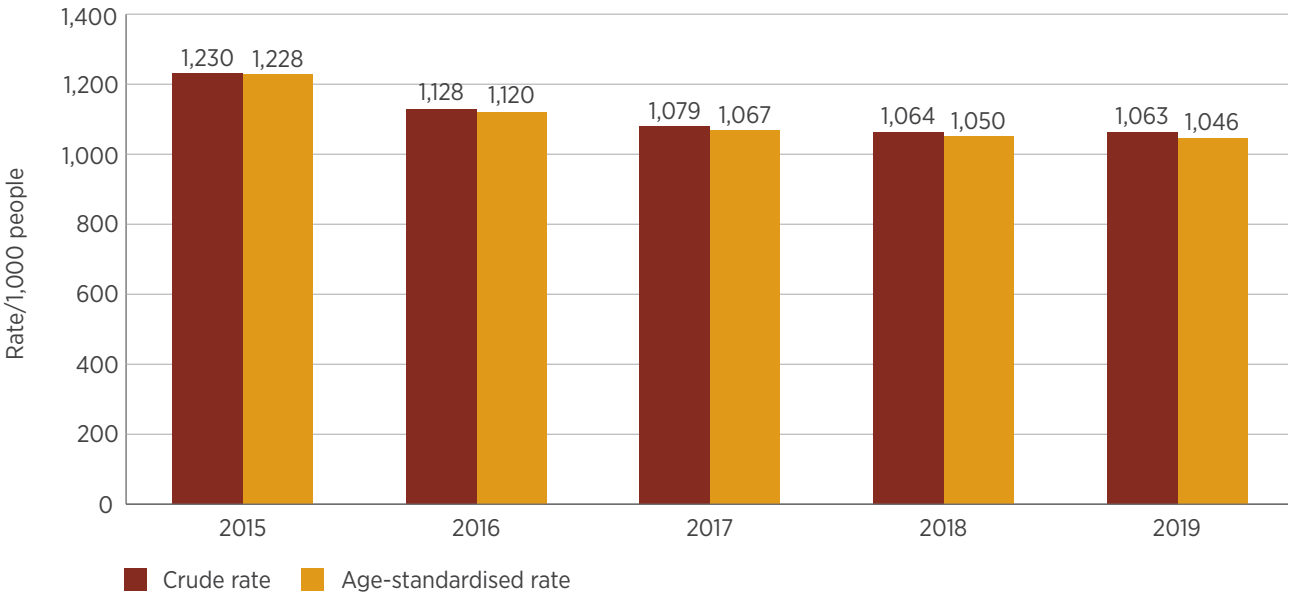
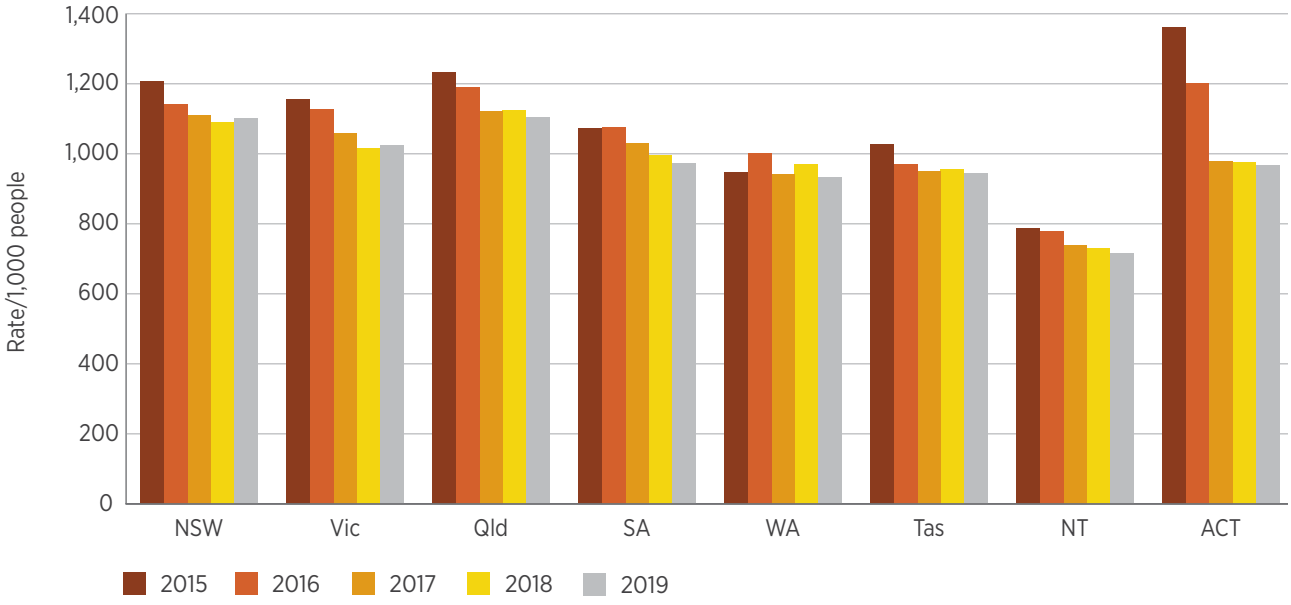


Figure 3.11: Number of PBS/RPBS antibacterial prescriptions dispensed per 1,000 people, crude and age-standardised rates, 2015–2019



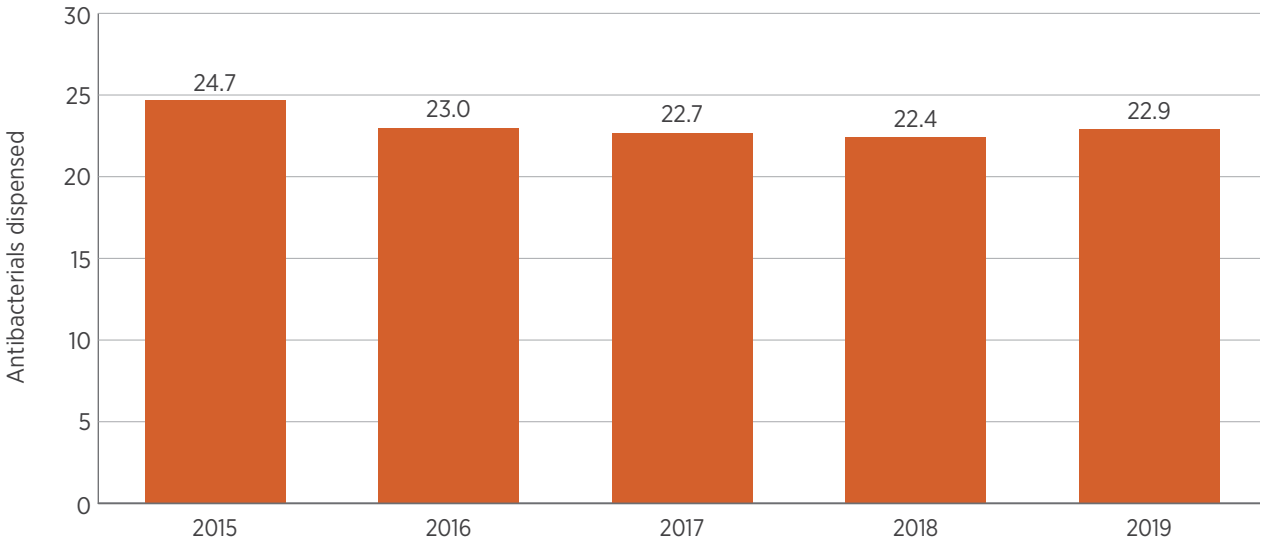
PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Source: Gadzhanova, Roughead[10]

Figure 3.12: Age-standardised rate of the number of PBS/RPBS antibacterial prescriptions dispensed per 1,000 people, by state and territory, 2015–2019



PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Source: Gadzhanova, Roughead[10]

Figure 3.13: Quantity of antibacterials dispensed under the PBS/RPBS (DDD/1,000 people/day), 2015–2019



DDD = defined daily dose; PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Source: Gadzhanova, Roughead[10]

Table 3.7: Highest and lowest antibacterial dispensing rates per 1,000 people, age standardised, by Statistical Area Level 3, 2019

State or territory	Lowest SA3 region	Rate	Highest SA3 region	Rate
NSW	Hawkesbury	514	Richmond – Windsor	2,030
Vic	Melbourne City	552	Melton – Bacchus Marsh	1,374
Qld	Jimboomba	380	Beenleigh	1,727
SA	Adelaide City	666	Playford	1,200
WA	Augusta – Margaret River – Busselton	273	Canning	1,302
Tas	Central Highlands	450	Brighton	1,562
NT	East Arnhem*	40	Darwin Suburbs	801
ACT	North Canberra	720	Weston Creek	1,133

* Rate may be influenced by the availability of other sources of supply of antibacterials, such as Aboriginal and Torres Strait Islander health services.
Source: Gadzhanova, Roughead[10]

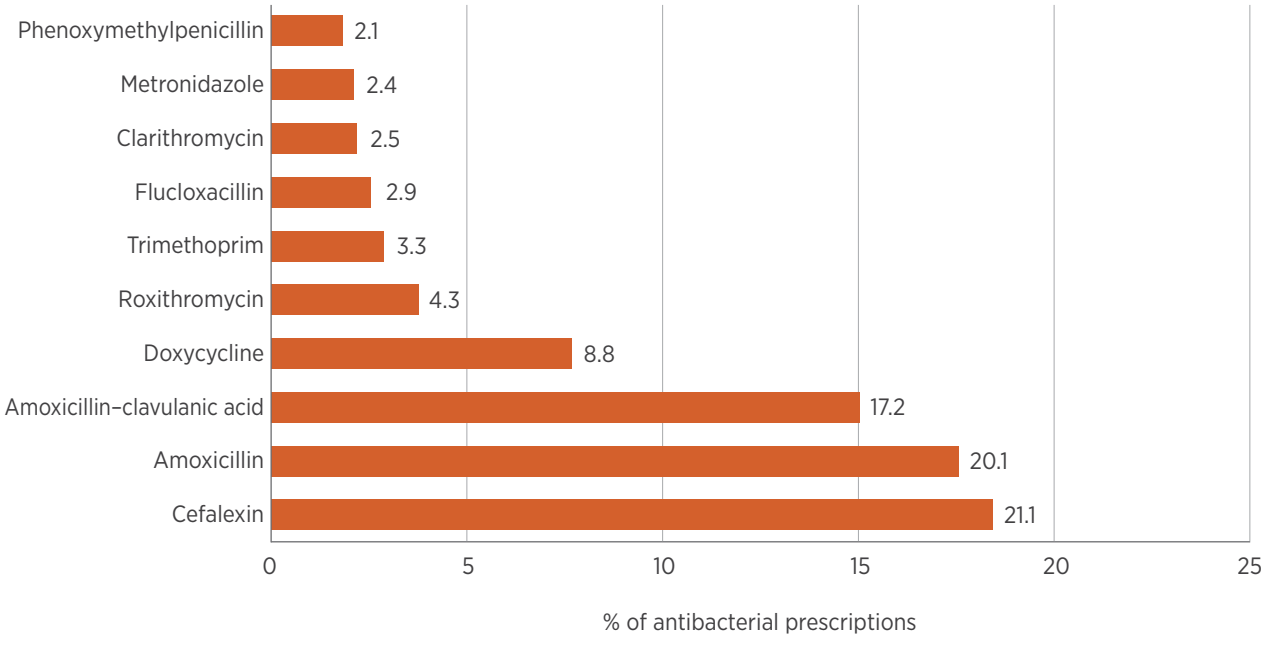
As in previous years, the three most common antibacterials dispensed in 2019 were cefalexin, amoxicillin and amoxicillin–clavulanic acid (Figure 3.14). These agents accounted for more than 50% of all prescriptions dispensed. The three most common antibacterial types dispensed (based on DDDs per 1,000 people per day and antibacterial class; Figure 3.15) were penicillins with extended spectrum (mainly amoxicillin), β-lactamase inhibitor combinations (amoxicillin–clavulanic acid) and tetracyclines (mainly doxycycline). These are followed by first-generation cephalosporins (cefalexin) (Figure 3.15). The difference in order of the three most commonly dispensed agents when measured by raw volumes (Figure 3.14) and DDDs per 1,000 people per day (Figure 3.15) is due to differences in common Australian dosing regimens compared with the World Health Organization DDDs. Between 2015 and 2019, there was seasonal variation in dispensing rates for amoxicillin and amoxicillin–clavulanic acid – both rates are higher during winter months. However, there was no seasonal variation in dispensing rates for cefalexin (data not shown).

There was substantial variation in antibacterial dispensing rates for different age groups (Figure 3.16). In 2019, the rate was highest for those aged over 65 years, followed by those in the 2–4-year age group. The lowest rate of antibacterial dispensing was observed for the 10–19-year age group.

Many antibacterial pack sizes are adequate for treating minor infections in the community. However, a high proportion of antibacterial prescriptions presented for dispensing were ordered with repeats (Table 3.8). The high rate of repeats for roxithromycin is likely to reflect the small pack size relative to the dosing regimen that is usually prescribed.

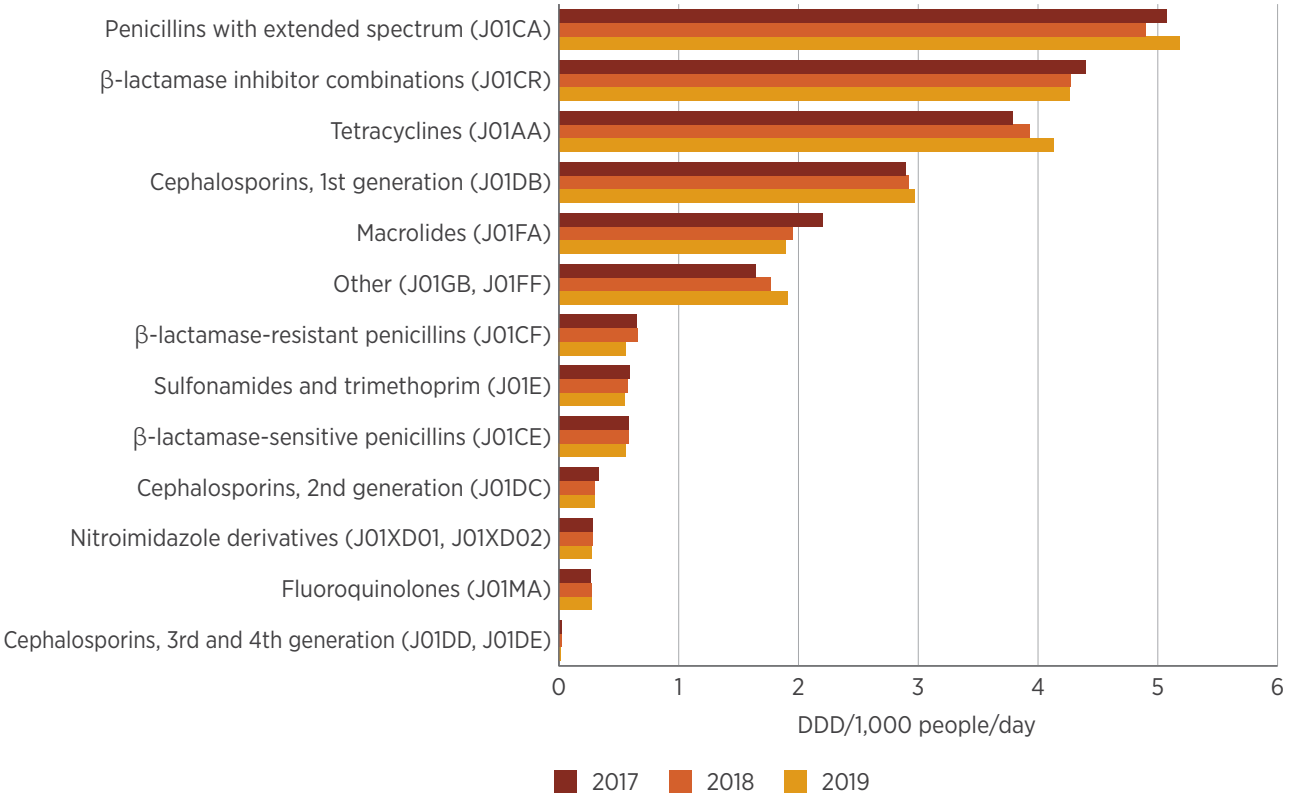
Repeat prescriptions filled within 10 days usually indicate a continuation of the original course of treatment. Repeat prescriptions

Figure 3.14: Ten most commonly dispensed antibacterials under the PBS/RPBS, by percentage of all antibacterial prescriptions, 2019



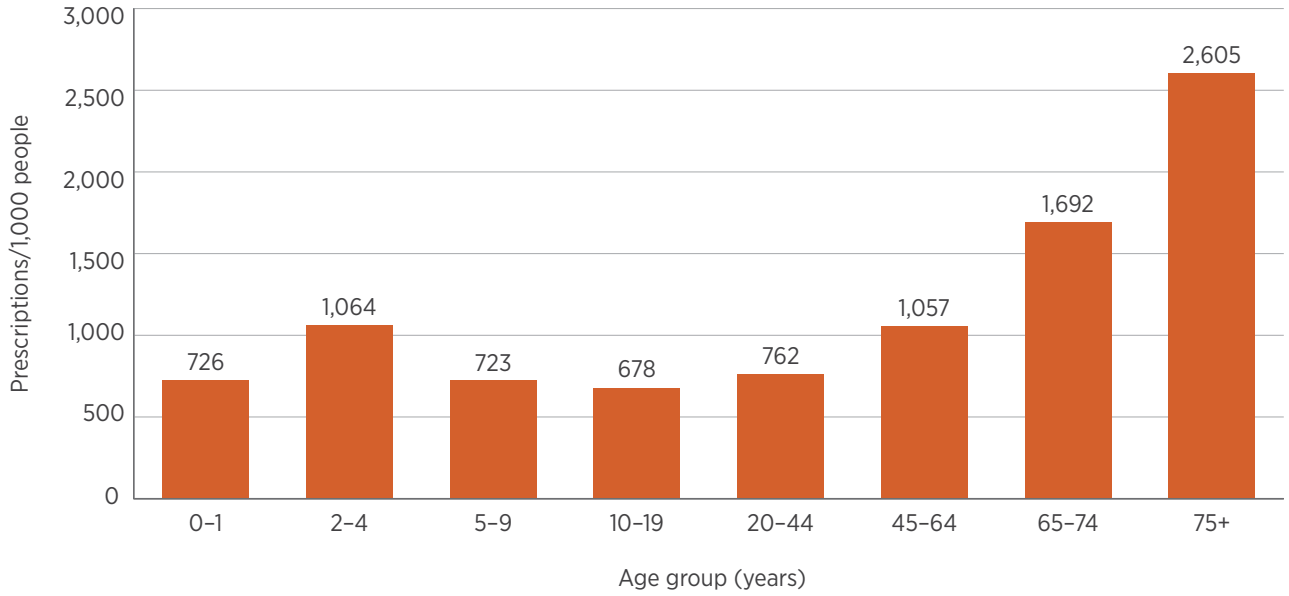
PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Source: Gadzhanova, Roughead[10]

Figure 3.15: Antibacterials dispensed under the PBS/RPBS (DDD/1,000 people/day), by class of systemic antibacterial (J01), 2017–2019



DDD = defined daily dose; PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Source: Gadzhanova, Roughead[10]

Figure 3.16: Number of PBS/RPBS prescriptions dispensed per 1,000 people, all antibacterials, by patient age group, 2019



PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Source: Gadzhanova, Roughead[10]

Table 3.8: Percentage of PBS/RPBS antibacterial prescriptions ordered with the maximum number of repeats allowed and repeats dispensed within 10 days, top 10 antibacterials dispensed, 2019

Antibacterial	Percentage of prescriptions ordered with maximum number of repeats allowed	Percentage of original prescriptions with repeats for which the first repeat was ordered less than 10 days from the original prescription
Cefalexin	38.9	51.3
Amoxicillin	26.2	50.3
Amoxicillin–clavulanic acid	51.7	61.1
Doxycycline	45.0	32.8
Roxithromycin	50.8	69.9
Trimethoprim	28.2	41.0
Clarithromycin	44.4	55.8
Metronidazole	26.8	44.8
Phenoxymethylpenicillin	7.9	32.5

PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Notes:
1. No repeats are allowed for flucloxacillin (not included in this table), even though it was one of the top 10 dispensed antibacterials in 2019.
2. Less than 10 days was chosen for analysis because most pack sizes provide treatment for 5–10 days.
Source: Gadzhanova, Roughead[10]

dispensed after 10 days may indicate an interruption of the original duration and increased potential for inappropriate use.

To encourage prescribers to issue repeat prescriptions for antibacterials only when clinically indicated, PBS policy changes relating to the five most commonly dispensed antibacterials (amoxicillin, amoxicillin–clavulanic acid, cefalexin, doxycycline and roxithromycin) came into effect in April 2020. These changes reduced the number of repeat prescriptions permissible for these antibacterials. Further detail about these changes and their impact is in Chapter 6.

Antimicrobial prescribing in general practice: NPS MedicineWise MedicineInsight program

MedicineInsight is a large general practice dataset managed by NPS MedicineWise. It collects longitudinal de-identified clinical data from participating general practices. The data include information on patterns of prescribing, as well as the demographic characteristics, diagnoses and risk factors of patients prescribed systemic antimicrobials.

MedicineInsight data – differences between the third and fourth AURA reports

Since the publication of AURA 2019, NPS MedicineWise has made several changes to MedicineInsight, including some of the rules and algorithms used for data analysis. These include:

- An ability to select antimicrobials by Anatomical Therapeutic Chemical code, rather than active ingredient alone
- Only counting patients who attended the general practice in the year of analysis, rather than also including the previous year
- Restricting reporting on prescribing rates for conditions of interest to prescriptions issued on the same day as the condition being recorded.

These changes have resulted in differences in the number of patients, general practices and antimicrobial prescribing rates included in this report compared with AURA 2019. However, NPS MedicineWise regards the methodology as providing a more accurate picture of the appropriateness of antimicrobial prescribing by general practitioners. Further detail about these changes is in Appendix 1.

AURA 2021 includes MedicineInsight data for 2015–2019. In 2019, data were contributed by 412 general practice sites for 2,081,855 patients. Analyses of trends for the period 2010–2019 are included, where available.

Data were analysed for antimicrobials included in the standard collection of ATC Class J01 (systemic antibacterials).

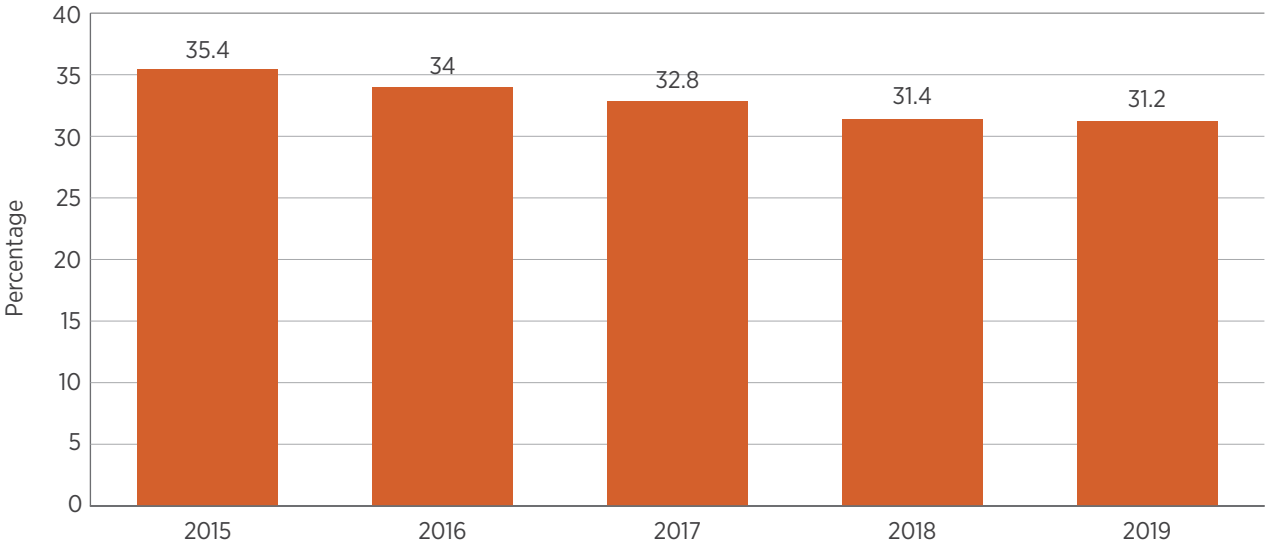
In 2019, 31.2% of MedicineInsight patients who attended a practice in that year (650,099 of 2,081,855) were prescribed systemic antimicrobials – a reduction of 4.2 percentage points compared with 2015 (Figure 3.17).

In 2019, 31.2% of NPS MedicineInsight patients were prescribed systemic antimicrobials – a reduction of 4.2 percentage points compared with 2015.

Among NPS MedicineInsight practices, people aged 90–94 years were more frequently prescribed systemic antimicrobials than any other age group in 2019 (43.2 per 100 patients). In patients aged less than 65 years, the highest rate of prescribing was for people aged 15–19 years (33.3 per 100 patients), followed by children aged 5–9 years (32.5 per 100 patients) (Figure 3.18). In 2019, the prescribing rate for females was 33.3 per 100 patients, compared with 28.7 per 100 patients for males.

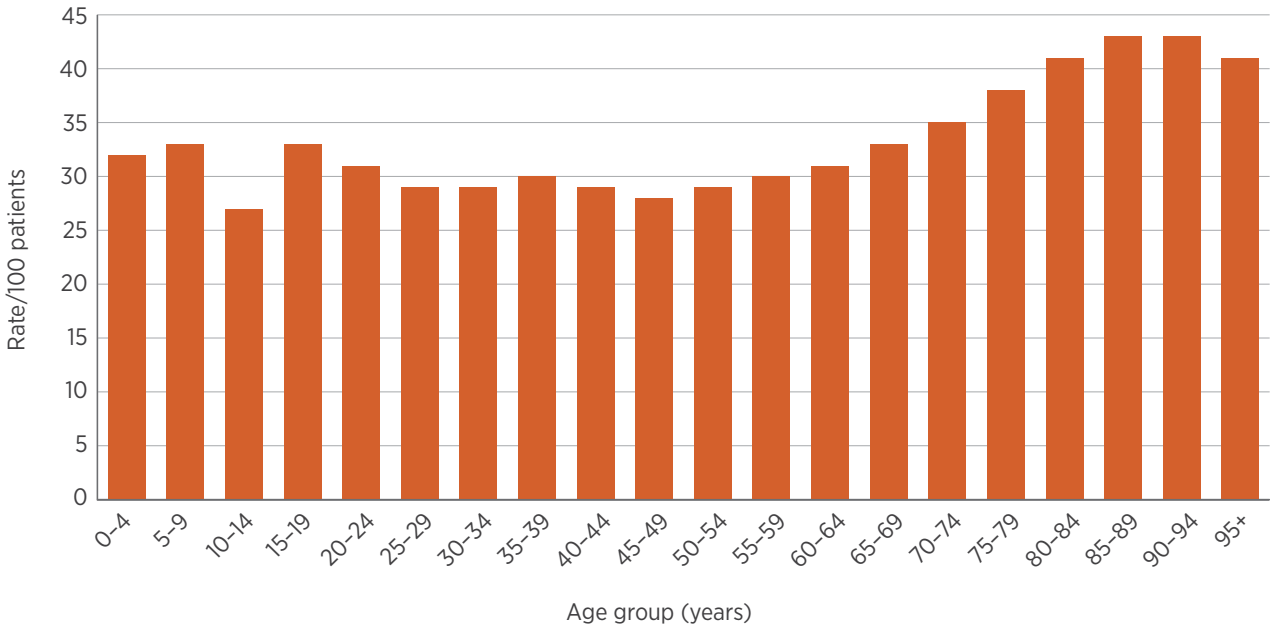
Table 3.9 summarises the demographics of patients prescribed antimicrobials in MedicineInsight practices between 2015 and 2019. Socioeconomic differences are measured using the Socio-Economic Indexes for Areas (SEIFA). In 2019, the rate of prescribing per 100 patients was 32.1 among people living within the most disadvantaged SEIFA decile and 32.0 among the least disadvantaged SEIFA decile.

Figure 3.17: Percentage of patients prescribed one or more systemic antimicrobials, MedicineInsight practices, 2015–2019



Note: Number of practices was 393 in 2015, 405 in 2016, 410 in 2017, 411 in 2018 and 412 in 2019. The number of denominator patients may change each year.
Source: NPS MedicineWise[12]

Figure 3.18: Number of patients prescribed one or more J01 antimicrobials, per 100 patients, by age group, MedicineInsight practices, 2019



Note: Number of practices in 2019 was 412.
Source: NPS MedicineWise[12]

Table 3.9: Region of residence and socioeconomic status for patients prescribed J01* antimicrobials, MedicineInsight practices, 2015–2019

		Percentage of patients prescribed one or more antimicrobial				
Measure	**Category**	**2015**	**2016**	**2017**	**2018**	**2019**
State or territory	NSW	35.6	33.4	32.6	31.6	31.9
	Vic	36.4	35.5	34.0	31.0	31.1
	Qld	36.4	34.9	33.1	32.5	32.2
	SA	32.5	33.1	32.7	29.9	30.5
	WA	32.7	33.1	31.4	30.7	29.1
	Tas	34.5	32.1	31.6	29.5	29.3
	NT	36.8	33.6	32.7	30.7	27.8
	ACT	34.8	35.9	34.7	32.9	35.0
Remoteness	Major cities	35.7	34.5	33.2	31.9	32.0
	Inner regional	34.2	32.5	31.5	30.0	29.7
	Outer regional	36.6	35.0	33.4	31.5	30.1
	Remote	30.2	31.2	32.5	28.8	26.3
	Very remote	29.9	27.0	28.0	26.8	26.0
	Unknown/other	23.1	23.7	17.9	19.8	22.5
SEIFA decile	1 (most disadvantaged)	37.1	34.6	33.4	31.7	32.1
	2	35.5	33.9	32.9	31.6	30.5
	3	35.9	34.5	33.1	31.2	30.7
	4	34.0	32.9	31.9	30.7	30.8
	5	34.9	33.5	32.6	31.5	31.0
	6	36.6	36.1	34.6	32.6	32.0
	7	36.5	34.5	33.2	32.0	31.8
	8	34.4	33.4	32.0	31.1	31.1
	9	34.6	33.3	31.8	30.0	30.3
	10 (least disadvantaged)	35.5	33.9	33.0	31.8	32.0
	Unknown/other	23.1	23.7	17.9	19.8	22.5

SEIFA = Socio-Economic Indexes for Areas

* Subgroup J01 of the Anatomical Therapeutic Chemical classification system is 'antibacterials for systemic use'.

Notes:

1. The number of MedicineInsight practices was 393 in 2015, 405 in 2016, 410 in 2017, 411 in 2018 and 412 in 2019.
2. The number of patients in the denominator may change each year.
3. Differences across states and territories should be interpreted with caution because of non-random sampling and varying levels of participation in the MedicineInsight program.

Source: NPS MedicineWise[12]

Differences were observed in antimicrobial prescribing between people living in major cities (32 per 100 patients) and people in very remote areas (26 per 100 patients). However, remote areas of Australia are under-represented in participating MedicineInsight practices. People living in rural and remote areas often have higher levels of disease and poorer health outcomes than those in metropolitan areas.[13]

Differences in antimicrobial prescribing rates among MedicineInsight practices were also observed between states and territories. The Australian Capital Territory had the highest antimicrobial prescribing rate (35 per 100 patients), followed by Queensland (32.2 per 100 patients), New South Wales (NSW; 31.9 per 100 patients), Victoria (31.1 per 100 patients), SA (30.5 per 100 patients), Tasmania (29.3 per 100 patients) and WA (29.1 per 100 patients). The lowest rate of prescribing was in the NT (27.8 per 100 patients). However, these differences across states and territories should be interpreted with great caution because of non-random sampling and varying levels of participation in the MedicineInsight program. It is encouraging to see that there has been a decline in prescribing rates in most states and territories since 2015, with the greatest decline in the NT.

Antimicrobial prescribing: 10-year trends among MedicineInsight practices

Between January 2010 and December 2019, the rate of systemic antimicrobial prescriptions (originals and repeats) per 100 general practitioner (GP) consultations in participating MedicineInsight practices steadily declined, from 18.2 to 16.5. Monthly variations were observed and were consistent with seasonal variations – the number of prescriptions per 100 GP visits increased during the winter months (Figure 3.19).

Six of these systemic antimicrobials showed the same seasonal prescribing variation. Cefalexin did not share this pattern, probably because it is infrequently prescribed as a first-line treatment if an antimicrobial is clinically indicated for a respiratory tract infection. A different but consistent seasonal variation was observed for cefalexin, with more prescriptions in the summer period (Figure 3.19).

Between January 2010 and December 2019, the rate of systemic antimicrobial prescriptions (originals and repeats) per 100 general practitioner consultations in participating MedicineInsight practices steadily declined, from 18.2 to 16.5.

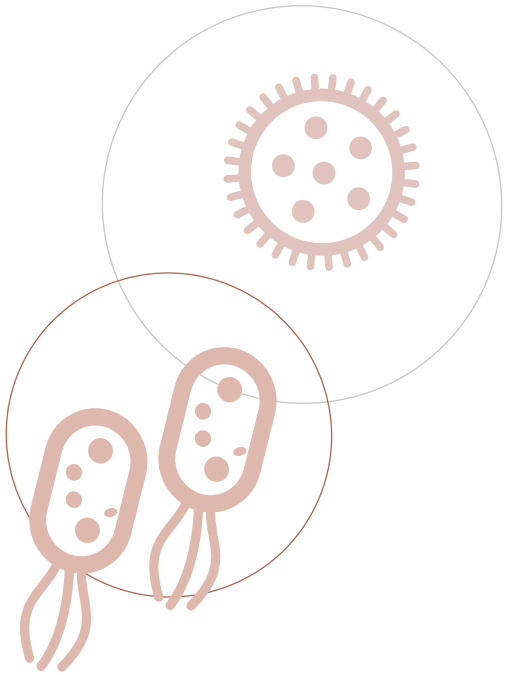
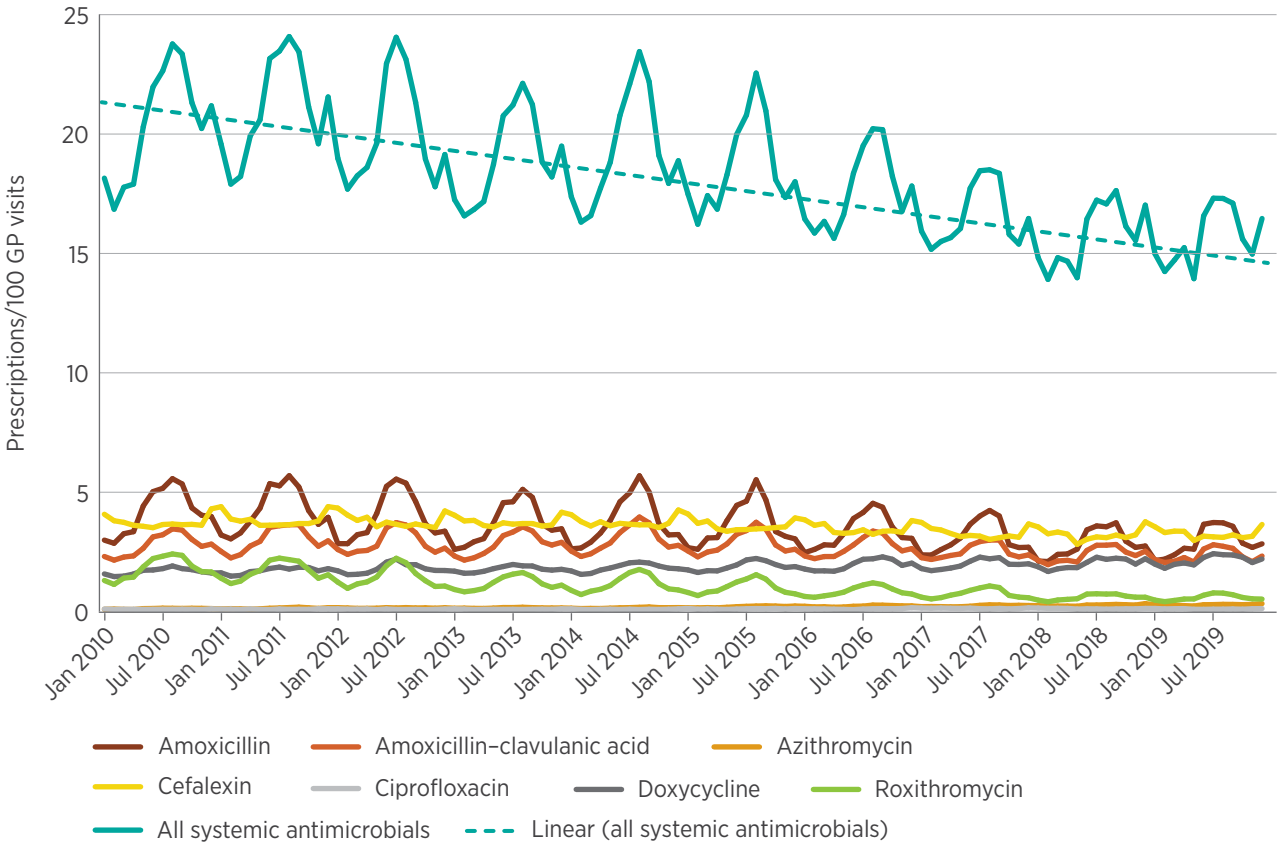


Figure 3.19: Rate of general practitioner PBS/RPBS prescriptions for J01 systemic antimicrobials (originals and repeats) per 100 visits, MedicineInsight practices, January 2010 to December 2019



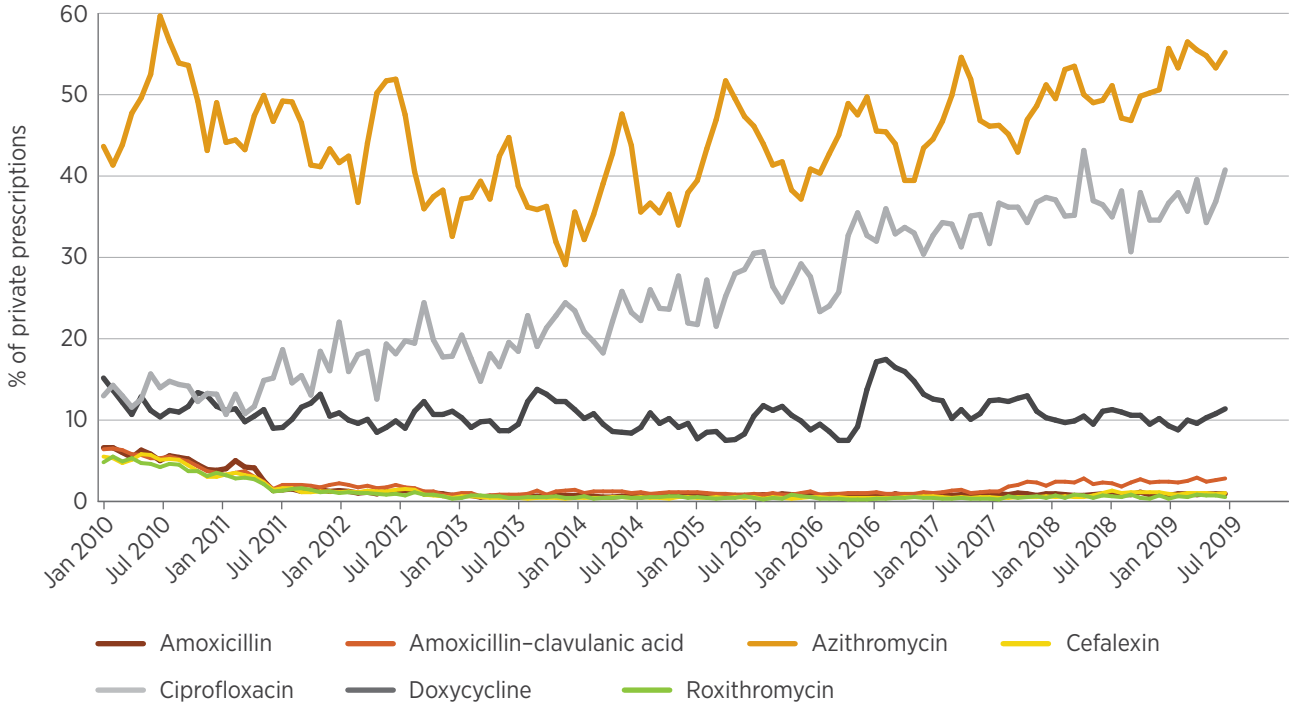
PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Source: NPS MedicineWise[12]

In Australia, prescriptions may be subsidised by the PBS/RPBS or ordered as private prescriptions. Prescribers may order prescriptions as private for many reasons, including prescribing an antimicrobial for an indication that is not subsidised by the PBS/RPBS, or prescribing a quantity that exceeds the PBS/RPBS limit.

Due to the increasing use of private prescriptions, which impacts the volumes of dispensing recorded on the PBS/RPBS, the MedicineInsight analysis for AURA 2021 also examined the rates of private prescriptions issued for the seven most frequently prescribed antimicrobials. Counting all prescriptions, including originals and repeats, the proportions of private to total prescriptions for the 10-year period 2010–2019 are shown in Figure 3.20.

It is notable that there has been a high proportion of private prescriptions for azithromycin throughout the 10-year period; this exceeded 50% in 2019. This is likely to reflect the fact that this antimicrobial is either PBS listed as 'restricted' or 'authority required', but the agent is becoming increasingly used in general practice instead of roxithromycin. To support this view, average monthly private prescriptions of azithromycin were 423 in 2010 (0.07 per 100 GP visits), increasing to 1,424 in 2019 (0.16 per 100 GP visits). For roxithromycin,

Figure 3.20: Proportions of private to total prescriptions, originals and repeats, for the seven most frequently prescribed antimicrobials, January 2010 to December 2019



Source: NPS MedicineWise[12]

the average monthly PBS/RPBS prescriptions decreased from 9,967 (1.76 per 100 GP visits) to 5,354 (0.61 per 100 GP visits) over the same period.

There was also a steady rise in the proportion of private prescriptions for ciprofloxacin over the 10-year period, reaching approximately 40% by 2019. This may be partly attributed to increasing restrictions placed on ciprofloxacin on the PBS/RPBS, combined with reduced costs once this agent became generic. The average number of private ciprofloxacin prescriptions increased over the 10-year period, from 95 per month in 2010 (0.02 per 100 GP visits) to 442 in 2019 (0.05 per 100 GP visits).

There was a steady rise in the proportion of private prescriptions for ciprofloxacin from 2010 to 2019, reaching approximately 40% by 2019.

Amoxicillin, roxithromycin and doxycycline are not restricted on the PBS/RPBS for all common indications. Nevertheless, private prescriptions accounted for approximately 10% of doxycycline prescriptions throughout the 10-year period. There have been increasing restrictions placed on amoxicillin–clavulanic acid within the PBS/RPBS, but the restrictions are relatively moderate, and private prescriptions account for less than 3% of total prescriptions.

Patterns of prescribing

Table 3.10 summarises patterns of GP prescribing for seven selected antimicrobials. In 2019, of the seven selected antimicrobials, amoxicillin was the most frequently prescribed (9.8 per 100 GP visits), followed by cefalexin (8.8 per 100 GP visits), amoxicillin–clavulanic acid (5.9 per 100 GP visits), doxycycline (3.9 per 100 GP visits), roxithromycin (1.7 per 100 GP visits), azithromycin (1.1 per 100 GP visits) and ciprofloxacin (0.4 per 100 GP visits). This order has remained the same since 2015. The most common indications for cefalexin prescribing in 2019 were skin/wound infections (35.9%) and urinary tract infections (UTIs) (24.7%) (Table 3.10).

Between 2015 and 2019, there was a slight increase in the overall rate of PBS prescribing of antimicrobials that have restricted benefits, with ciprofloxacin increasing from 0.35 to 0.37 per 100 prescriptions, and azithromycin increasing from 0.84 to 1.1 per 100 prescriptions. It is important to note that the use of azithromycin for the treatment of conditions such as chlamydia and gonorrhoea in the sexual health clinic setting may not be captured in these data.

The data analysis also explored indications for antimicrobial prescribing in participating MedicineInsight practices. Information about the clinical indication for an antimicrobial prescription can be collected from general practice clinical information software in a number of ways. The most straightforward approach is through the 'Reason for Prescription' (RfP) field associated with the record for a clinical encounter. However, it is not mandatory for GPs to complete this field, and it is often left blank. When this information was lacking, the clinical notes and the antimicrobial choice were used to infer the reason for prescribing.

Over the five-year period from 2015 to 2019, clinical indications for antimicrobial prescriptions were recorded in the RfP field in 36.4% of cases. Where an RfP was not recorded, the analysis used information recorded on the same day as the antimicrobial prescription from other fields – 'Reason for Encounter' and 'Diagnosis' – to identify the clinical indications for which the prescription had been issued.

In 2019, there were changes in the prescribing patterns for ciprofloxacin. The most common indication for ciprofloxacin prescribing was not evident, because it was described as 'other infection' (20.2%). The fourth most common indication for prescribing ciprofloxacin in 2019 was UTI (15.3%), which was the fifth most common indication (7.7%) in 2015. The increase is of particular concern because greater use of ciprofloxacin is likely to increase the number of ciprofloxacin-resistant urinary pathogens.[14] This increase may also be a response to increasing multidrug-resistant *Escherichia coli*.

The increasing use of ciprofloxacin to treat urinary tract infections is of particular concern. Greater use of ciprofloxacin is likely to increase the number of ciprofloxacin-resistant urinary pathogens.

This is a difficult clinical problem because there are very limited oral therapeutic options for UTIs apart from ciprofloxacin. Ciprofloxacin should be reserved for treating infections that are resistant to other antimicrobials, and when alternative antimicrobials are not available.[8]

Table 3.10: Patterns of general practitioner prescribing for seven antimicrobials, MedicineInsight practices, 2019

Antimicrobial	Patients issued a prescription (PBS/RPBS or private) (%)*	Most common indication (%)†	Patient age group with highest rate§ of prescribing (years)	Prescriptions (PBS/RPBS or private) ordered with repeats (%)	Prescriptions ordered as private (%)
Amoxicillin	9.8	• URTI (acute) (26.3) • Pneumonia (17.2) • Otitis media (15.3) • Sinusitis (acute/ chronic) (11.1)	0–4	23.7	0.7
Cefalexin	8.8	• Skin/wound infection (35.9) • UTI (24.7) • Other infection (9.6) • Unclassified RfP# (8.0)	>95	38.2	0.8
Amoxicillin–clavulanic acid	5.9	• Sinusitis (acute/ chronic) (15.2) • Pneumonia (13.7) • URTI (acute) (11.4) • Skin/wound infection (8.5)	80–84	51.9	2.7
Doxycycline	3.9	• Pneumonia (19.9) • Acne (16.9) • Sinusitis (10.8) • Unclassified RfP# (10.4)	75–79	54.0	10.9
Roxithromycin	1.7	• URTI (acute) (30.2) • Pneumonia (24.5) • Bronchitis (acute) (11.4) • Sinusitis (acute/ chronic) (10.8)	85–89	48.9	0.4
Azithromycin	1.1	• *Chlamydia* infection (17.3) • Unclassified RfP# (16.2) • Pneumonia (14.0) • Other infection (10.4)	20–24	14.3	52.0

continues

Table 3.10: *continued*

Antimicrobial	Patients issued a prescription (PBS/RPBS or private) (%)*	Most common indication (%)†	Patient age group with highest rate§ of prescribing (years)	Prescriptions (PBS/RPBS or private) ordered with repeats (%)	Prescriptions ordered as private (%)
Ciprofloxacin	0.4	• Other infection (20.2) • Unclassified RfP# (19.8) • Skin/wound infection (18.8) • UTI (15.3)	90–94	28.6	44.5

PBS = Pharmaceutical Benefits Scheme; RfP = reason for prescription; RPBS = Repatriation Pharmaceutical Benefits Scheme; URTI = upper respiratory tract infection; UTI = urinary tract infection

* Percentage of MedicineInsight patients who visited a general practitioner at least once between 1 January and 31 December 2019, and had one or more prescriptions for the specified antimicrobial issued on the day of the visit

† 34.7% of prescriptions in 2019 had an explicit RfP recorded. If an explicit recorded reason for the prescription was missing, an association was assumed between the antimicrobial prescribed and a reason for the encounter and/or a diagnosis recorded on the same day as the prescription

§ Number of patients in the MedicineInsight data prescribed one or more antimicrobial prescriptions, per 100 patients

\# Prescriptions with a recorded entry in the RfP field that did not match an antimicrobial-related indication

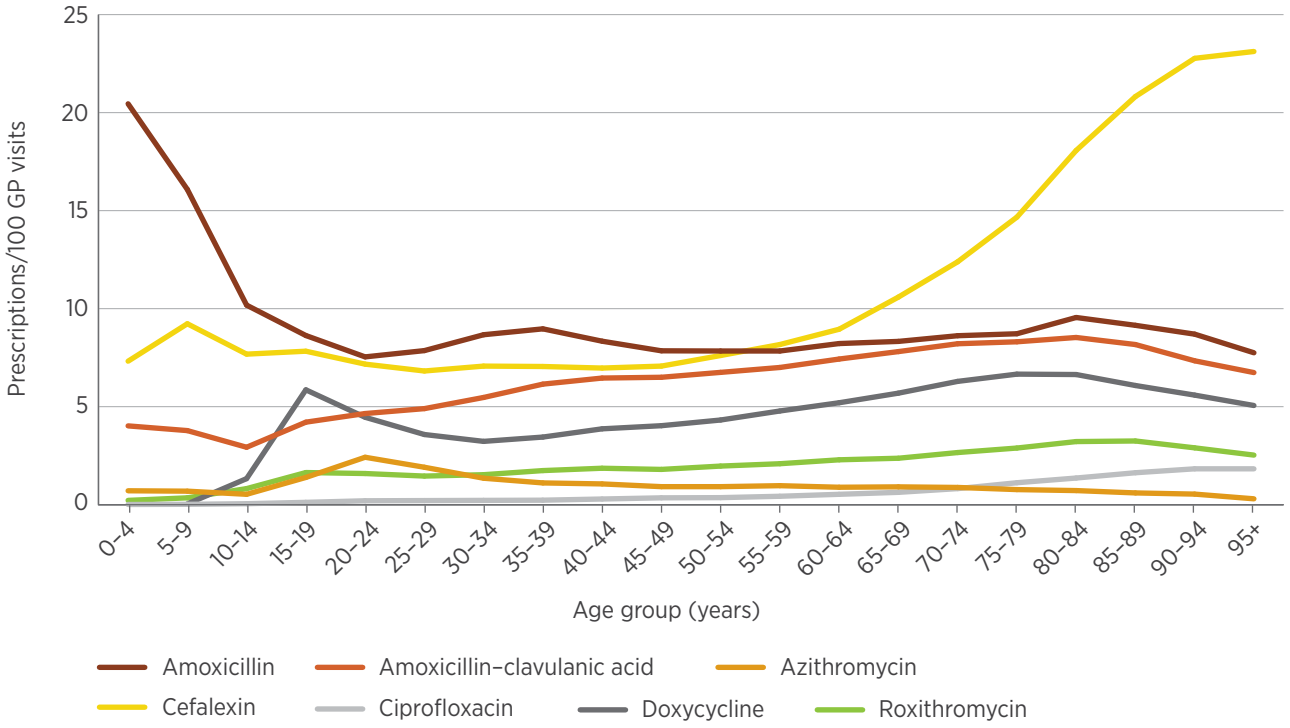
Source: NPS MedicineWise[12]

Differences in prescribing were also found across patient age groups, with children aged 0–4 years most commonly prescribed amoxicillin (20.4 per 100 patients). People aged 90–94 years were most commonly prescribed cefalexin (22.8 per 100 patients) (Figure 3.21). This reflects the infection types most commonly seen in these age groups.

More than half (52.0%) of all azithromycin prescriptions and 44.5% of ciprofloxacin prescriptions were ordered as private. Compared with 2015, the proportion of these two antimicrobials being prescribed as private has increased. The greatest increase was for ciprofloxacin (up 12.5 percentage points), followed by azithromycin (up 8.5 percentage points). The remaining antimicrobials were mostly prescribed on the PBS/RPBS.

The proportion of prescriptions issued with a repeat varied between antimicrobials. This is expected, as repeats are appropriate for some indications. For example, treatment of acne using doxycycline requires longer time frames. However, common infections almost never require repeat prescriptions, and there is evidence to support a recommendation for shorter antimicrobial courses.[15]

Figure 3.21: Number of patients per 100 patients prescribed one or more J01* antimicrobials, by age group, MedicineInsight practices, 2019



* Subgroup J01 of the Anatomical Therapeutic Chemical classification system is 'antibacterials for systemic use'.
Note: The number of MedicineInsight practices was 412 in 2019.
Source: NPS MedicineWise[12]

Appropriateness of prescribing: MedicineInsight program

The proportion of patients prescribed antimicrobials for eight selected conditions is outlined in Table 3.11. These conditions were selected because they are often seen in the primary care setting and, other than UTIs, are conditions for which antimicrobials are not routinely recommended in guidelines.

In the context of *Therapeutic Guidelines: Antibiotic* recommendations, antimicrobials continue to be overprescribed in Australia, even accounting for the use of delayed prescriptions in some instances, which might never have been dispensed. Antimicrobial prescribing is generally not recommended for most of the conditions listed in Table 3.11.[8]

Of particular concern is antimicrobial prescribing for acute bronchitis, for which antimicrobials are never recommended. A remarkable 81.5% of patients aged 18–75 years with acute bronchitis were prescribed an antimicrobial. Prescribing of antimicrobials may be required in 19–40% of patients with acute tonsillitis[16], but 84.6% of MedicineInsight patients with acute tonsillitis were prescribed an antimicrobial. Similarly, 84.5% of patients with acute otitis media received an antimicrobial despite estimates that only 20–31% may require one. Although direct comparisons should be made with caution, it is clear that antimicrobials are being overprescribed for these conditions.

Table 3.11: Number and percentage of patients prescribed systemic antimicrobials by general practitioners for selected conditions, MedicineInsight practices, 2017 and 2019

Condition†	Patients	2017			2019			Expected new cases to be managed with antimicrobials[16], range (%)*
		No.	%	95% CI	No.	%	95% CI	
Acute bronchitis	Aged 18–75 years prescribed antimicrobials	22,412	81.4	79.3–83.5	20,632	81.5	78.9–84.2	0
Acute otitis media	Older than 2 years prescribed antimicrobials	33,135	84.6	83.1–86.1	30,598	84.5	82.8–86.1	20–31
	And prescribed TG-recommended amoxicillin	22,362	67.5	65.4–69.6	21,190	69.2	67.2–71.3	20–31
Acute tonsillitis	Older than 1 year prescribed antimicrobials	37,233	84.4	79.2–89.5	32,692	84.6	78.9–90.4	19–40
	And prescribed TG-recommended penicillin V	19,545	52.5	48.4–56.6	18,564	56.8	52.8–60.8	19–40
Influenza-like illness	Older than 1 year prescribed antimicrobials	3,600	13.2	12.0–14.3	3,491	12.5	11.4–13.6	0
Pneumonia	Aged 18–65 years prescribed antimicrobials	42,461	84.4	82.8–86.0	44,610	85.4	84.0–86.9	nd
	And prescribed TG-recommended antimicrobial (for mild CAP – amoxicillin or doxycycline)	22,209	52.3	49.8–54.8	25,996	58.2	55.7–60.9	100

continues

Table 3.11: *continued*

Condition†	Patients	2017			2019			Expected new cases to be managed with antimicrobials[16], range (%)*
		No.	%	95% CI	No.	%	95% CI	
Sinusitis (acute/chronic)	Older than 18 years prescribed antimicrobials	43,521	81.2	79.7–82.8	44,905	80.7	79.1–82.3	0.5–8
	And prescribed TG-recommended amoxicillin	15,894	36.5	34.2–38.8	17,890	39.8	37.7–42.0	0.5–8
Acute URTI	Older than 1 year prescribed antimicrobials	96,306	37.4	35.1–39.7	95,650	35.8	33.7–38.0	nd
UTI	Females older than 18 years prescribed antimicrobials	49,259	89.0	87.6–90.3	50,629	89.4	88.0–90.9	nd
	And prescribed TG-recommended trimethoprim	23,753	48.2	46.6–49.9	23,284	46.0	44.4–47.5	nd

CAP = community-acquired pneumonia; CI = confidence interval; nd = not determined; TG = *Therapeutic Guidelines: Antibiotic*; URTI = upper respiratory tract infection; UTI = urinary tract infection

* Mean percentage of new cases to be managed with antimicrobials, based on guideline recommendations, where available[16]

† NPS MedicineWise develops algorithms to identify specific conditions and measures of interest in the MedicineInsight database, based on commonly accepted definitions. These definitions may differ slightly from McCullough et al.[16]

Note: Number of practices was 410 in 2017 and 412 in 2019.

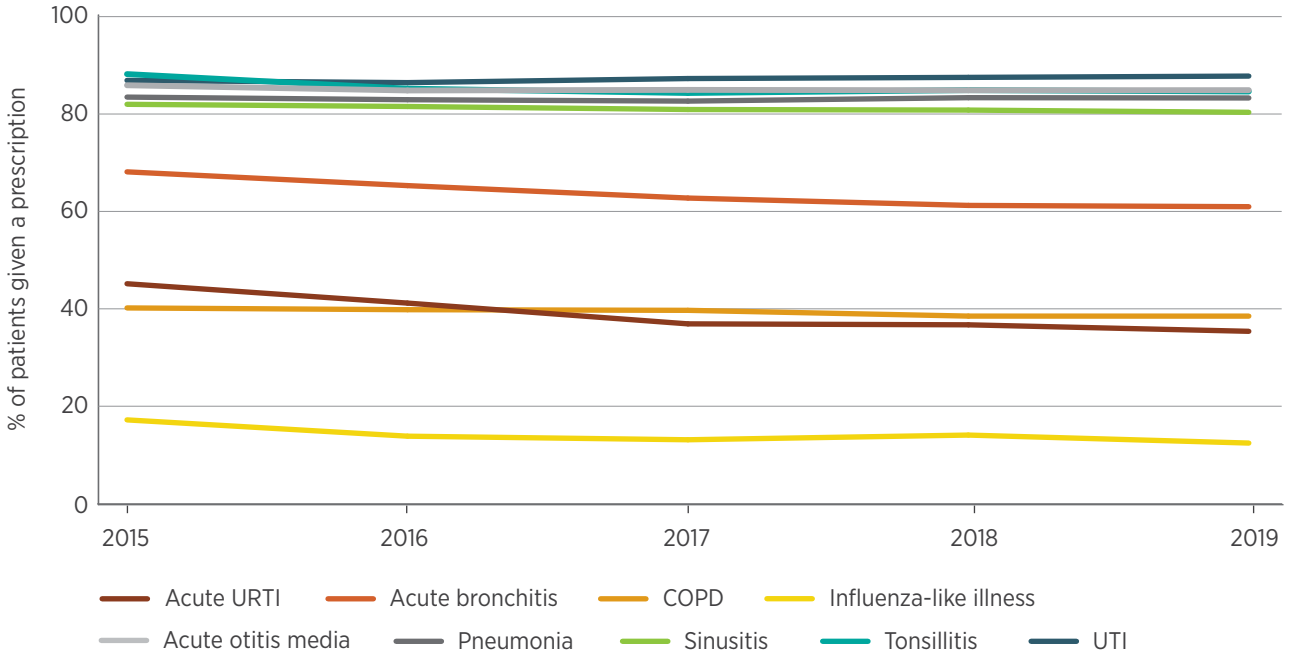
Sources: NPS MedicineWise[12]; McCullough et al.[16]

In the context of Therapeutic Guidelines: Antibiotic *recommendations, antimicrobials continue to be overprescribed in Australia. Of particular concern is antimicrobial prescribing for acute bronchitis, for which antimicrobials are never recommended. A remarkable 81.5% of patients aged 18–75 years with acute bronchitis were prescribed an antimicrobial.*

The data also highlighted that, for some conditions, antimicrobial prescribing was not consistent with first-line agents recommended in *Therapeutic Guidelines: Antibiotic*.[8] For example, only 46% of women with a UTI who were prescribed an antimicrobial received guideline-recommended trimethoprim. Similarly, only 39.8% of MedicineInsight patients with sinusitis who were prescribed an antimicrobial received guideline-recommended amoxicillin.

As shown in Figure 3.22, of the conditions for which prescribing rates greatly exceeded national guidelines[16], signs of improvement

Figure 3.22: Trends in prescribing rates for specific conditions, MedicineInsight practices, 2015–2019



COPD = chronic obstructive pulmonary disorder; URTI = upper respiratory tract infection; UTI = urinary tract infection
Source: NPS MedicineWise[12]

(that is, reducing rates) were seen for acute bronchitis, acute upper respiratory tract infection and influenza-like illness from 2015 to 2019, but not the other syndromes. Nevertheless, prescribing rates for all these conditions remain unacceptably high. For conditions for which antimicrobials are generally recommended, such as pneumonia and UTI, rates of prescribing remained stable.

Inappropriate antimicrobial prescribing by GPs may occur for a range of reasons, including limited time, poor doctor–patient communication, diagnostic uncertainty and patient expectations. Other reasons include GP attitudes and beliefs about AMR – GPs may not view antimicrobial prescribing in the primary care setting as a major contributor to the development of AMR, or consider that their individual prescribing may contribute very little to AMR compared with other settings, such as hospital or veterinary prescribing.[17] However, although AMR is found more frequently in hospitals, and the intensity of AU is much greater in hospitals, most AU occurs in the community setting.

GPs play a crucial role in improving the appropriateness of antimicrobial prescribing and reducing AMR, and strategies should continue to be implemented to support reduced antimicrobial prescribing. These strategies include audit and feedback activities, delayed prescribing, community education and shared decision making. These are all important measures to help improve antimicrobial prescribing in primary care, and recognise the important role that GPs have in reducing AMR.[18]

Antimicrobial use in residential aged care services: Aged Care National Antimicrobial Prescribing Survey

In Australia, aged care services are primarily provided through the Commonwealth Home Support Programme, home care packages, and permanent or respite residential care

in aged care homes and multi-purpose services.[19]

Aged care homes are recognised nationally and internationally as an important community setting for monitoring AMR and AU because of the prevalence of infections and colonisation with antimicrobial-resistant organisms in residents.[20] High levels of inappropriate antimicrobial prescribing and use in aged care homes are also well documented.[7,21]

Aged care home residents are susceptible to infections for a variety of reasons, including advanced age, multiple comorbidities, poor functional status and compromised immune status. In addition, because this is their 'home', there is a close living environment for residents, and they will likely be in frequent contact with potentially colonised or infected staff or other residents. Some aged care home residents may also have multiple or prolonged hospitalisations for the same reasons that make them susceptible to infections.

The AC NAPS is a standardised surveillance tool that can be used to monitor the prevalence of infections and AU in aged care homes and multi-purpose services (together referred to as residential aged care services). All Australian residential aged care services can participate in AC NAPS, and participation is mostly voluntary. Since 2017, aged care homes operated by the Victorian Government have been required to participate in AC NAPS as part of the Infection Control Indicator Program of the Victorian Healthcare Associated Infection Surveillance System Coordinating Centre.[22]

Participation in AC NAPS supports these facilities to identify areas for improvement in AU, preventing infections and helping reduce AMR. Participation also helps improve care for residents and helps demonstrate compliance with the Australian Aged Care Quality Standards.[23]

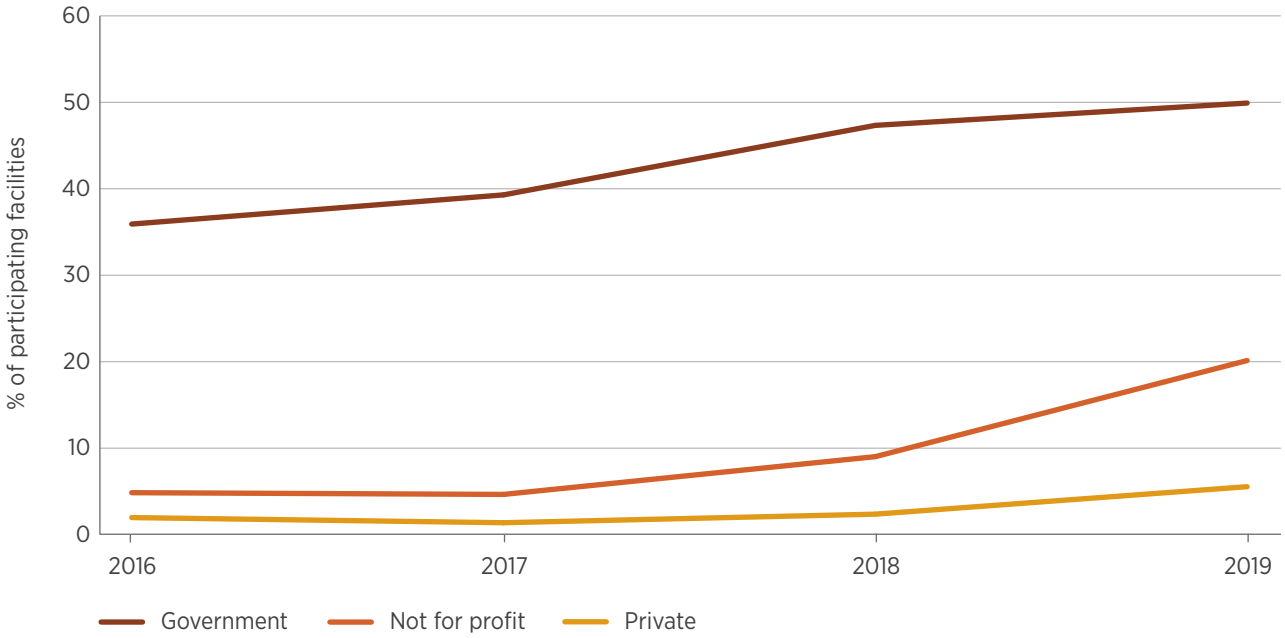
AC NAPS was piloted in 2015, and has subsequently been conducted each year.[24-28]

Highlights of analyses of data from the 2018 and 2019 surveys are presented in this report; more extensive information on the results of each survey is available in other reports published by NCAS and the Commission.

In 2019, 568 residential aged care services (510 aged care homes and 58 multi-purpose services) collected and submitted AC NAPS data at least once during the official time frame. Since 2017, 154 residential aged care services have participated each year during the official data collection period. The percentage of participating residential aged care services increased for all provider types in 2019. Nationally, half (50.0%) of all government-operated residential aged care services, and smaller proportions of not-for-profit (20.0%) and private (5.3%) services, participated (Figure 3.23).

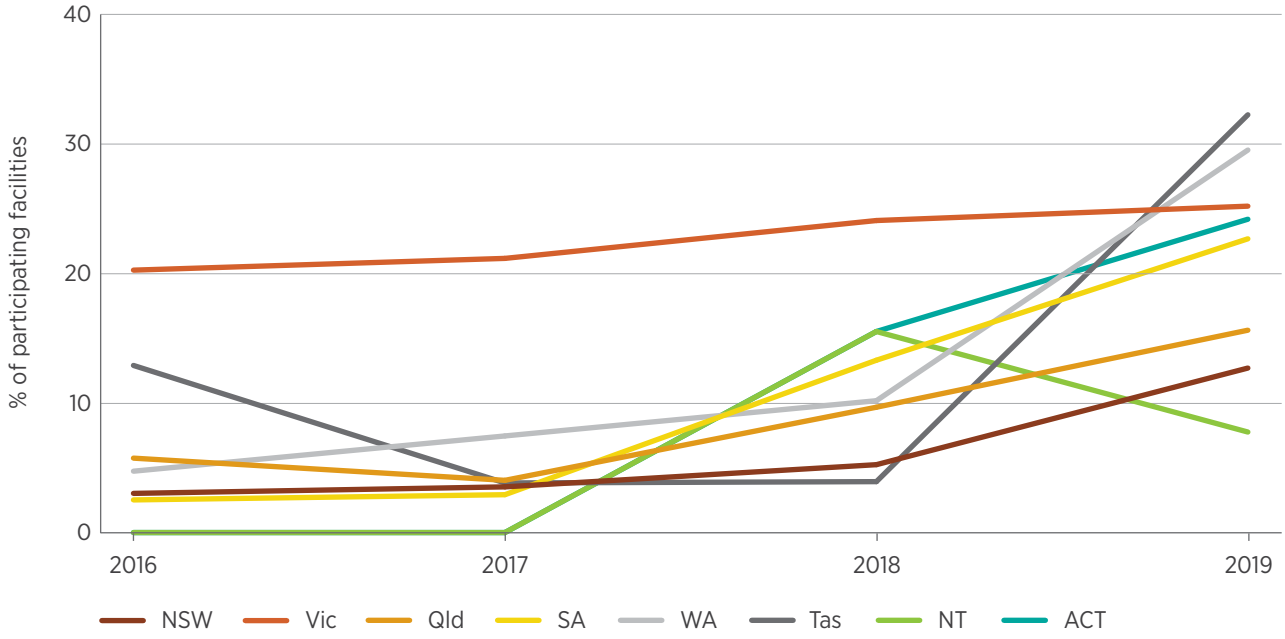
In 2019, for the first time, there were more participating services from other states and territories combined than from Victoria (*n* = 373; 65.7%); 119 (21.0%) participants were from NSW. About three-quarters of participating residential aged care services were located in either major cities (*n* = 249; 43.8%) or inner regional areas (*n* = 175; 30.8%). Also for the first time, more than half of participating services (*n* = 312; 54.9%) were not-for-profit operated. The percentage of participating residential aged care services increased for most states and territories. Representation within the AC NAPS cohort varied from 7.7% in the NT to 32.0% in Tasmania, and across remoteness areas from 14.7% for major cities to 29.5% for outer regional areas (Figure 3.24).

Figure 3.23: Percentage of participating facilities by provider type, AC NAPS contributors, 2016–2019



AC NAPS = Aged Care National Antimicrobial Prescribing Survey
Source: AC NAPS[28]

Figure 3.24: Percentage of participating facilities by state and territory, AC NAPS contributors, 2016–2019



AC NAPS = Aged Care National Antimicrobial Prescribing Survey
Source: AC NAPS[28]

The number of residents whose records were audited in 2019 significantly increased (*n* = 32,347) compared with 2017 (*n* = 10,727) and 2018 (*n* = 18,245). Similar to previous years, more than half (58.8%) of these residents were older than 85 years, and about one-third (32.1%) were male. One in 20 residents (*n* = 1,529; 4.7%) had been admitted to a hospital in the previous 30 days, and 2.9% (*n* = 943) had an indwelling catheter on the survey day.

The prevalence of residents who had a suspected infection and who were prescribed an antimicrobial remained stable. In 2019, the prevalence of residents who had signs and/or symptoms of at least one suspected infection on the survey day was 3.1% (*n* = 1,017). The most commonly reported infections were suspected skin or soft tissue infection (32.1%), respiratory tract infection (31.2%) and UTI (23.1%) (Table 3.12). About three-quarters (74.1%) of these suspected infections were facility associated (occurring more than 48 hours after admission), and 29.0% met the McGeer et al. infection surveillance definitions (Table 3.12).[29]

The prevalence of residents prescribed at least one antimicrobial was 8.2% (*n* = 2,643). Excluding all topical antimicrobials, the prevalence was 5.5% (*n* = 1,768). Excluding all PRN (as required) orders not administered in the last seven days, the prevalence was 7.2% (*n* = 2,340) (Table 3.13).

The start date was unknown for 0.9% (*n* = 35) of the antimicrobial prescriptions; 5.5% (*n* = 206) were started more than six months before the survey day. For those antimicrobials still prescribed on the survey day, with a known start date that was less than six months before the survey day, 43.4% (*n* = 1,318) had been started more than seven days before the survey day.

In 2019, compared with previous years, there was a decrease in the percentage of antimicrobial prescriptions that had an indication documented (*n* = 2,820; 75.5%). At the same time, there was an increase in the percentage of antimicrobial prescriptions that had a review or stop date documented (*n* = 2,415; 64.7%) (Table 3.14). For the 154 residential aged care services that

Table 3.12: Number and percentage of suspected infections by body system and location of acquisition, AC NAPS contributors, 2019

Body system	No. of suspected infections*	Suspected infections >48 hours after admission	Suspected infections that met McGeer et al. definition
		No. (%)	No. (%)
Skin or soft tissue	334	230 (68.9)	127 (38.0)
Respiratory tract	325	256 (78.8)	96 (29.5)
Urinary tract	240	191 (79.6)	12 (5.0)
Eye	64	46 (71.9)	60 (93.8)
Oral	29	22 (75.9)	7 (24.1)
Other systems	49	26 (53.1)	0 (0.0)
Total	**1,041**	**771 (74.1)**	**302 (29.0)**

AC NAPS = Aged Care National Antimicrobial Prescribing Survey

* A resident could have more than one suspected infection across different body systems.

Source AC NAPS[28]

Table 3.13: Prevalence of suspected infections and antimicrobial use on the survey day, AC NAPS contributors, 2016–2019

On survey day	2016 no. (%)	2017 no. (%)	2018 no. (%)	2019 no. (%)
Residents prescribed at least one antimicrobial	892 (7.7)	792 (7.4)	1,425 (7.8)	2,643 (8.2)
Residents prescribed at least one antimicrobial excluding topical antimicrobials	668 (5.8)	571 (5.3)	996 (5.5)	1,768 (5.5)
Residents prescribed at least one antimicrobial excluding PRN orders not administered in the last seven days	892 (7.7)	792 (7.4)	1,302 (7.1)	2,340 (7.2)
Residents with signs and/or symptoms of at least one suspected infection	393 (3.4)	350 (3.3)	588 (3.2)	1,017 (3.1)
Number of residents present	11,560	10,727	18,245	32,347

AC NAPS = Aged Care National Antimicrobial Prescribing Survey; PRN = as required
Source: AC NAPS[28]

Table 3.14: Key quality indicators for all participating facilities, AC NAPS contributors, 2016–2019

Indicator	Category	2016 no. (%)	2017 no. (%)	2018 no. (%)	2019 no. (%)
Indication for prescribing an antimicrobial	Documented	1,169 (84.2)	1,017 (84.3)	1,625 (83.5)	2,820 (75.5)
	Not documented	219 (15.8)	190 (15.7)	321 (16.5)	915 (24.5)
Total		*1,388*	*1,207*	*1,946*	*3,735*
Review or stop date	Documented	858 (61.8)	754 (62.5)	1,136 (58.4)	2,415 (64.7)
	Not documented	530 (38.2)	453 (37.5)	810 (41.6)	1,320 (35.3)
Total		*1,388*	*1,207*	*1,946*	*3,735*

AC NAPS = Aged Care National Antimicrobial Prescribing Survey
Source: AC NAPS[28]

participated annually from 2017 to 2019, there was no significant change over time in how often an indication for prescribing an antimicrobial was documented (*n* = 601; 76.4%), or review or stop date (*n* = 476; 60.5%).

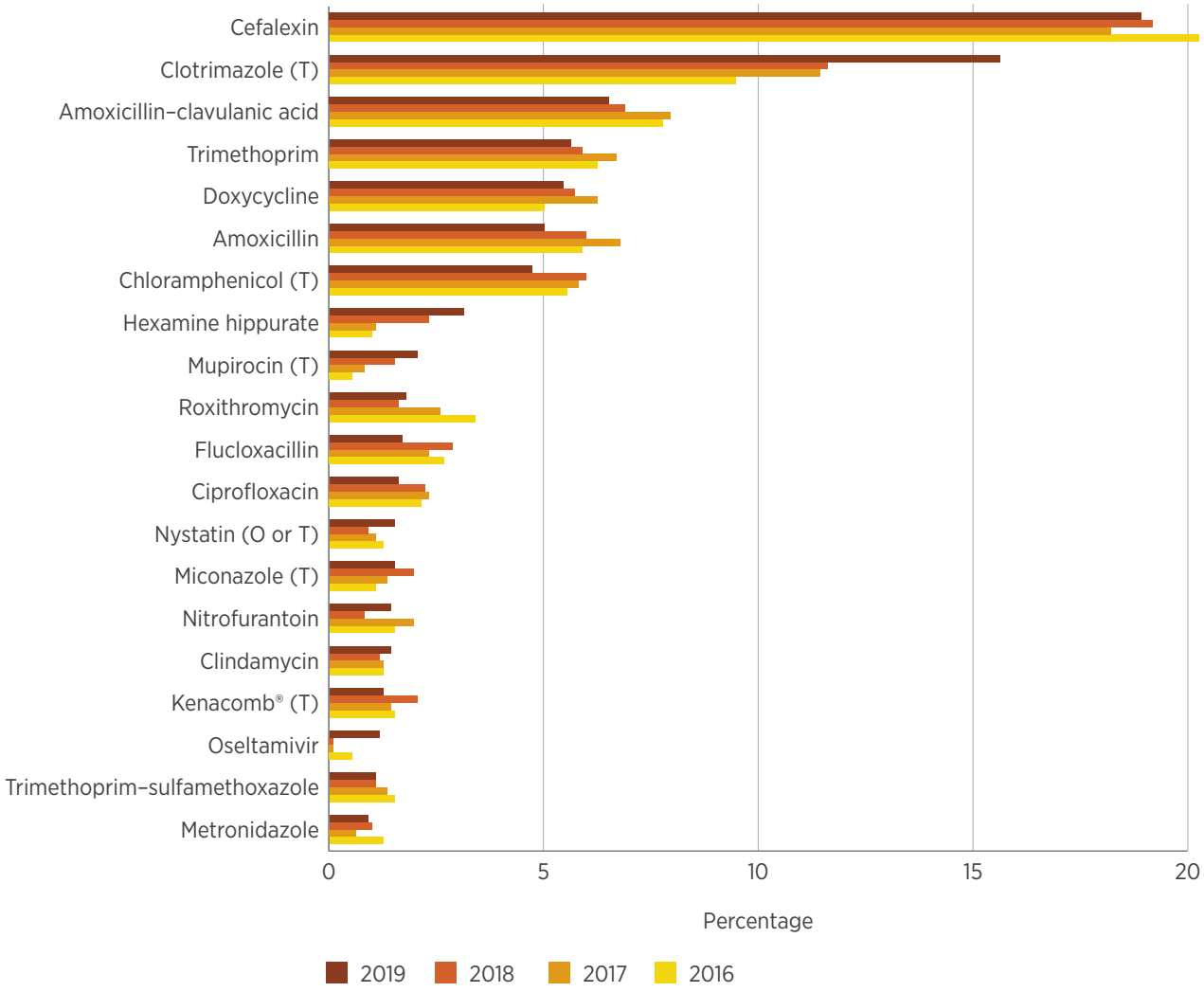
For the 154 residential aged care services that participated annually from 2017 to 2019, there was no significant change over time in the documentation of an indication for prescribing an antimicrobial (n = 601; 76.4%), or review or stop date (n = 476; 60.5%).

Most commonly prescribed antimicrobials reported by AC NAPS contributors

In 2019, most antimicrobials were prescribed for oral (*n* = 2,545; 68.1%) or topical (*n* = 1,136; 30.4%) administration. The majority of prescriptions were for therapeutic use (*n* = 3,003; 80.4%); the remainder were for prophylaxis. As in previous years, cefalexin (*n* = 790; 21.2%), clotrimazole (*n* = 654; 17.5%) and amoxicillin–clavulanic acid (*n* = 274; 7.3%) were the most frequently prescribed antimicrobials (Figure 3.25).

Almost 1 in 6 (*n* = 455; 15.0%) antimicrobials prescribed on the survey day (*n* = 3,040) were for PRN administration. The majority of these (*n* = 413; 90.8%) were for topical antimicrobials, most commonly clotrimazole (*n* = 337; 74.1%). About three-quarters of these (*n* = 339; 74.5%) had been prescribed for durations of between one week and six months. For both 2018 (*n* = 27) and 2019 (*n* = 63), about 14% were administered on the survey day or in the six days before the survey day.

Figure 3.25: Most commonly prescribed antimicrobials, AC NAPS contributors, 2016–2019



AC NAPS = Aged Care National Antimicrobial Prescribing Survey; O = oral; T = topical
Note: Kenacomb contains triamcionolone, neomycin, nystatin and gramicidin.
Source: AC NAPS[28]

Common indications for prescribing antimicrobials reported by AC NAPS contributors

The top five known indications for prescribing antimicrobials from 2016 to 2019 were cystitis; skin, soft tissue or mucosal infection; pneumonia; wound infection (non-surgical); and tinea. The indication was reported as unknown for a small proportion of prescriptions (*n* = 187; 5.1%).

Antimicrobials were consistently and most commonly prescribed for prophylactic indications associated with the urinary tract. In 2019, about half of the 694 prophylactic prescriptions were for cystitis (33.4%), UTIs (5.9%), asymptomatic bacteriuria (4.5%) and catheter-associated UTI (2.7%). Therapeutic use of antimicrobials was more common in skin and soft tissue infections, and respiratory tract infections.

The 2019 AC NAPS identified the same resident safety issues in relation to AU as previous surveys since 2015. The issues of concern, which require urgent attention, continue to be:

- Prolonged duration of AU
- High rates of PRN prescriptions for antimicrobials
- High rates of topical AU, particularly for PRN administration for conditions where antimicrobials are not usually indicated
- Prolonged prophylaxis for conditions where this is not recommended by guidelines
- Poor documentation of indication, review and stop dates for antimicrobial prescriptions.

Although there is variation from year to year in the cohort of AC NAPS contributors, there is no indication that the overall safety of AU in services that contribute to AC NAPS has improved since 2015, and the consistency of the issues identified as the number of contributors has increased suggests that these issues are widespread in Australian residential aged care services. Findings such as increases in the proportion of PRN prescriptions prescribed for longer than six months are concerning, but may reflect practices in new contributor services.

There is no indication that the overall safety of antimicrobial use in services that contribute to AC NAPS has improved since 2015. The consistency of the antimicrobial safety issues identified each year suggests that these issues are widespread in Australian residential aged care services, and need urgent attention.

For long-term contributors, the only improvement related to documentation of indication or review dates. The minimal improvement in the appropriateness of AU in services that participated in AC NAPS consistently from 2017 to 2019 (*n* = 154) reinforces the need for strategies that will lead to action in response to resident safety issues. This finding also highlights the importance of strategies to address reported barriers to improvement in AU in residential aged care services, including difficulties in diagnosis of infections (including sample collection and cognitively impaired residents), staffing issues (including off-site GPs and pharmacists, nursing staffing levels and workload), off-site laboratory services, and family expectations.[21,30,31]

Continuing reports of high rates of topical AU, the duration of use and the large proportion of PRN prescriptions are concerning, in relation to compliance with prescribing guidelines and the potential to contribute to the development of AMR. The use of PRN

prescriptions may reduce opportunities for clinical review of antimicrobial choice, including decisions regarding duration of treatment.

The aged care home setting is of particular importance for appropriate AU and AMR control because of the high levels of prescribing. Data presented in Chapters 4 and 5 show that, for some organisms, rates of AMR in aged care homes were as high as, or higher than, rates in hospitals. The rate of AMR, in combination with the inappropriate AU identified by AC NAPS, reinforces the potential for aged care homes to amplify AMR in Australia.

3.5 Commentary – overall antimicrobial use in the community

Based on PBS/RPBS dispensing and MedicineInsight prescribing data, it is encouraging that, overall, AU in the Australian community has declined since 2017. A decline was seen in most states and territories. However, AU remains high compared with European countries and Canada (see Chapter 6). Although PBS/RPBS dispensing rates appear to have stabilised between 2018 and 2019, the COVID-19 pandemic has had a dramatic impact on prescribing rates, as detailed in Chapter 6.

The dispensing of antimicrobials on repeat PBS/RPBS prescriptions remains common, ranging from 33% to 70% depending on the antimicrobial. Much of this repeat prescribing is likely to result in unnecessarily prolonged use, and increase the risk of individuals acquiring resistant pathogens. In April 2020, amendments to the PBS/RPBS eliminated repeats for many commonly prescribed antibacterials and, in some cases, amended the standard duration of a single prescription.

When examined at the SA3 level in each state and territory, the highest dispensing rates were up to four times higher than the lowest rates. In NSW, for example, a four-fold difference between the regions with the lowest and highest dispensing rates was identified, despite these being adjacent areas in western Greater Sydney. The reasons for this large variation are unclear but worthy of investigation.

Variation in AU between age groups was observed in both the PBS/RPBS dispensing data and MedicineInsight prescribing data. Children under 5 years of age continue to have the highest rates of dispensing among people under 65 years of age.

Some variation in the patterns of AU between the PBS/RPBS data and NPS MedicineWise MedicineInsight data is expected. PBS/RPBS data include prescriptions generated by a broad range of prescribers, including GPs, specialist doctors, non-medical prescribers and hospital prescribers. MedicineInsight data relate only to prescribing in general practices that have voluntarily joined the program.

Both PBS/RPBS and MedicineInsight data showed variation in AU between states and territories, and a decline in antibiotic dispensing and prescribing rates in all states and territories. The reasons for these differences are not clear. Notably, dispensing rates in WA have been lower than in other states and territories, and have been decreasing, since the first AURA analyses were undertaken on 2013 data. The reasons for the differences between states and territories, and the decline in AU rates, are not clear.

As in previous years, amoxicillin, cefalexin and amoxicillin–clavulanic acid were the three most commonly used antibiotics in the community. These three antibiotics are also among the six most frequently used antimicrobials in AC NAPS.

In MedicineInsight data, prescribing of cefalexin was more common for older people than for any other age group (Figure 3.21). The most commonly recorded indication for prescribing cefalexin was skin/wound infections. These were also the most commonly reported type of infection in residential aged care services, which may explain the high use of cefalexin in aged care. The high rate of cefalexin use is concerning, because this antimicrobial is not usually recommended as a first-line treatment for any infection.

The inappropriate use of cefalexin has been an ongoing concern, which was highlighted in Chapter 6 of AURA 2019; its use in asymptomatic bacteriuria has been flagged as a key driver. In response, the Commission developed the fact sheet *Asymptomatic Bacteriuria: Reducing inappropriate antimicrobial prescribing for aged care facility residents* to promote appropriate prescribing in this area.[32] The Commission also published the fact sheet *Improving Antimicrobial Prescribing through Selective Reporting of Antimicrobials* in 2019 to help primary care prescribers understand the importance of selective reporting of antimicrobial susceptibilities by laboratories to minimise broad-spectrum antimicrobial use.[33]

Unfortunately, there were no significant improvements in AU in residential aged care services that participated in AC NAPS; the proportion of residents of aged care services who were prescribed antimicrobials increased slightly from 2017 to 2019.

AC NAPS continues to show evidence of poor prescribing practices in many instances. For example, no indication was recorded for approximately 25% of prescriptions in AC NAPS data and 35% of prescriptions in MedicineInsight data in 2019. Understanding the reason for an antimicrobial being prescribed is key to measuring appropriateness and undertaking quality improvement activities.

The residential aged care setting is of particular importance for appropriate AU and AMR control because of the high levels of prescribing. Data presented in Chapter 4 show that, for some organisms, rates of AMR in aged care homes were as high as, or higher than, rates in hospitals. The rate of AMR, in combination with the inappropriate AU identified by AC NAPS, reinforces the potential for residential aged care services to amplify AMR in Australia.

During the last year, the Commission has published two new chapters of *Antimicrobial Stewardship in Australian Health Care* to support AMS in general practice, and in community and residential aged care.[34] These chapters highlight AU and appropriateness of use, strategies to improve AU and consideration of the barriers to implementation of AMS strategies in these settings. The Commission will continue to promote these and other resources, and collaborate with GPs and aged care providers to improve AU.

3.6 Developments and future plans – community antimicrobial use

The Commission will continue to monitor community-based antimicrobial prescribing and use. It will support the Australian Government Department of Health, and the Australian Strategic and Technical Advisory Group on AMR in the review of antibiotic listings on the PBS/RPBS to promote appropriate prescribing. This includes reviewing the impact of changes that commenced on 1 May 2020 in relation to the Authority Required (streamlined) PBS listings of amoxicillin, amoxicillin–clavulanic acid, cefalexin and roxithromycin.

These changes allow patients who require prolonged oral antibiotic therapy to access an increased maximum quantity and/or repeat(s), regardless of whether they were initiated on intravenous antimicrobial therapy. The Commission will also continue to liaise regularly with Therapeutic Guidelines Limited to provide updated analyses of AMR data and information regarding AU to support review of prescribing guidelines.

Prescribing in general practice

The preliminary analyses of NPS MedicineWise MedicineInsight data presented in this report highlight the importance of improving monitoring and understanding of privately prescribed antibiotics. Concerning issues identified in these analyses include the high proportion of prescriptions for azithromycin from 2010 to 2019, apparent substitution of this agent for roxithromycin, and the steady rise in the proportion of private prescriptions for ciprofloxacin over the 10-year period. It is particularly important to understand these issues and potential unintended impacts of restrictions in the PBS/RPBS, because they may affect AMR prevention and control efforts.

A concerning development in relation to private prescriptions is the commercial initiative that enables patient access to online prescribers in community pharmacy settings for a range of medications, including antibiotics. These arrangements are outside the scope of the Medical Benefits Schedule telehealth items.

Options should be considered for increasing capacity to monitor the volume of antimicrobials dispensed on private prescriptions and the indications for which they are prescribed.

Aged care prescribing

The very high proportion of PRN prescriptions and high rates of topical AU in aged care settings continue to place the safety of residents at risk. The Commission will continue to work with and support the Aged Care Quality and Safety Commission to promote antimicrobial prescribing improvement programs informed by the AC NAPS findings, in addition to ongoing surveillance of infections and AU in residential aged care services.

The Commission will also continue to communicate directly with residential aged care service provider organisations and GPs to advocate for the development and implementation of effective infection prevention and control and AMS strategies to improve the safety of care provided to residents of aged care services. These may include:

- Regular review of prescribing patterns, in collaboration with medical and nursing staff, particularly regarding prescriptions for antimicrobial prophylaxis, and compliance with Australian prescribing guidelines for recommended duration and choice of antimicrobials
- Use of medication charts that are consistent with the Commission's national residential medication chart, to improve documentation
- Policies that require fixed-length courses of treatment and mandatory review dates, particularly for PRN prescriptions
- Education for staff who provide care to residents on the importance of infection prevention and control, basic personal and hygiene care, and hydration to preserve skin integrity and minimise the risk of UTIs.

Participation in programs that monitor appropriateness of AU in residential aged care and general practice will also be encouraged.

Data from these programs are essential to inform quality improvement programs and change prescribing practice.

3.7 Overall use and appropriateness in the acute and community sectors

The analyses presented in AURA 2021 show that a number of aspects of AU are similar in acute hospital and community settings. In both settings, there are continuing high rates of unnecessary and inappropriate AU. The changing patterns of AMR, particularly the continued increases in methicillin resistance in *Staphylococcus aureus* and fluoroquinolone non-susceptibility in *Escherichia coli* in community settings (described in Chapter 4), highlight the importance of promoting appropriate AU to address AMR in Australia.

High rates of use of antimicrobial agents is often associated with high rates of inappropriate use. Eight of the top 10 antimicrobials used in hospitals that contribute to NAUSP are also included in the top 10 antimicrobials with the highest rates of inappropriate use in hospitals, as assessed by NAPS. Inappropriateness of antimicrobial prescribing for respiratory conditions, particularly COPD, continues to be a problem in hospital practice. Targeted strategies will be developed in collaboration with experts in primary care, respiratory medicine and AMS to address this issue.

As shown in Table 3.15, six of the top 10 antibiotics (cefalexin, amoxicillin, amoxicillin–clavulanic acid, doxycycline, flucloxacillin and metronidazole) dispensed under the PBS/RPBS were also in the top 10 antibiotics used in hospitals that contributed to NAUSP in 2019. These six agents account for 72.6% of AU under the PBS/RPBS. These antibiotics are not usually high-priority agents for AMS programs, which traditionally focus on broad-spectrum, intravenous, expensive antimicrobials. However, because these six antibiotics account for a large proportion of AU in both the acute hospital and community sectors, they should be prioritised for improvement interventions.

The data highlight several areas for targeting of improvement interventions, including:

- The most frequently prescribed antimicrobials
- The antimicrobials that are most frequently prescribed inappropriately
- Documentation of the reason for prescribing
- The indications for which antimicrobials are most frequently inappropriately prescribed (respiratory and skin conditions).

Multiple AURA reports have demonstrated similar issues regarding appropriateness for primary and acute settings. Overall appropriateness of AU in hospitals has remained static since 2013; however, this varies widely between peer groups. Providing support to peer groups that have made minimal improvement is a priority.

The 2021 Preventing and Controlling Infections Standard has criteria relating to AMS, as do the Aged Care Quality Standards. There is continued benefit in analysing PBS/RPBS data alongside NPS MedicineWise MedicineInsight data, as well as AU in hospitals, because the majority of AU is in the community. Information on the clinical impacts of prescribing can inform policy and practice change. The Commission will work with stakeholders that provide hospital, aged care and primary health services to disseminate these findings and prioritise interventions to reduce inappropriate prescribing of selected antimicrobials to improve the care of patients with respiratory conditions.

Table 3.15: Ten most commonly prescribed antimicrobials in Hospital NAPS and NAUSP contributor hospitals, and the most frequently dispensed antimicrobials under the PBS/RPBS, 2019

Ranking	NAUSP contributor hospitals	NAPS contributor hospitals	PBS/RPBS*
1	Cefazolin†	Cefazolin†	Cefalexin
2	Flucloxacillin§	Ceftriaxone	Amoxicillin
3	Amoxicillin–clavulanic acid§	Amoxicillin–clavulanic acid§	Amoxicillin–clavulanic acid
4	Doxycycline	Piperacillin–tazobactam	Doxycycline
5	Ceftriaxone	Cefalexin	Roxithromycin
6	Amoxicillin	Metronidazole§	Trimethoprim
7	Piperacillin–tazobactam	Doxycycline	Flucloxacillin
8	Cefalexin	Flucloxacillin§	Clarithromycin
9	Azithromycin§	Trimethoprim–sulfamethoxazole§	Metronidazole
10	Metronidazole§	Nystatin	Phenoxymethylpenicillin

NAPS = National Antimicrobial Prescribing Survey; NAUSP = National Antimicrobial Utilisation Surveillance Program; PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme

* Oral preparations only

† Intravenous preparations only

§ Includes both oral and intravenous preparations

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4

Chapter 4
Antimicrobial resistance

Key findings

- National rates of resistance for many priority organisms have not changed substantially from those reported in AURA 2019. However, several changes in resistance are important to consider in the context of infection prevention and control, and antimicrobial prescribing.
- In *Escherichia coli*, resistances to common agents used for treatment continue to increase. Resistance to ciprofloxacin and other fluoroquinolones has continued to rise in isolates from community-onset infections, despite restriction of access to these agents on the Pharmaceutical Benefits Scheme. These changes in resistance may mean increasing treatment failures and greater reliance on last-line treatments such as carbapenems. Meropenem resistance has remained low.
- In *Enterobacterales*, rates of resistance were somewhat lower in the community than in hospitals for most agents with available data. There were no major differences between rates in public versus private hospitals. Rates in aged care homes were often as high as, or higher than, rates in hospitals.
- Carbapenem resistance in *Enterobacterales* remains uncommon, but is found more often in the *Enterobacter cloacae* complex than in *E. coli* or *Klebsiella pneumoniae.*
- In *Enterococcus faecium*, the overall rates of vancomycin resistance are declining nationally, but are still above 40%.
- In *Neisseria gonorrhoeae*, rates of azithromycin resistance have declined since 2017, with resistance at 4.6% in 2019. However, the total number of notifiable cases continues to increase.
- In *Neisseria meningitidis*, the number of notifiable cases has decreased since 2017. Reduced susceptibility to benzylpenicillin has declined from 44.9% in 2017 to 21.0% in 2019. Full resistance to benzylpenicillin is now found in less than 1% of isolates.
- In *Salmonella*, ciprofloxacin resistance in typhoidal species (*Salmonella* Typhi and *Salmonella* Paratyphi) exceeded 78% in 2019, confirming that ciprofloxacin should no longer be relied on for empirical treatment.

continues

- In *Staphylococcus aureus*, patterns of methicillin resistance continue to evolve. Clones that were previously dominant are being replaced by other clones, and community-associated methicillin-resistant *S. aureus* has become prominent everywhere, but especially in remote and very remote regions. This demonstrates a need for a renewed focus on infection prevention and control in both community and acute settings.
- In *Shigella sonnei*, resistance to ceftriaxone, ciprofloxacin and ampicillin increased rapidly compared with the 2017 rates noted in AURA 2019.
- In *Streptococcus agalactiae*, resistance to erythromycin and clindamycin has steadily increased to around 33% in 2019.
- Macrolide resistance in *Streptococcus pyogenes* has doubled since 2017 to 9% in 2019, reducing the utility of these second-line agents.

This chapter provides analyses of data collected through the passive (Australian Passive AMR Surveillance [APAS]) and targeted (Australian Group on Antimicrobial Resistance [AGAR]) surveillance components of the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System from hospitals, aged care homes and the community. The results have been compiled for each of the 13 human health priority organisms determined for AURA.

4.1 Introduction

Antimicrobial-resistant bacteria and their resistance genes can spread readily between people. This can happen in the community, primary care services, hospitals and aged care homes. It can happen rapidly, and can often go unnoticed. The spread of these bacteria can significantly affect the community, patients, health services and the health system. Therefore, it is critical that resistant bacteria with the highest risk of causing harm to humans are identified and monitored through enhanced surveillance, and communicated about and managed appropriately.

AURA has included genomics data in a number of AGAR reports and technical papers since 2013. Some confirming laboratories for the National Alert System for Critical Antimicrobial Resistances (CARAlert) are able to provide whole-genome sequencing data on critical antimicrobial resistances such as carbapenemase-producing *Enterobacterales*. The incorporation of whole-genome sequencing analyses complements the phenotypic antimicrobial susceptibility data, and greatly increases the utility of the data from these programs. The information is increasingly important in identifying antimicrobial resistance (AMR) control and prevention strategies, and is key to enhancing the capacity of these surveillance programs to describe trends and to monitor the emergence and spread of AMR. The Australian Commission on Safety and Quality in Health Care (the Commission) will continue to use genomics data, and promote standardisation of whole-genome sequencing procedures to ensure reliable AMR data are available for surveillance and clinical purposes.

Priority organisms for surveillance

To focus Australia's AMR surveillance efforts, the Commission consulted on, and developed, a list of organisms and key antimicrobials

that are high priorities for human health AMR strategies in Australia. Key experts involved in the AURA Surveillance System Project Reference Group advised on the development of this list.

The Commission coordinates surveillance of these organisms by working with programs that are now part of AURA, and develops new systems when gaps are identified. AURA 2016 provided data on these organisms for the first time at a national level. AURA 2021 provides more data as the surveillance coverage in Australia, and in the public and private sectors, has grown. These enhanced datasets improve understanding of rates of resistance, as well as commentary on some related outcome measures, and an assessment of trends over time (when enough data are available). The Commission continues its role in directing, coordinating and reporting on this enhanced surveillance to support improvements in Australia's capacity to prevent and contain AMR.

The priority organisms list (Appendix 2) comprises four sets of organisms. AURA reports on organisms in sets 1, 2 and 4, which have enough data available, including:

- *Acinetobacter baumannii* complex
- *Enterobacterales*
- *Enterococcus* species
- *Mycobacterium tuberculosis*
- *Neisseria gonorrhoeae*
- *Neisseria meningitidis*
- *Pseudomonas aeruginosa*
- *Salmonella* species
- *Shigella* species
- *Staphylococcus aureus*
- *Streptococcus agalactiae*
- *Streptococcus pneumoniae*
- *Streptococcus pyogenes.*

Sets 3 and 4 include organisms for which surveillance capacity needs to be further developed, and organisms that have been identified for monitoring for potential inclusion in future surveillance activity. The Commission will continue to support the review and update of the priority organisms list, as new data become available, to inform the organisms reported by APAS and CARAlert.

Data on priority organisms

This report includes data from:

- APAS (using the Queensland Health OrgTRx system), which collects data from public hospitals and health services across New South Wales (NSW), Victoria, Queensland, South Australia (SA), Western Australia (WA), Tasmania and the Australian Capital Territory (ACT), as well as some private hospitals in Queensland and SA
- The Sullivan Nicolaides Pathology information system, which collects data from its own laboratories in Queensland and northern NSW; these laboratories service private hospitals, community-based services and aged care homes
- AGAR, which collects data on minimum inhibitory concentrations (MICs) of antimicrobials from laboratories across Australia for selected organism groups, as well as some demographic and outcome data, and undertakes further characterisation of strains
- The National Neisseria Network, which collects data and undertakes confirmatory susceptibility testing for all *N. gonorrhoeae* and *N. meningitidis* cases across Australia
- The National Notifiable Diseases Surveillance System (NNDSS), which collects susceptibility testing data for all confirmed *M. tuberculosis* cases across Australia.

Tables with more detailed information are provided in *AURA 2021: Supplementary data*. Also see Appendix 1 for an overview of each data source program and a link to its website for more information.

Data from CARAlert are separately reported in Chapter 5.

The Commission's coordinating role has ensured that the AURA Surveillance System monitors changes in the nature of AMR for each organism across programs. The Commission will include information on AMR in regular reporting in the future, for both AURA-related activities and its core roles in regard to infection prevention and control and antimicrobial stewardship.

Table 4.1 provides a summary of the data sources for each organism, and Table 4.2 summarises the priority organisms and their AMR prevalence. Table 4.2 also shows some changes in the prevalence of resistance in some organisms from 2015 to 2019. Increases were noted in multidrug-resistant *Shigella sonnei*, clindamycin-resistant *S. agalactiae*, and *S. pyogenes*. Reports of *N. gonorrhoeae* with resistance to azithromycin decreased.

Table 4.1: Data sources for priority organisms included in this report

Section of report	Organism	Data source
4.2	*Acinetobacter baumannii* complex	AGAR, APAS, SNP
4.3	*Enterobacterales*	AGAR, APAS, SNP
4.4	*Enterococcus faecalis* and *E. faecium*	AGAR, APAS, SNP
4.5	*Mycobacterium tuberculosis*	NNDSS
4.6	*Neisseria gonorrhoeae*	NNN
4.7	*Neisseria meningitidis*	NNN
4.8	*Pseudomonas aeruginosa*	AGAR, APAS, SNP
4.9	*Salmonella* species	AGAR, APAS, SNP
4.10	*Shigella* species	APAS, SNP
4.11	*Staphylococcus aureus*	AGAR, APAS, SNP
4.12	*Streptococcus agalactiae*	APAS, SNP
4.13	*Streptococcus pneumoniae*	APAS, SNP
4.14	*Streptococcus pyogenes*	APAS, SNP

AGAR = Australian Group on Antimicrobial Resistance – 36 national public and private hospitals in 2018 and 39 in 2019; APAS = Australian Passive AMR Surveillance – public hospitals and health services nationally (except the NT), one private pathology service in Qld and several private hospitals in SA; NNDSS = National Notifiable Diseases Surveillance System – national hospitals and community health services; NNN = National Neisseria Network – national hospitals and community health services; SNP = Sullivan Nicolaides Pathology – Qld and northern NSW communities, private hospitals and aged care homes

Table 4.2: Summary of antimicrobial resistance for high-priority organisms

Organism	Main types of infection	Most common setting	Important antimicrobials for treatment	% resistant				
				2015	2016	2017	2018	2019
Acinetobacter baumannii complex	Ventilator-associated pneumonia, severe burn infections	Intensive care units, burn units	Ciprofloxacin/norfloxacin	5.0	6.5	4.8	4.2	5.4
			Gentamicin	2.1	4.9	3.8	3.1	3.6
			Meropenem	2.6	4.9	3.6	2.4	3.1
			Trimethoprim–sulfamethoxazole	5.2	8.5	6.1	7.5	5.8
Enterobacter cloacae complex	Urinary tract infections, biliary tract infections, other intra-abdominal infections, septicaemia	Hospitals	Cefepime	3.6	1.6	7.1	5.8	2.3
			Ceftriaxone/cefotaxime	30.4–39.7	33.2–38.7	35.0–41.5	34.7–42.6	32.2–43.2
			Ciprofloxacin/norfloxacin	3.7–6.1	1.9–6.1	4.5–7.2	5.9–6.9	5.7–8.0
			Gentamicin	7.2–8.4	4.5–6.7	5.7–6.8	6.1–6.8	5.3–7.9
			Meropenem	1.6–1.7	1.1–1.2	1.0–1.1	1.4–1.5	1.4–2.0
			Piperacillin–tazobactam	23.4–27.8	28.2–28.2	28.2–33.8	30.1–30.5	28.9–30.5
			Trimethoprim (urine)	20.2	19.4	18.7	18.1	18.2
			Trimethoprim–sulfamethoxazole (non-urine)	14.7	13.5	16.1	14.8	15.6
			Multidrug-resistant (blood)*	9.6	7.1	11.1	8.2	7.3
Enterococcus faecalis	Urinary tract infections, biliary tract infections, other intra-abdominal infections, septicaemia, endocarditis	Community, hospitals	Ampicillin/amoxicillin	0.2–0.8	0.4–1.0	0.4–0.8	0.2–0.7	0.0–0.4
			Ciprofloxacin/norfloxacin (urine)	16.2	20.3	30.7	30.3	9.3
			Linezolid	0.5–1.7	0.4–1.1	0.5–0.8	0.4–0.5	0.1–0.5
			Nitrofurantoin (urine)	0.4	0.3	0.3	0.6	0.7
			Teicoplanin	0.0–<0.1	0.0–0.1	0.0–0.4	0.0–0.1	0.0–0.3
			Vancomycin	0.3–0.4	0.2–0.6	0.3–0.5	0.2–0.4	0.1–0.3

continues

Table 4.2: *continued*

Organism	Main types of infection	Most common setting	Important antimicrobials for treatment	% resistant				
				2015	2016	2017	2018	2019
Enterococcus faecium	Urinary tract infections, biliary tract infections, other intra-abdominal infections, septicaemia	Hospitals	Ampicillin/amoxicillin	85.1–96.0	86.1–95.9	88.1–96.6	85.8–96.5	87.8–96.9
			Linezolid	0.4–0.7	0.2–0.6	0.4–1.0	0.1–0.4	0.2–0.4
			Teicoplanin	9.5–15.4	10.8–18.2	10.0–19.8	7.4–20.4	1.1–17.7
			Vancomycin	45.7–55.5	44.6–47.2	39.3–44.5	36.4–41.6	33.1–38.0
Escherichia coli	Urinary tract infections, biliary tract infections, other intra-abdominal infections, septicaemia	Community, hospitals	Amoxicillin–clavulanic acid	10.3–16.4	10.7–15.3	13.5–16.4	10.6–16.0	10.9–17.6
			Ampicillin/amoxicillin	44.1–52.3	44.4–52.6	45.3–53.2	45.1–54.0	44.9–54.0
			Cefalexin (urine)	6.5	7.2	7.6	8.3	8.7
			Cefazolin	16.2–21.4	16.7–21.8	17.3–23.3	19.9–26.3	20.0–27.3
			Ceftriaxone/cefotaxime	6.6–9.6	7.1–9.7	7.8–10.4	7.9–12.0	8.0–11.9
			Ciprofloxacin/norfloxacin	7.1–10.7	8.4–10.3	10.0–12.4	10.8–12.8	11.4–13.7
			Gentamicin	4.6–7.4	4.9–7.1	5.2–8.1	5.5–8.1	6.0–8.4
			Meropenem	0.00–0.02	0.01–0.05	0.01–0.03	0.02–0.04	0.01–0.05
			Nitrofurantoin (urine)	1.3	1.2	1.0	1.1	1.1
			Piperacillin–tazobactam	4.9–5.8	5.2–5.9	5.3–6.2	5.5–5.9	5.4–6.1
			Trimethoprim (urine)	22.1	22.8	24.2	23.9	24.0
			Trimethoprim–sulfamethoxazole (non-urine)	28.6	28.0	29.4	28.6	28.4
			Multidrug-resistant (blood)*	24.2	25.2	25.1	26.9	26.0

continues

Table 4.2: *continued*

Organism	Main types of infection	Most common setting	Important antimicrobials for treatment	% resistant				
				2015	2016	2017	2018	2019
Klebsiella pneumoniae complex	Urinary tract infections, biliary tract infections, other intra-abdominal infections, septicaemia	Community	Amoxicillin–clavulanic acid	4.9–6.2	4.3–5.5	6.3–6.8	4.5–6.4	4.6–7.3
			Cefazolin	7.3–8.2	7.0–9.5	7.6–11.5	7.9–12.1	8.0–14.9
			Ceftriaxone/cefotaxime	5.3–5.5	4.4–5.5	5.4–7.3	5.3–7.3	5.7–6.1
			Ciprofloxacin/norfloxacin	4.1–4.6	3.5–4.7	6.0–6.7	6.1–7.3	6.3–7.2
			Gentamicin	3.3–3.8	2.6–3.7	3.0–4.1	2.8–3.4	2.7–3.8
			Piperacillin–tazobactam	5.5–7.6	6.6–7.8	7.6–8.1	7.7–7.9	7.7–7.9
			Meropenem	0.2–0.3	0.1–0.2	0.3–0.5	0.1–0.5	0.3–0.6
			Trimethoprim (urine)	12.6	11.7	12.8	12.6	12.4
			Trimethoprim–sulfamethoxazole (non-urine)	11.0	12.3	12.4	13.8	12.8
			Multidrug-resistant (blood)*	9.7	10.9	10.9	12.1	11.8
Mycobacterium tuberculosis	Pulmonary tuberculosis, extrapulmonary tuberculosis	Community	Ethambutol	0.9	1.5	0.7	1.3	1.8
			Isoniazid	10.7	9.4	8.9	9.2	10.8
			Pyrazinamide	2.7	2.1	1.5	1.8	2.2
			Rifampicin	3.8	2.8	2.2	2.8	2.7
			Multidrug-resistant†	2.9	2.4	2.1	2.5	2.3
Neisseria gonorrhoeae	Gonorrhoea	Community	Azithromycin	2.6	5.0	9.3	6.2	4.6
			Benzylpenicillin	22.5	32.5	26.1	21.1	22.1
			Ceftriaxone (decreased susceptibility)	1.8	1.7	1.1	1.7	1.3
			Ciprofloxacin	27.2	30.0	27.5	25.6	28.4

continues

Table 4.2: *continued*

Organism	Main types of infection	Most common setting	Important antimicrobials for treatment	% resistant				
				2015	2016	2017	2018	2019
Neisseria meningitidis	Septicaemia, meningitis	Community	Benzylpenicillin (decreased susceptibility)	25.6	44.4	44.9	35.4	21.0
			Ceftriaxone	0.0	0.0	0.0	0.0	0.0
			Ciprofloxacin	0.0	0.0	0.7	0.5	0.0
			Rifampicin	0.9	0.0	0.4	0.0	0.6
Pseudomonas aeruginosa	Urinary tract infections, septicaemia, burn infections, cystic fibrosis exacerbations	Community, hospitals	Ceftazidime	4.3	4.7	4.8	4.6	4.4
			Ciprofloxacin	5.7	5.3	5.9	6.3	6.6
			Gentamicin	4.0	4.7	5.0	4.6	4.2
			Meropenem	3.5	3.2	3.4	3.2	3.1
			Piperacillin–tazobactam	6.2	5.6	5.8	5.9	5.8
Salmonella species (non-typhoidal)	Gastroenteritis, septicaemia	Community	Ampicillin/amoxicillin	2.8–7.2	5.6–7.7	6.1–8.0	5.7–8.6	4.9–6.8
			Ceftriaxone/cefotaxime	0.5–1.3	0.4–0.9	0.8–0.8	0.0–2.2	0.9–2.1
			Ciprofloxacin	1.6–2.3	2.2–2.9	0.6–2.7	2.1–4.8	1.9–5.1
			Trimethoprim–sulfamethoxazole	0.7–4.3	1.9–5.4	2.1–4.4	1.7–4.5	0.8–1.8
Salmonella Typhi/ Paratyphi	Typhoid fever (septicaemia)	Community	Ampicillin/amoxicillin	5.9	7.2	12.1	6.1	8.3
			Ceftriaxone/cefotaxime	1.2	0.0	0.0	1.8	3.4
			Ciprofloxacin	36.3	34.2	42.4	65.2	78.3
			Trimethoprim–sulfamethoxazole	4.1	3.8	11.5	5.8	7.2

continues

Table 4.2: *continued*

Organism	Main types of infection	Most common setting	Important antimicrobials for treatment	% resistant				
				2015	2016	2017	2018	2019
Shigella flexneri	Bacillary dysentery	Community	Ampicillin/amoxicillin	nd	nd	91.3	97.0	94.2
			Ceftriaxone/cefotaxime	nd	nd	1.4	0.4	3.0
			Ciprofloxacin	nd	nd	10.1	1.2	8.3
			Trimethoprim–sulfamethoxazole	nd	33.3	24.1	16.2	28.4
Shigella sonnei	Bacillary dysentery	Community	Ampicillin/amoxicillin	12.7	47.9	31.1	40.5	59.6
			Ceftriaxone/cefotaxime	3.3	5.6	0.5	5.3	11.8
			Ciprofloxacin	14.3	24.7	11.4	30.5	58.6
			Trimethoprim–sulfamethoxazole	54.5	66.7	71.3	84.2	89.5
Staphylococcus aureus	Skin, wound and soft tissue infections; bone and joint infections; device-related infections; pneumonia; septicaemia; endocarditis	Community, hospitals	Benzylpenicillin	83.5–87.8	83.3–87.5	83.6–87.1	81.5–87.1	82.5–86.6
			Clindamycin	13.6–15.0	13.8–15.1	14.4–15.2	14.4–15.8	15.5–15.7
			Erythromycin (and other macrolides)	16.6–17.4	15.9–16.7	16.2–16.5	15.6–16.6	16.9–17.1
			Oxacillin (methicillin)	17.7–19.2	18.1–19.3	18.1–19.4	16.7–18.9	17.7–18.9
			Tetracycline (and doxycycline)	4.1–5.2	4.0–4.6	3.7–4.8	4.0–4.6	3.9–5.1
			Trimethoprim–sulfamethoxazole	2.8–3.0	3.1–3.3	3.1–3.3	2.3–2.4	2.5–2.6

continues

Table 4.2: *continued*

Organism	Main types of infection	Most common setting	Important antimicrobials for treatment	% resistant				
				2015	2016	2017	2018	2019
Staphylococcus aureus (methicillin-resistant)	Skin, wound and soft tissue infections; bone and joint infections; device-related infections; pneumonia; septicaemia; endocarditis	Community, hospitals	Ciprofloxacin	28.5–48.3	24.0–42.6	22.4–43.8	21.7–39.2	22.1–37.5
			Clindamycin	25.6–35.7	21.9–35.0	21.8–35.8	22.4–33.6	21.9–31.9
			Daptomycin	0.4–0.4	0.3–0.4	0.2–0.3	0.4–1.2	0.0–0.3
			Erythromycin (and other macrolides)	30.9–44.6	26.9–41.6	25.4–41.3	24.9–36.5	24.4–35.2
			Fusidic acid	4.3–4.6	3.0–4.2	3.5–4.2	3.9–4.5	3.5–6.0
			Gentamicin	8.5–14.4	8.7–16.7	8.8–17.1	8.9–13.8	9.3–15.6
			Linezolid	0.0–0.1	0.0–0.0	0.1–0.1	0.1–0.2	0.0–0.1
			Rifampicin	0.8–1.5	0.6–1.6	0.6–1.2	0.5–1.1	0.5–0.9
			Trimethoprim–sulfamethoxazole	6.9–10.9	6.7–9.4	6.4–9.6	6.3–7.8	6.3–9.3
			Tetracycline (and doxycycline)	10.4–20.3	9.4–17.8	9.0–17.5	9.4–15.1	9.1–15.9
			Vancomycin	0.0–<0.1	0.0–<0.1	0.0	0.0–<0.1	0.0–<0.1
Streptococcus agalactiae	Skin and soft tissue infections, urinary tract infections, bone and joint infections, newborn septicaemia and meningitis	Community	Benzylpenicillin	<0.1	<0.1	<0.1	<0.1	<0.1
			Clindamycin	23.5	26.6	31.1	31.0	33.2
			Erythromycin (and other macrolides)	26.2	28.4	30.6	32.3	34.0
			Trimethoprim	13.9	11.3	8.8	8.0	11.7

continues

Table 4.2: *continued*

Organism	Main types of infection	Most common setting	Important antimicrobials for treatment	% resistant				
				2015	2016	2017	2018	2019
Streptococcus pneumoniae	Otitis media, sinusitis, acute exacerbation of chronic obstructive pulmonary disease, pneumonia, meningitis, septicaemia	Community	Benzylpenicillin (outside the central nervous system)	4.4–5.3	3.0–4.4	2.4–2.4	1.2–1.9	0.9–1.4
			Ceftriaxone (and cefotaxime)	0.4–0.6	0.6–0.9	0.1–0.3	0.1–0.7	0.4–0.4
			Clindamycin	14.3–19.2	16.7–18.6	15.4–19.2	13.9–19.1	6.4–19.3
			Erythromycin (and other macrolides)	13.2–24.4	16.2–24.0	17.3–24.4	14.5–24.4	12.6–24.2
			Trimethoprim–sulfamethoxazole	18.5–25.6	21.6–24.9	15.0–24.1	19.2–22.4	11.5–19.6
			Tetracycline (and doxycycline)	13.7–21.1	15.5–18.7	14.7–19.0	13.9–18.5	12.4–18.8
Streptococcus pyogenes	Skin and soft tissue infections, bone and joint infections, necrotising fasciitis, septicaemia	Community	Benzylpenicillin	0.1	0.0	0.0	0.0	0.0
			Clindamycin	3.0	3.8	4.2	5.4	7.1
			Erythromycin (and other macrolides)	3.7	4.4	4.9	6.3	8.7
			Trimethoprim–sulfamethoxazole	1.2	1.0	1.1	1.6	1.4

nd = no data (tested against an inadequate number of isolates)

* Multi-drug resistance is defined as resistance to at least one agent in three or more antimicrobial categories as defined by Magiorakos.[1] Resistance determined using EUCAST 2020 breakpoints for all years.

† Resistance to at least isoniazid and rifampicin

Notes:

1. Percentages for 2015 to 2017 may have changed from previous reports as more data have become available.
2. A number range is shown when different specimen sources were analysed. If only one specimen source or all specimen sources were analysed, there is no range.

Notes on data sources

APAS reports data for antimicrobials for which at least 75% of isolates were tested using either the European Committee on Antimicrobial Susceptibility Testing (EUCAST), the Clinical and Laboratory Standards Institute (CLSI) or the calibrated dichotomous sensitivity (CDS) methods, and for which at least 30 strains were tested for each grouping. Victoria, Queensland, SA, Tasmania and the ACT used EUCAST; WA used CLSI; and NSW used CLSI, CDS and EUCAST.

Sullivan Nicolaides Pathology reports data for antimicrobials for which at least 75% of isolates were tested using the EUCAST interpretive criteria, and at least 30 strains were tested. For *S. pneumoniae*, there were insufficient data to report the prevalence of resistance for strains causing meningitis.

AGAR reports national data using EUCAST interpretive criteria.

The NNDSS reports data from the Australian Mycobacterium Reference Laboratory Network (AMRLN). All AMRLN laboratories that provide data to the NNDSS now use the same commercial broth system for susceptibility testing of *M. tuberculosis*, but different susceptibility testing methods have been used in the past, in some laboratories. For reporting historical trend data, the results of other methods have been assumed to be equivalent. All laboratories in the AMRLN test every isolate against the four first-line agents (isoniazid, rifampicin, ethambutol and pyrazinamide). Tests against additional antimycobacterial agents are conducted when 1) resistance to isoniazid and rifampicin is detected; 2) resistance to two or more first-line agents is detected; and 3) patients experience severe adverse reactions to first-line agents. Resistance is currently determined using CLSI interpretive criteria.

The National Neisseria Network reports data on *Neisseria* infections. Most cases of gonococcal infection are now diagnosed using nucleic acid techniques, without subsequent culture. Currently, approximately 25% of isolates undergo susceptibility testing.

4.2 *Acinetobacter baumannii* complex

This section describes the health impact and treatment of the *A. baumannii* complex, and the types, impact and rates of resistance in this species complex.

Health impact

The *A. baumannii* complex is a group of environmental organisms that cause infections in patients with compromised physical barriers and immunity. The most common infections caused by this species complex are ventilator-associated pneumonia and severe burn infections. The species complex can cause sustained outbreaks in certain clinical settings, such as intensive care and severe burn units.

Treatment

Because of the organisms' pattern of intrinsic resistances to many antimicrobial classes, the preferred agents to treat serious *A. baumannii* complex infections are carbapenems.

Types and impact of resistance

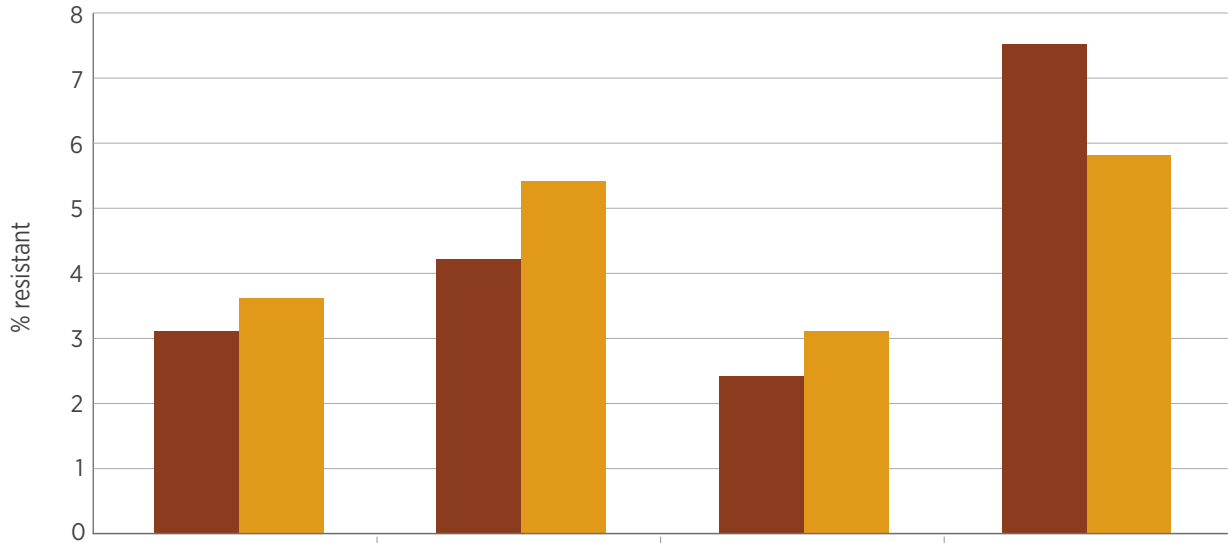
The members of the *A. baumannii* complex have a high propensity for developing resistance to multiple antimicrobial agents, including broad-spectrum agents such as carbapenems. Sometimes, they are susceptible only to potentially toxic antimicrobials, such as colistin. Even this agent is a problem because of hetero-resistance (strains that naturally

harbour resistant subpopulations), which requires combination treatment with other antimicrobials.

Key findings: national

Rates of resistance to key antimicrobial agents remained low in 2018 and 2019 (Figure 4.1) – often less than 5%. Resistance rates were higher in hospitals than in the community (Figure 4.2), which might be attributable to more resistant strains being established in some hospital units.

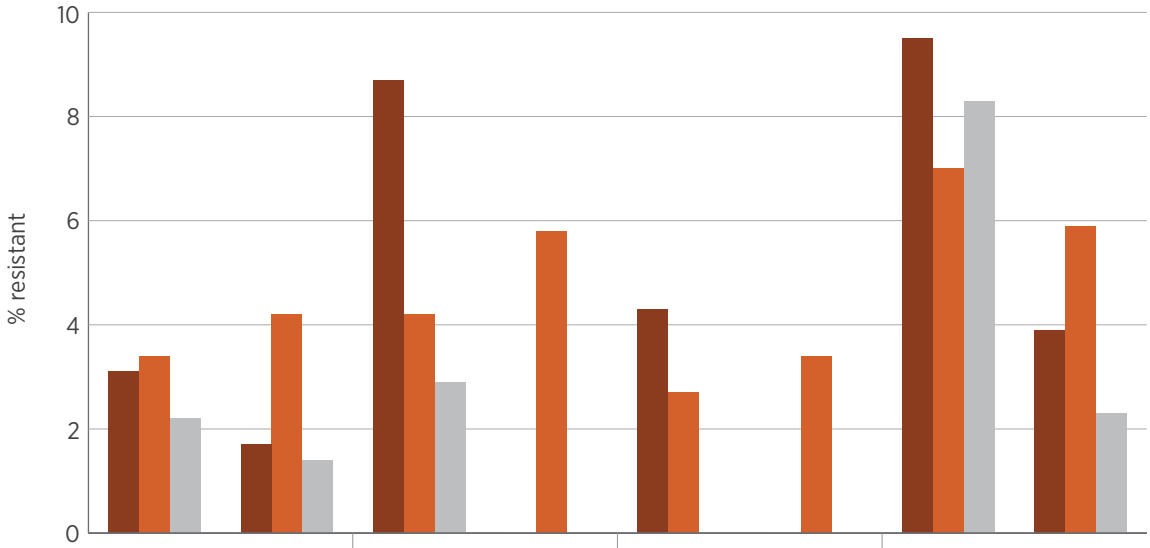
Figure 4.1: *Acinetobacter baumannii* complex resistance, 2018–19



	GEN	CIP/NOR	MER	SXT
2018, %	3.1	4.2	2.4	7.5
2019, %	3.6	5.4	3.1	5.8
2018, *n*	1,505	1,276	1,275	1,173
2019, *n*	1,195	895	1,046	938

CIP = ciprofloxacin; GEN = gentamicin; MER = meropenem; NOR = norfloxacin; SXT = trimethoprim–sulfamethoxazole
Sources: AGAR (national); APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); SNP (Qld, northern NSW)

Figure 4.2: *Acinetobacter baumannii* complex resistance, by clinical setting, 2018–19



	2018	2019	2018	2019	2018	2019	2018	2019
	GEN		CIP/NOR		MER		SXT	
Private hospitals, %	3.1	1.7	8.7	0.0	4.3	0.0	9.5	3.9
Public hospitals, %	3.4	4.2	4.2	5.8	2.7	3.4	7.0	5.9
Community, %	2.2	1.4	2.9	0.0	0.0	0.0	8.3	2.3
Private hospitals, *n*	64	59	23	56	23	52	21	51
Public hospitals, *n*	1,153	937	1,104	757	1,104	901	1,009	796
Community, *n*	229	146	104	32	103	45	96	43

CIP = ciprofloxacin; GEN = gentamicin; MER = meropenem; NOR = norfloxacin; SXT = trimethoprim–sulfamethoxazole
Sources: AGAR and APAS (public hospitals); AGAR, APAS (Qld, SA) and SNP (private hospitals); APAS and SNP (community)

4.3 *Enterobacterales*

This section describes the health impact and treatment of *Enterobacterales*, and the types, impact and rates of resistance in this bacterial group.

Health impact

The order *Enterobacterales* is a large group of related bacteria. Many of its members are associated with infections in humans. Of these, *Escherichia coli* and *Klebsiella pneumoniae* are the most common and important species, and cause both community- and hospital-associated infections. The *Enterobacter cloacae* complex is a common pathogen group in hospital care. *Enterobacterales* also includes *Salmonella* and *Shigella* species; these are reported on separately in Sections 4.9 and 4.10, respectively.

E. coli, *K. pneumoniae* and the *E. cloacae* complex are associated with a variety of infections, including urinary tract infections, biliary tract infections, other intra-abdominal infections (including those following surgery, and often mixed with other pathogens) and septicaemia. *E. coli* is the most common cause of urinary tract infection and septicaemia in the community and in otherwise healthy people. Less often, the three species can cause meningitis, and bacteraemia from intravascular lines.

Treatment

The aminoglycosides (especially gentamicin) are recommended for empirical use, pending the results of culture and susceptibility testing. β-lactam agents, including those combined with β-lactamase inhibitors, are preferred for treatment of infections caused by these species when prolonged treatment or a switch from parenteral to oral therapy is considered. In Australia, fluoroquinolones are recommended only for strains that are resistant to other classes of antimicrobials. In addition to β-lactams, trimethoprim is recommended for treatment of lower urinary tract infections.

Types and impact of resistance

The most common resistance mechanisms in *Enterobacterales* are β-lactamases. The acquired TEM-1 β-lactamase has become so common worldwide that it is found in at least half of the strains isolated from humans in the community in Australia, making these strains resistant to ampicillin and amoxicillin. Both *K. pneumoniae* and the *E. cloacae* complex contain intrinsic β-lactamases that make them naturally resistant to ampicillin/amoxicillin. In addition, the intrinsic β-lactamase of the *E. cloacae* complex makes this species complex resistant to first-generation cephalosporins such as cefazolin and cefalexin, and the enzyme can be easily up-regulated to make the species resistant to third-generation cephalosporins such as ceftriaxone, cefotaxime and ceftazidime. The β-lactam/β-lactamase inhibitor combinations amoxicillin–clavulanic acid and piperacillin–tazobactam are the usual treatments for TEM-1-producing *E. coli* and *K. pneumoniae*, along with third-generation cephalosporins.

The acquired β-lactamases of greatest interest are the extended-spectrum β-lactamases (ESBLs), the plasmid-borne AmpC enzymes (pAmpCs) and the carbapenemases. ESBLs and pAmpCs render *Enterobacterales* resistant to third-generation cephalosporins, and carbapenemases confer resistance to carbapenems and almost all other β-lactams. Carbapenemase-producing *Enterobacterales* are almost always highly multidrug-resistant.

Other resistance mechanisms in *Enterobacterales* that have a clinical impact include the aminoglycoside-modifying enzymes, which render strains resistant to gentamicin and tobramycin (but susceptible to amikacin), and the ribosomal methyltransferases, which confer resistance to gentamicin, tobramycin and amikacin. Resistance to fluoroquinolones is usually through mutations at the target sites (the topoisomerases), but, recently, plasmid-borne resistance has emerged. Resistance to trimethoprim–sulfamethoxazole is common and occurs through several mechanisms.

E. coli, *K. pneumoniae* and the *E. cloacae* complex are noted for their capacity to acquire and transmit resistance genes among themselves and to some other genera through horizontal gene transfer. In addition, this family has specialised mechanisms (integrons) for capturing and accumulating resistance genes, giving them great capacity to become multidrug-resistant. Few agents are available for treatment of highly multidrug-resistant strains, and all are more toxic than the β-lactams.

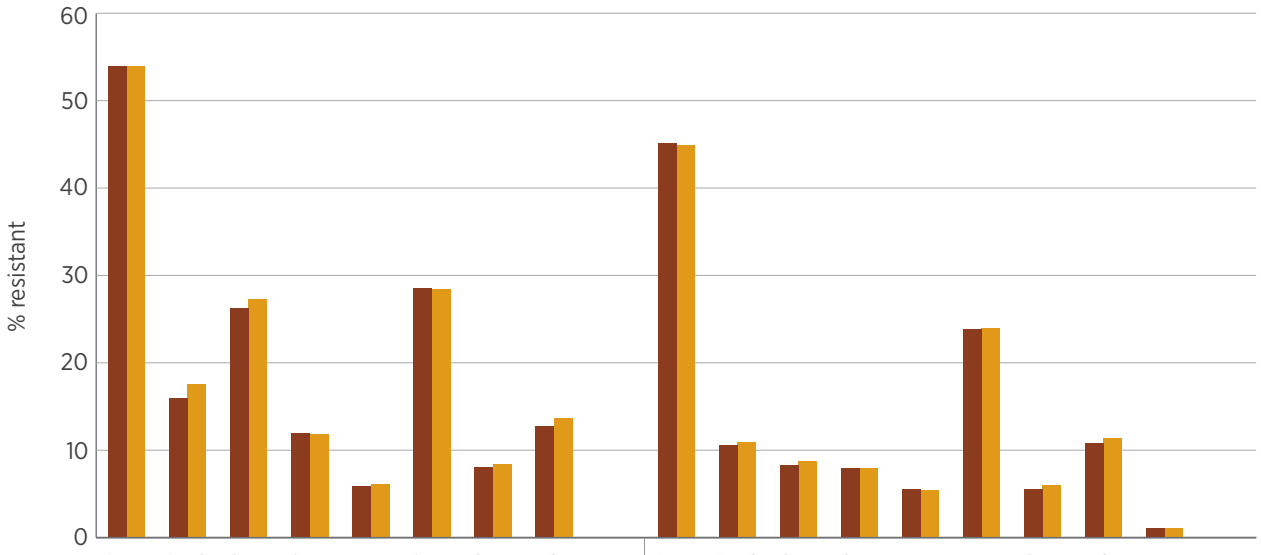
Key findings: national

As observed in previous survey years, in 2018–19, there were no substantial differences in resistances between specimen sources for any of the three reported species. Resistance to ampicillin (and therefore amoxicillin) remains the most common resistance in *E. coli*, while being intrinsic in *K. pneumoniae* and the *E. cloacae* complex. Resistance to amoxicillin–clavulanic acid increased from 11–16% of *E. coli* in 2018 to 11–18% in 2019

(Figure 4.3), but remains less than 10% for *K. pneumoniae* (Figure 4.5). Resistance to cefazolin and trimethoprim (with or without sulfamethoxazole) was common in *E. coli*, but less so in *K. pneumoniae*. Resistance to third-generation cephalosporins (ceftriaxone or cefotaxime) was found in 8–12% of *E. coli* in both 2018 and 2019; the rates in *K. pneumoniae* were 5–7% in 2018 and 6% in 2019. In the *E. cloacae* complex, ceftriaxone/cefotaxime resistance was found in 32–43% (Figure 4.7), mostly resulting from stably derepressed mutants of its intrinsic cephalosporinase. The resistance rate to cefepime in this complex (6% in 2018; 2% in 2019) is an indication of the proportion of this complex that harbours ESBLs. Fluoroquinolone (ciprofloxacin or norfloxacin) resistance was detected in 11–13% of *E. coli* in 2018 and 11–14% in 2019. The rates in *K. pneumoniae* were 6–7% in 2018 and 2019, and in the *E. cloacae* complex 6–7% in 2018 and 6–8% in 2019. Resistance to carbapenems (meropenem) was less than 0.1% in *E. coli*, less than 0.6% in *K. pneumoniae*, but 1–2% in the *E. cloacae* complex (Figures 4.3, 4.5 and 4.7).

Rates of resistance were somewhat lower in the community than in hospitals for most agents with available data (Figures 4.4, 4.6 and 4.8). There were no major differences between rates in public versus private hospitals. Rates in aged care homes were often as high as, or higher than, rates in hospitals (Figures 4.4, 4.6 and 4.8).

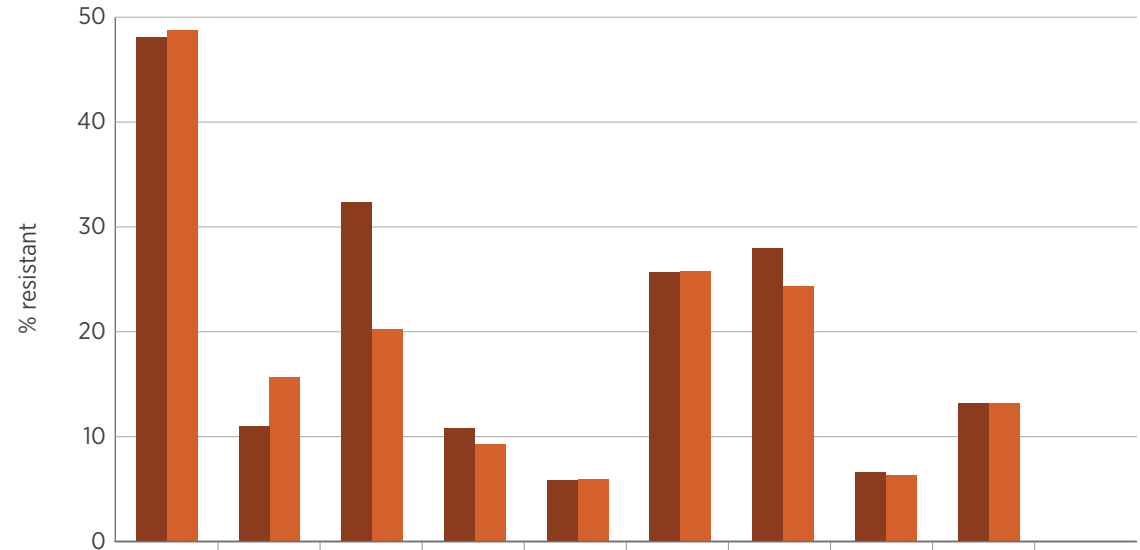
Figure 4.3: *Escherichia coli* acquired resistance, by specimen source, 2018–19



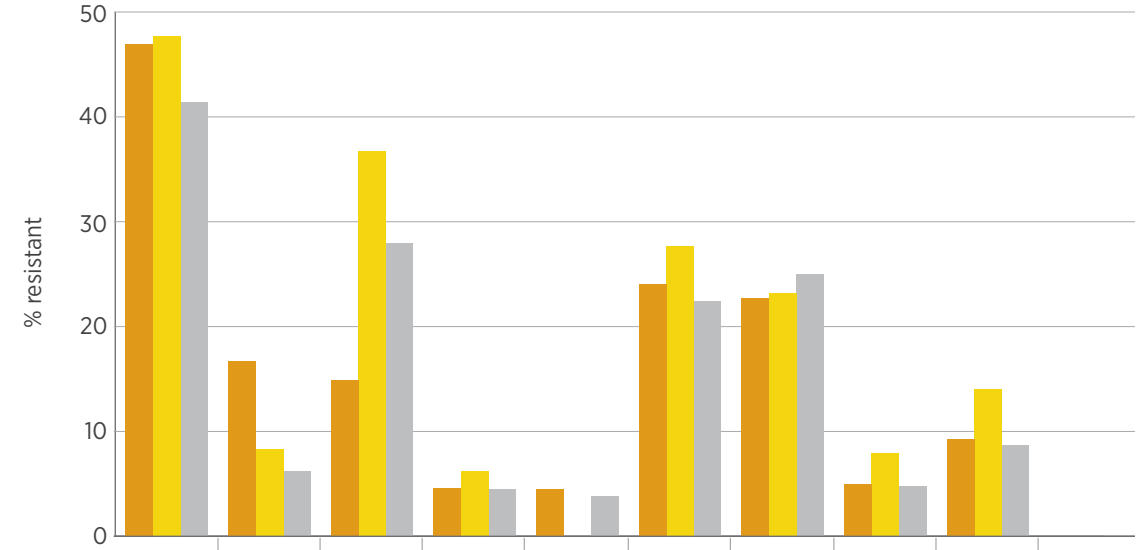
	Blood									Urine									
	AMP	AMC	CZL	CTR	PTZ	SXT	GEN	FQs	MER	AMP	AMC	CLX	CTR	PTZ	TMP	GEN	FQs	NIT	MER
2018, %	54.0	16.0	26.3	12.0	5.9	28.6	8.1	12.8	0.0	45.1	10.6	8.3	7.9	5.5	23.9	5.5	10.8	1.1	0.0
2019, %	54.0	17.6	27.3	11.9	6.1	28.4	8.4	13.7	0.0	44.9	10.9	8.7	8.0	5.4	24.0	6.0	11.4	1.1	0.0

AMC = amoxicillin–clavulanic acid; AMP = ampicillin/amoxicillin; CLX = cefalexin; CTR = ceftriaxone/cefotaxime; CZL = cefazolin; FQs = ciprofloxacin/norfloxacin; GEN = gentamicin; MER = meropenem; NIT = nitrofurantoin; PTZ = piperacillin–tazobactam; SXT = trimethoprim–sulfamethoxazole; TMP = trimethoprim
Sources: AGAR (national); APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); SNP (Qld, northern NSW)

Figure 4.4: *Escherichia coli* acquired resistance, by clinical setting, 2018–19



	AMP	AMC	CZL	CTR	PTZ	TMP	SXT	GEN	FQs	MER
Private hospitals, %	48.1	11.0	32.4	10.8	5.9	25.7	28.0	6.6	13.2	0.0
Public hospitals, %	48.8	15.7	20.3	9.3	6.0	25.8	24.4	6.3	13.2	0.0



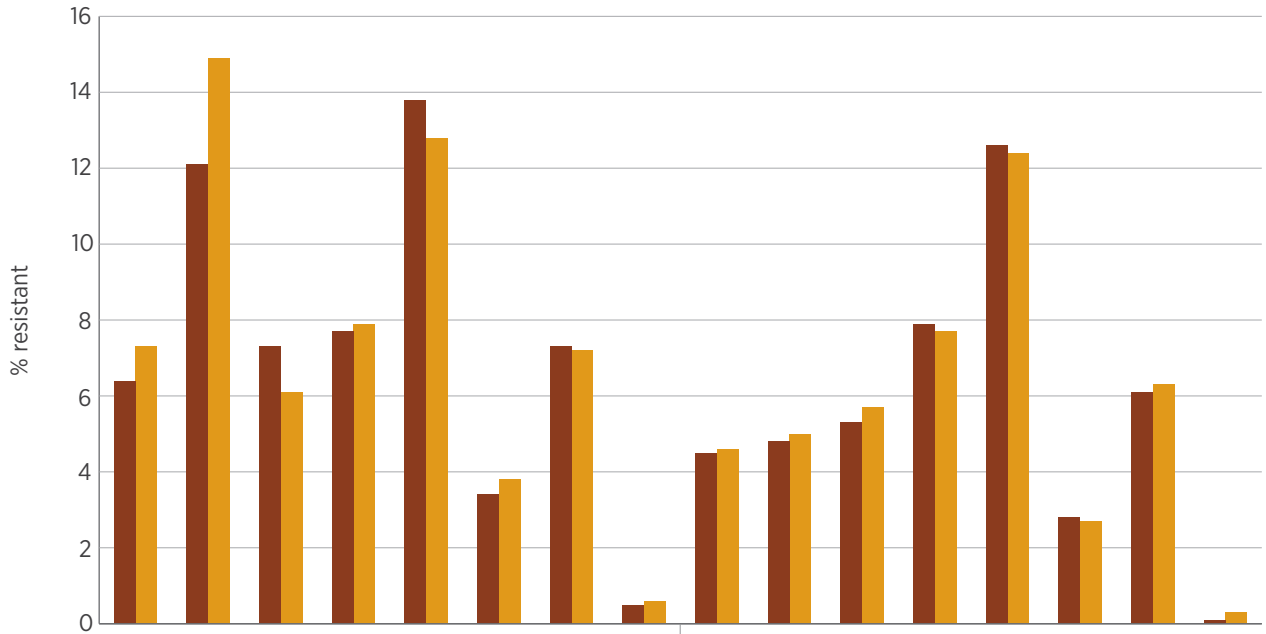
	AMP	AMC	CZL	CTR	PTZ	TMP	SXT	GEN	FQs	MER
Multi-purpose services %	46.9	16.7	14.9	4.6	4.5	24.0	22.7	5.0	9.3	0.0
Aged care homes, %	47.7	8.3	36.7	6.2	0.0	27.7	23.2	7.9	14.0	0.0
Community, %	41.4	6.2	28.0	4.5	3.8	22.4	25.0	4.8	8.7	0.1

AMC = amoxicillin–clavulanic acid; AMP = ampicillin; CTR = ceftriaxone/cefotaxime; CZL = cefazolin; FQs = ciprofloxacin/norfloxacin; GEN = gentamicin; MER = meropenem; PTZ = piperacillin–tazobactam; SXT = trimethoprim–sulfamethoxazole; TMP = trimethoprim

Note: For clarity of presentation, data for 2018 and 2019 have been combined. Raw data for the individual years are available in *AURA 2021: Supplementary data*.

Sources: AGAR and APAS (public hospitals); AGAR, APAS (Qld, SA) and SNP (private hospitals); APAS and SNP (community and aged care homes); APAS (multi-purpose services)

Figure 4.5: *Klebsiella pneumoniae* acquired resistance, by specimen source, 2018–19



	AMC	CZL	CTR	PTZ	SXT	GEN	FQs	MER	AMC	CZL	CTR	PTZ	TMP	GEN	FQs	MER
2018, %	6.4	12.1	7.3	7.7	13.8	3.4	7.3	0.5	4.5	4.8	5.3	7.9	12.6	2.8	6.1	0.1
2019, %	7.3	14.9	6.1	7.9	12.8	3.8	7.2	0.6	4.6	5.0	5.7	7.7	12.4	2.7	6.3	0.3

AMC = amoxicillin–clavulanic acid; CTR = ceftriaxone/cefotaxime; CZL = cefazolin; FQs = ciprofloxacin/norfloxacin; GEN = gentamicin; MER = meropenem; PTZ = piperacillin–tazobactam; SXT = trimethoprim–sulfamethoxazole; TMP = trimethoprim

Sources: AGAR (national); APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); SNP (Qld, northern NSW)

For many agents with available data, resistance rates for Enterobacterales *in aged care homes were as high as, or higher than, rates in hospitals.*

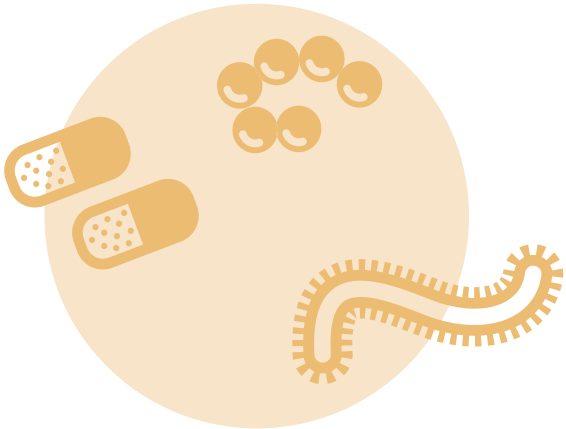
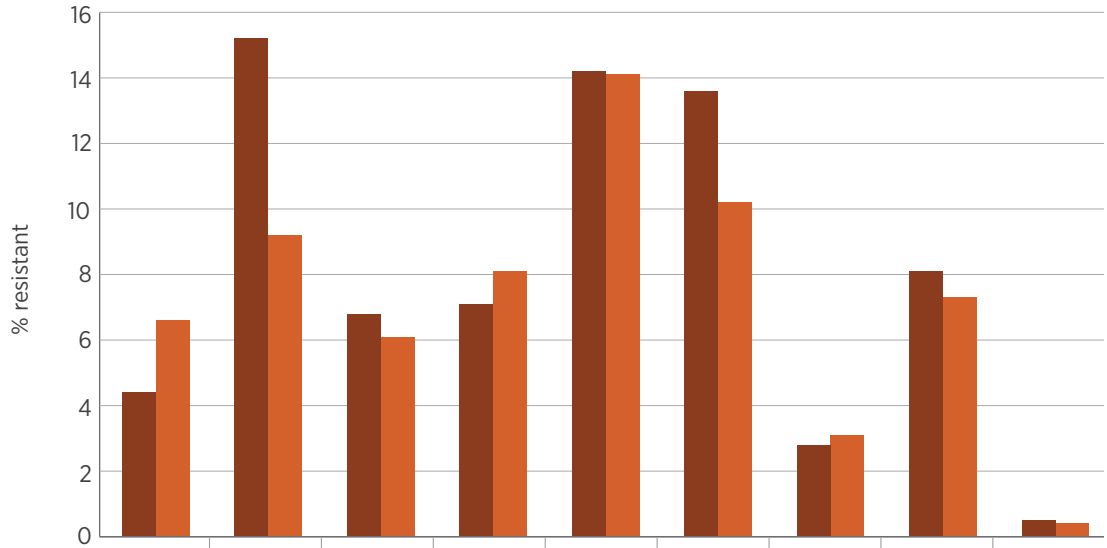
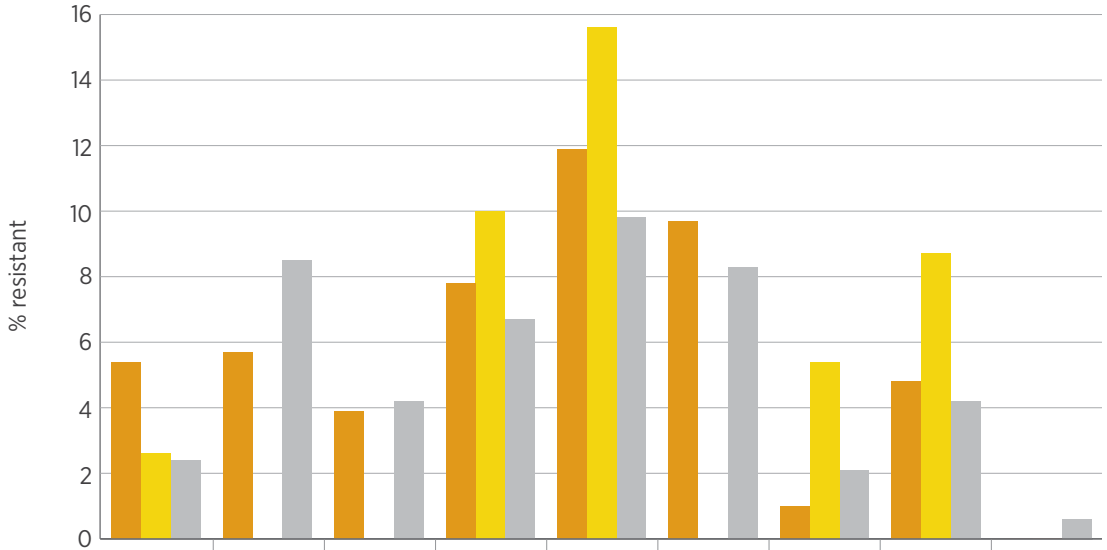


Figure 4.6: *Klebsiella pneumoniae* acquired resistance, by clinical setting, 2018–19



	AMC	CZL	CTR	PTZ	TMP	SXT	GEN	FQs	MER
Private hospitals, %	4.4	15.2	6.8	7.1	14.2	13.6	2.8	8.1	0.5
Public hospitals, %	6.6	9.2	6.1	8.1	14.1	10.2	3.1	7.3	0.4



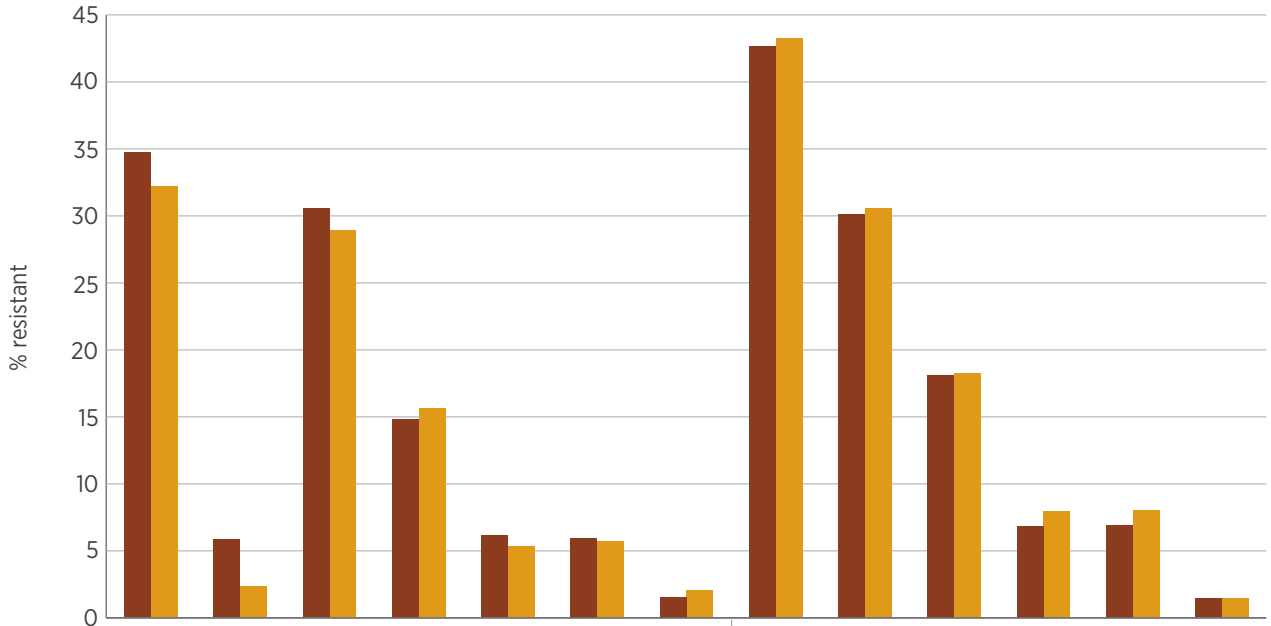
	AMC	CZL	CTR	PTZ	TMP	SXT	GEN	FQs	MER
Multi-purpose services, %	5.4	5.7	3.9	7.8	11.9	9.7	1.0	4.8	0.0
Aged care homes, %	2.6	nd	nd	10.0	15.6	nd	5.4	8.7	0.0
Community, %	2.4	8.5	4.2	6.7	9.8	8.3	2.1	4.2	0.6

AMC = amoxicillin–clavulanic acid; CTR = ceftriaxone/cefotaxime; CZL = cefazolin; FQs = ciprofloxacin/norfloxacin; GEN = gentamicin; MER = meropenem; nd = no data (either not tested or tested against an inadequate number of isolates); PTZ = piperacillin–tazobactam; SXT = trimethoprim–sulfamethoxazole; TMP = trimethoprim

Note: For clarity of presentation, data for 2018 and 2019 have been combined. Raw data for the individual years are available in *AURA 2021: Supplementary data*.

Sources: AGAR and APAS (public hospitals); AGAR, APAS (Qld, SA) and SNP (private hospitals); APAS and SNP (community and aged care homes); APAS (multi-purpose services)

Figure 4.7: *Enterobacter cloacae* complex acquired resistance, by specimen source, 2018–19



	Blood							Urine					
	CTR	CPM	PTZ	SXT	GEN	FQs	MER	CTR	PTZ	TMP	GEN	FQs	MER
2018, %	34.7	5.8	30.5	14.8	6.1	5.9	1.5	42.6	30.1	18.1	6.8	6.9	1.4
2019, %	32.2	2.3	28.9	15.6	5.3	5.7	2.0	43.2	30.5	18.2	7.9	8.0	1.4

CPM = cefepime; CTR = ceftriaxone/cefotaxime; FQs = ciprofloxacin/norfloxacin; GEN = gentamicin; MER = meropenem; PTZ = piperacillin–tazobactam; SXT = trimethoprim–sulfamethoxazole; TMP = trimethoprim
Sources: AGAR (national); APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); SNP (Qld, northern NSW)

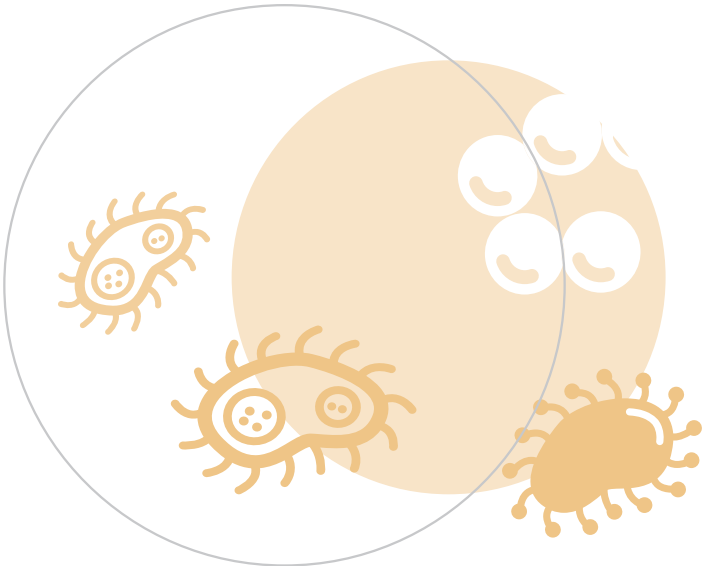
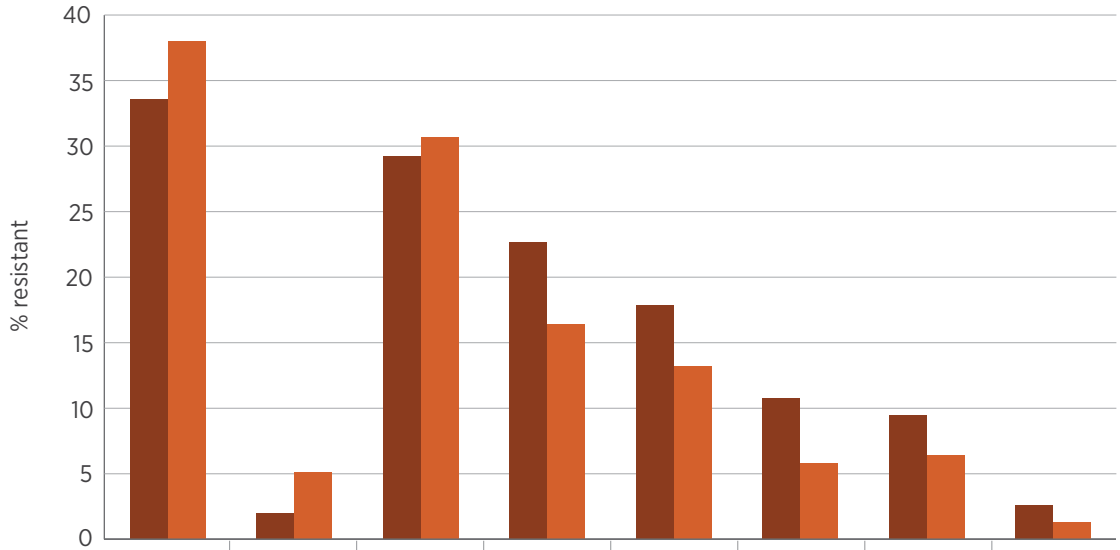
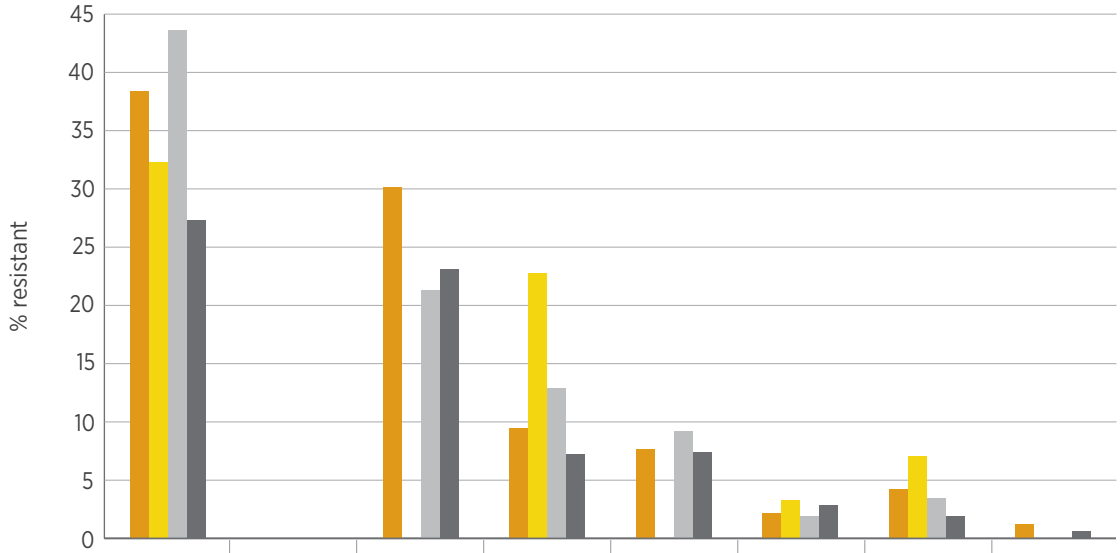


Figure 4.8: *Enterobacter cloacae* complex acquired resistance, by clinical setting, 2018–19



	CTR	CPM	PTZ	TMP	SXT	GEN	FQs	MER
Private hospitals, %	33.6	2.0	29.2	22.7	17.9	10.8	9.5	2.6
Public hospitals, %	38.0	5.1	30.7	16.4	13.2	5.8	6.4	1.3



	CTR	CPM	PTZ	TMP	SXT	GEN	FQs	MER
Multi-purpose services, %	38.4	nd	30.2	9.5	7.7	2.2	4.2	1.2
Aged care homes, %	32.3	nd	nd	22.8	nd	3.3	7.1	nd
Community, %	43.6	nd	21.3	12.9	9.2	1.9	3.5	0.1
Other, %	27.3	nd	23.1	7.2	7.4	2.9	1.9	0.6

CPM = cefepime; CTR = ceftriaxone/cefotaxime; FQs = ciprofloxacin/norfloxacin; GEN = gentamicin; MER = meropenem; nd = no data (either not tested or tested against an inadequate number of isolates); PTZ = piperacillin–tazobactam; SXT = trimethoprim–sulfamethoxazole; TMP = trimethoprim

Note: For clarity of presentation, data for 2018 and 2019 have been combined. Raw data for the individual years are available in *AURA 2021: Supplementary data*.

Sources: AGAR and APAS (public hospitals); AGAR, APAS (Qld, SA) and SNP (private hospitals); APAS and SNP (community and aged care homes); APAS (multi-purpose services)

Key findings: states and territories

Data on resistance were analysed by AURA in blood culture isolates from across the states and territories through the AGAR program. The resistance rates to all antimicrobials tested can be found in *AURA 2021: Supplementary data*. There were some notable differences between the states and territories in the prevalence of some important resistances (Figure 4.9).

For *E. coli*, acquired resistance to ceftriaxone ranged from 7.1% in Tasmania to 17.5% in the Northern Territory (NT) in 2018, and from 7.0% in Tasmania to 16.7% in Victoria in 2019. Acquired resistance to gentamicin ranged from 3.8% in Tasmania to 13.8% in the NT in 2018, and from 6.0% in Tasmania to 16.6% in the NT in 2019. Resistance to ciprofloxacin ranged from 7.6% in Tasmania to 20.5% in WA in 2018, and from 10.4% in Queensland to 20.5% in the ACT in 2019 (Figure 4.9).

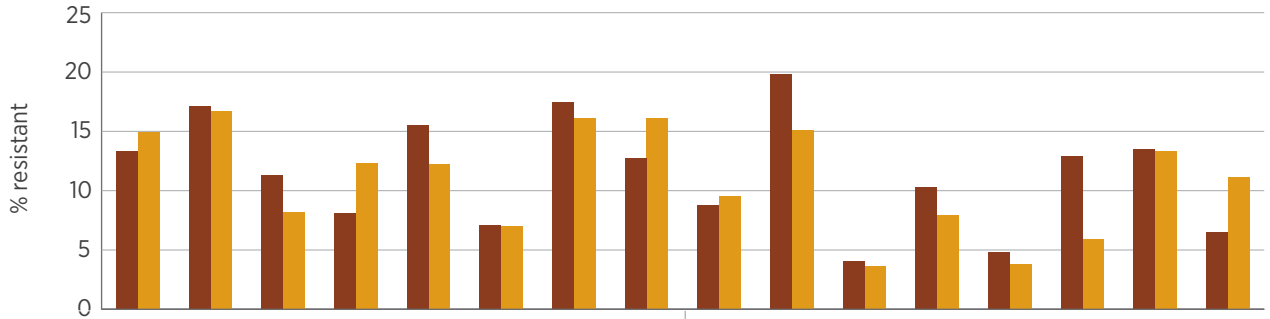
Overall, Tasmania continued to have lower rates of resistance in *E. coli* to the three indicator agents (ceftriaxone, gentamicin and ciprofloxacin) in 2018 and 2019 than other states and territories. The reasons for this are unclear and warrant further investigation.

For *K. pneumoniae* complex, in 2019, acquired resistance to ceftriaxone ranged from 3.6% in Queensland to 15.1% in Victoria, acquired resistance to gentamicin ranged from 2.4% in Queensland to 13.3% in the NT. Acquired resistance to ciprofloxacin ranged from 5.0% in WA to 17.0% in Victoria (Figure 4.9).

Overall, Tasmania continues to have lower rates of resistance in Escherichia coli *to the three indicator agents in 2018 and 2019 than other states and territories. The reasons for this remain unclear and will continue to be monitored.*

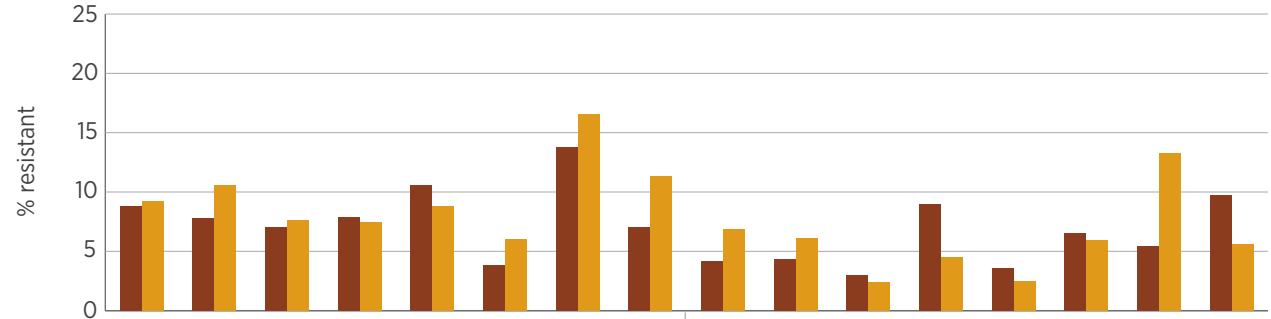
Figure 4.9: *Escherichia coli* and *Klebsiella pneumoniae* complex acquired resistance (blood culture isolates), by state and territory, 2018–19

Ceftriaxone



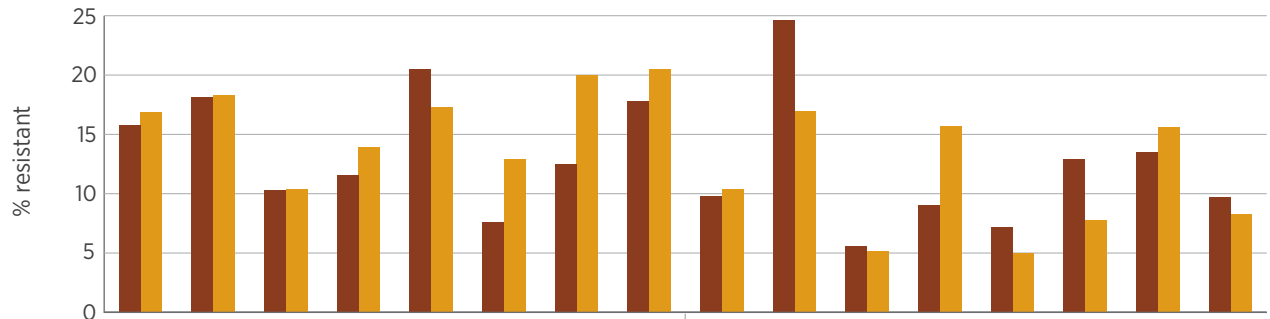
	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
	E. coli								*K. pneumoniae* complex							
2018, %	13.3	17.1	11.3	8.1	15.5	7.1	17.5	12.7	8.8	19.8	4.1	10.3	4.8	12.9	13.5	6.5
2019, %	14.9	16.7	8.2	12.3	12.2	7.0	16.1	16.1	9.5	15.1	3.6	7.9	3.8	5.9	13.3	11.1

Gentamicin



	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
	E. coli								*K. pneumoniae* complex							
2018, %	8.8	7.8	7.0	7.9	10.6	3.8	13.8	7.0	4.2	4.3	3.0	9.0	3.6	6.5	5.4	9.7
2019, %	9.2	10.6	7.6	7.5	8.8	6.0	16.6	11.3	6.9	6.1	2.4	4.5	2.5	5.9	13.3	5.6

Ciprofloxacin



	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
	E. coli								*K. pneumoniae* complex							
2018, %	15.8	18.1	10.3	11.6	20.5	7.6	12.5	17.8	9.8	24.6	5.6	9.0	7.2	12.9	13.5	9.7
2019, %	16.9	18.3	10.4	13.9	17.3	12.9	20.0	20.5	10.4	17.0	5.2	15.7	5.0	7.8	15.6	8.3

Source: AGAR (national)

National trends

From AGAR data, acquired resistance of *E. coli* to key anti-gram-negative antimicrobial agents showed a steady increase over the seven-year period 2013–2019 (Figure 4.10).

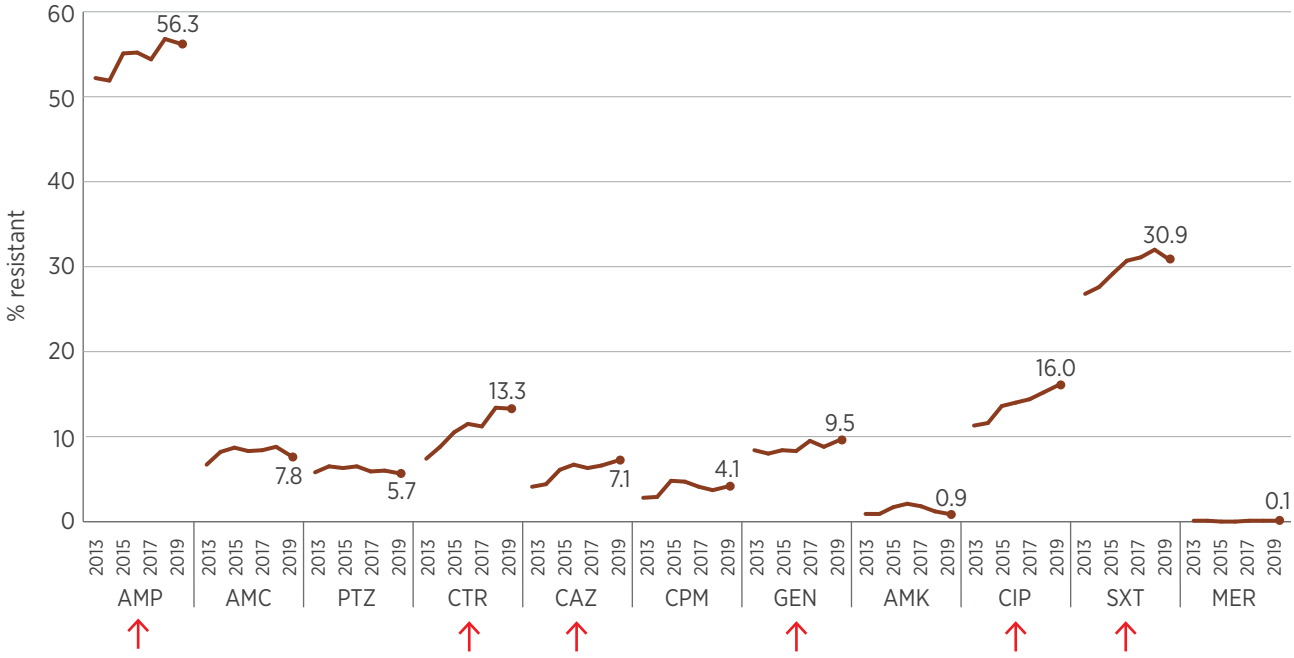
Resistance to fluoroquinolones is increasing in *E. coli*, despite no increase in the use of this antimicrobial class in the community (where access is restricted) or in hospitals. APAS data show substantial increases in fluoroquinolone resistance in *E. coli* in all remoteness areas for 2015–2019 (Figure 4.11).

The likely impact of these changes in resistance is:

- Increasing treatment failures of empirical therapy in community-onset urinary tract infections and septicaemia
- Increasing treatment failures in combination regimens used for the treatment of complicated intra-abdominal infections
- Greater reliance on 'last-line' treatments such as carbapenems.

Increasing resistance in Escherichia coli *may mean treatment failure and greater reliance on last-line treatments.*

Figure 4.10: Trends in acquired resistance (EUCAST) of *Escherichia coli* to key antimicrobials (blood culture isolates), 2013–2019



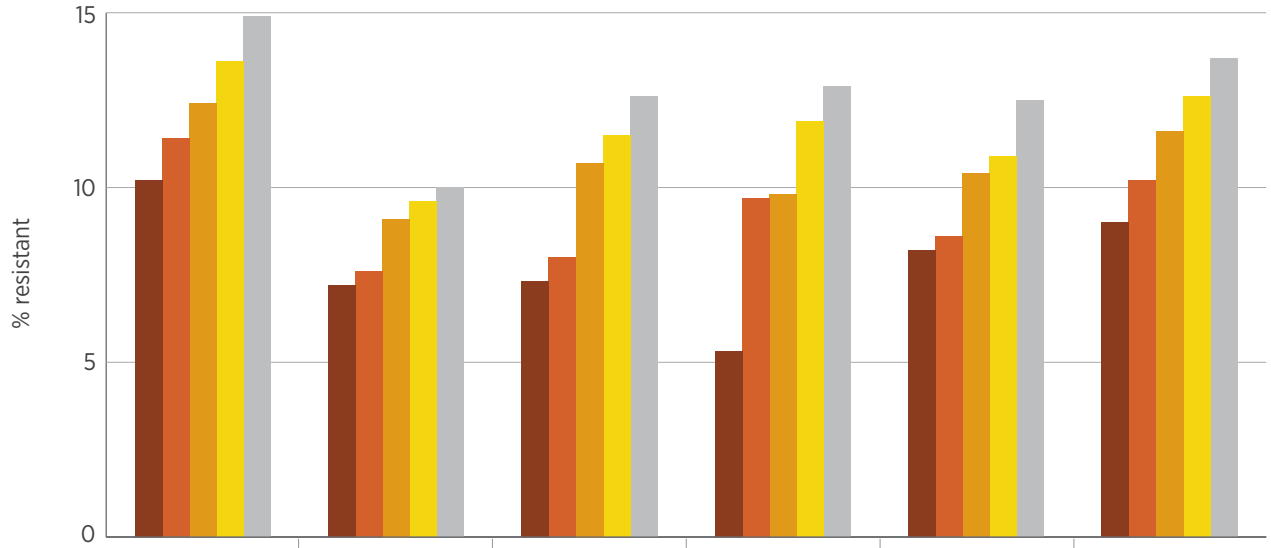
AMC = amoxicillin–clavulanic acid (2:1 ratio); AMK = amikacin; AMP = ampicillin; CAZ = ceftazidime; CIP = ciprofloxacin; CPM = cefepime; CTR = ceftriaxone; EUCAST = European Committee on Antimicrobial Susceptibility Testing; GEN = gentamicin; MER = meropenem; PTZ = piperacillin–tazobactam; SXT = trimethoprim–sulfamethoxazole

Notes:

1. Percentage resistance determined using EUCAST 2020 breakpoints for all years. Filled circles indicate values for 2019.
2. Red arrows indicate antimicrobial agents with significant increase ($P < 0.01$) over the period 2013 to 2019.

Source: AGAR (national)

Figure 4.11: Percentage of fluoroquinolone non-susceptible *Escherichia coli* by remoteness area, 2015–2019



	Major cities	Inner regional	Outer regional	Remote	Very remote	All areas combined
2015, %	10.2	7.2	7.3	5.3	8.2	9.0
2016, %	11.4	7.6	8.0	9.7	8.6	10.2
2017, %	12.4	9.1	10.7	9.8	10.4	11.6
2018, %	13.6	9.6	11.5	11.9	10.9	12.6
2019, %	14.9	10.0	12.6	12.9	12.5	13.7
2015, *n*	48,220	13,450	11,886	3,443	2,097	79,096
2016, *n*	55,850	14,071	11,183	2,479	1,900	85,483
2017, *n*	58,998	14,045	9,180	2,503	1,971	86,697
2018, *n*	59,040	14,306	9,010	2,596	1,880	86,832
2019, *n*	59,026	14,530	9,143	2,497	1,760	86,956

Notes:
1. Fluoroquinolone refers to ciprofloxacin or norfloxacin.
2. Remoteness area is based on postcode of patient's place of residence.

Source: APAS (national, excluding NT)

Additional findings from targeted surveillance

AGAR also captured data on 30-day all-cause mortality (Tables 4.3 and 4.4). Unless otherwise stated, these findings apply to all species of *Enterobacterales* detected.

E. coli had significantly higher 30-day all-cause mortality in both 2018 and 2019 for hospital-onset than for community-onset bacteraemia. The effect of ESBLs (*E. coli* and *K. pneumoniae*) on 30-day all-cause mortality was small or absent. All-cause mortality rates were higher in hospital-onset sepsis than in community-onset sepsis, most likely because of greater comorbidities in hospitalised patients.

Data for gram-negative bacteria can be found on the AURA[2] and AGAR[3] websites.

Table 4.3: Onset setting and 30-day all-cause mortality for the three most commonly isolated *Enterobacterales* species (blood culture isolates), 2018–19

Species	Year	Community, *n*	Community mortality, % (*n*)	Hospital, *n*	Hospital mortality, % (*n*)	Total, *n*	Total mortality, % (*n*)
Escherichia coli	2018	2,427	8.6 (209)	523	13.4 (70)	2,950	9.5 (279)
	2019	2,733	9.3 (255)	606	16.2 (98)	3,339	10.6 (353)
Klebsiella pneumoniae complex	2018	551	10.5 (58)	232	15.9 (37)	783	12.1 (95)
	2019	590	12.4 (73)	255	15.7 (40)	845	13.4 (113)
Enterobacter cloacae complex	2018	163	11.7 (19)	152	11.8 (18)	315	11.7 (37)
	2019	182	8.2 (15)	143	18.2 (26)	325	12.6 (41)
All *Enterobacterales*	2018	3,831	9.6 (366)	1,204	14.1 (170)	5,035	10.6 (536)
	2019	4,220	10.5 (442)	1,289	16.1 (207)	5,509	11.8 (649)

Source: AGAR (national)

Table 4.4: Onset setting and 30-day all-cause mortality for the two most commonly isolated *Enterobacterales* species (blood culture isolates), by extended-spectrum β-lactamase phenotype, 2018–19

Species	Year	ESBL phenotype	Community, *n*	Community mortality, % (*n*)	Hospital, *n*	Hospital mortality, % (*n*)	Total, *n*	Total mortality, % (*n*)
Escherichia coli	2018	*Total*	*2,422*	*8.6 (209)*	*523*	*13.4 (70)*	*2,945*	*9.5 (279)*
		Non-ESBL	2,092	8.4 (175)	403	13.4 (54)	2,495	9.2 (229)
		ESBL	330	10.3 (34)	120	13.3 (16)	450	11.1 (50)
	2019	*Total*	*2,720*	*9.3 (253)*	*598*	*16.1 (96)*	*3,318*	*10.5 (349)*
		Non-ESBL	2,359	9.2 (216)	453	15.2 (69)	2,812	10.1 (285)
		ESBL	361	10.2 (37)	145	18.6 (27)	506	12.6 (64)
Klebsiella pneumoniae complex	2018	*Total*	*549*	*10.6 (58)*	*231*	*16.0 (37)*	*780*	*12.2 (95)*
		Non-ESBL	502	9.8 (49)	185	14.6 (27)	687	11.1 (76)
		ESBL	47	19.1 (9)	46	21.7 (10)	93	20.4 (19)
	2019	*Total*	*588*	*12.4 (73)*	*254*	*15.7 (40)*	*842*	*13.4 (113)*
		Non-ESBL	536	12.3 (66)	208	14.4 (30)	744	12.9 (96)
		ESBL	52	13.5 (7)	46	21.7 (10)	98	17.3 (17)

ESBL = extended-spectrum β-lactamase
Source: AGAR (national)

From information to action

AURA data – Improving the quality of the data to enhance antimicrobial choices

Australian Passive AMR Surveillance (APAS) information is commonly used to create hospital-specific antibiograms. The data can also highlight areas for attention; track resistance patterns over time; and assist in reviewing the appropriateness of national or local guidelines.

For example, APAS data can support clinical decision-making when selecting the most appropriate treatments for serious urinary tract infections. To cover the pathogens of the urogenital tract, the resistance patterns of organisms that commonly cause urinary tract infections (UTIs) can be examined and the results compared with the *Therapeutic Guidelines: Antibiotic* recommendation for initial empirical therapy in serious UTIs requiring intravenous therapy, such as acute pyelonephritis. The guidelines currently recommend a combination of ampicillin/amoxicillin plus gentamicin for severe cases of pyelonephritis in adults.

The national antibiogram for urine cultures shows the five most commonly isolated pathogens for a specified year. Table A shows that APAS data support the recommendation of the guidelines, with resistance rates to ampicillin/amoxicillin plus gentamicin at <5% for all five common pathogens of the urogenital tract.

APAS continues to expand to provide more information about antimicrobial resistance across Australia. The aim is to increase participation from all states and territories, from the private sector, and from rural and remote areas. The data will be available both locally and through reports to inform clinical policy and practice, and to inform antimicrobial choices.

Table A: Top five pathogens causing urinary tract infections in adults, resistance to ampicillin or amoxicillin, gentamicin, and ampicillin plus gentamicin

		% resistant (n)		
Organism	**Total**	**Ampicillin or amoxicillin**	**Gentamicin**	**Ampicillin + gentamicin**
Escherichia coli	86,397	44.8 (38,732)	5.1 (4,409)	4.8 (4,149)
Klebsiella pneumoniae	16,670	99.1 (16,526)	3.1 (512)	3.1 (512)
Proteus mirabilis	9,366	14.8 (1,382)	3.7 (342)	2.5 (238)
Pseudomonas aeruginosa	4,990	R	2.7 (137)	2.7 (137)*
Enterococcus faecalis	1,775	0.3 (5)	R	0.3 (5)†

R = intrinsically resistant
* Values reflect the resistance to gentamicin
† Value reflects the resistance to ampicillin or amoxicillin
Source: APAS, 2020

4.4 *Enterococcus* species

This section describes the health impact and treatment of *Enterococcus* species, and the types, impact and rates of resistance in these species.

Health impact

Enterococcus species are opportunistic pathogens that cause a variety of infections in patients whose physical barriers are compromised through surgery or invasive devices. They rarely cause disease in healthy people, but may cause infections in vulnerable people, such as the very elderly or people who are immunosuppressed.

The most common clinical syndromes associated with enterococcal septicaemia are biliary and urinary tract infections. Enterococci are a cause of urinary tract infection in patients with catheters or structural abnormalities of the urinary tract. They are also associated with other intestinal organisms in many intra-abdominal infections, especially those of the biliary tract (particularly *E. faecium*). These infections can be complicated by septicaemia. *E. faecalis* is also a less common, but important, cause of endocarditis.

Treatment

Enterococci are naturally resistant to several common antimicrobial classes, including anti-staphylococcal penicillins, cephalosporins, macrolides and lincosamides. Amoxicillin administered orally is the most common treatment for minor infections. More serious infections are treated with intravenous ampicillin or amoxicillin; for endocarditis, one of these agents is often combined with low-dose gentamicin. Vancomycin is used instead of ampicillin/amoxicillin for serious infections in patients who are allergic to penicillins.

Types and impact of resistance

Ampicillin resistance has emerged worldwide at high levels in *E. faecium* during the past 20 years, including in Australia. This has led to increased use of vancomycin for treatment. More recently, vancomycin-resistant enterococci (VRE) have also emerged, most notably in *E. faecium*, but also in *E. faecalis*. The gene complexes responsible are of two main types: *vanA* and *vanB*. In Australia, unlike in most other countries, VRE have been dominated until recently by the *vanB*, rather than the *vanA*, genotype. VRE require treatment with agents that are usually reserved, such as teicoplanin or daptomycin.

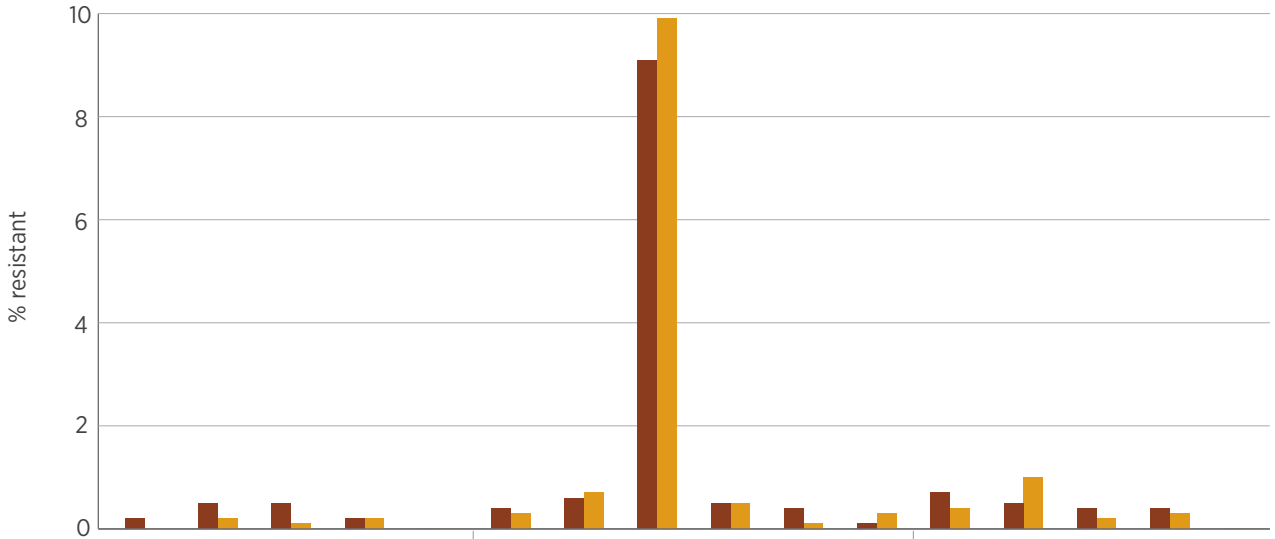
Key findings: national

Rates of acquired resistance to key antimicrobials in *E. faecalis* were very low. In 2018–19, less than 1% of isolates from blood (n = 1,351 in 2018; n = 1,271 in 2019), urine (n = 13,571 in 2018; n = 12,989 in 2019) and other sites (n = 2,929 in 2018; n = 2,829 in 2019) were resistant to ampicillin, nitrofurantoin, vancomycin or linezolid (Figure 4.12). Rates of resistance showed little differences by clinical setting (Figure 4.13).

In contrast, rates of resistance in *E. faecium* to ampicillin, ciprofloxacin/norfloxacin and vancomycin were high (Figures 4.14 and 4.15). Linezolid resistance was rare. Specimen source did not substantially influence rates of resistance (Figure 4.14). There was some variation in the rates of vancomycin resistance in *E. faecium*, depending on the setting (Figure 4.15).

Data from APAS reveal a downward trend in vancomycin resistance in all remoteness areas during the period 2015–2019 (Figure 4.16).

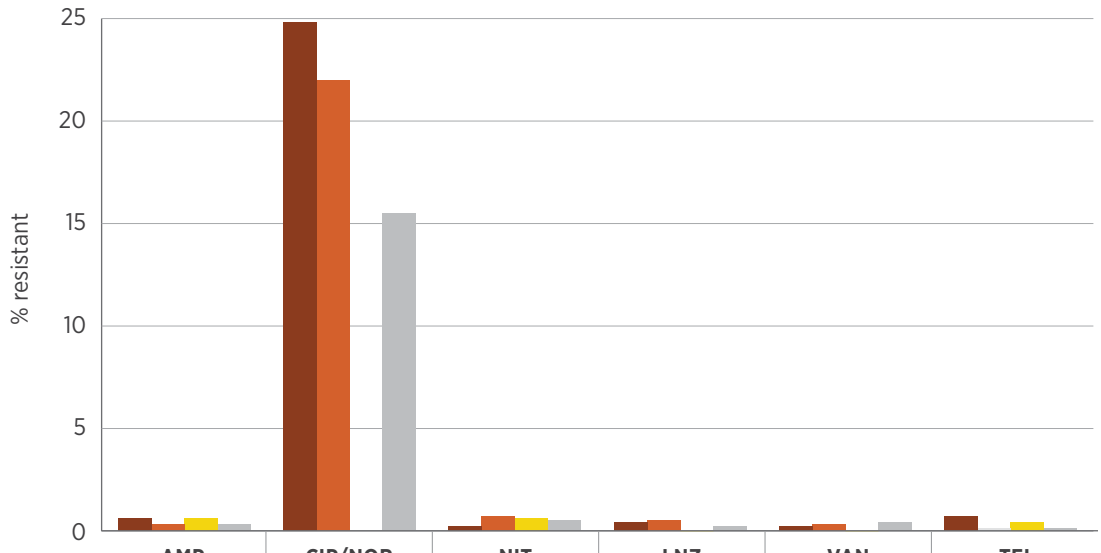
Figure 4.12: *Enterococcus faecalis* resistance, by specimen source, 2018–19



	AMP	NIT	LNZ	VAN	TEI	AMP	NIT	CIP	LNZ	VAN	TEI	AMP	NIT	LNZ	VAN	TEI
	Blood					Urine						Other				
2018, %	0.2	0.5	0.5	0.2	0.0	0.4	0.6	9.1	0.5	0.4	0.1	0.7	0.5	0.4	0.4	0.0
2019, %	0.0	0.2	0.1	0.2	0.0	0.3	0.7	9.9	0.5	0.1	0.3	0.4	1.0	0.2	0.3	0.0
2018, *n*	1,351	666	1,174	1,329	397	13,571	13,530	2,424	7,855	11,710	2,704	2,929	1,064	2,410	2,790	356
2019, *n*	1,271	436	1,043	1,267	314	12,989	12,937	2,649	7,365	12,123	3,116	2,829	613	1,952	2,735	290

AMP = ampicillin; CIP = ciprofloxacin; LNZ = linezolid; NIT = nitrofurantoin; TEI = teicoplanin; VAN = vancomycin
Note: Due to the nature of the available data, norfloxacin could not be included.
Sources: AGAR (national); APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); SNP (Qld, northern NSW)

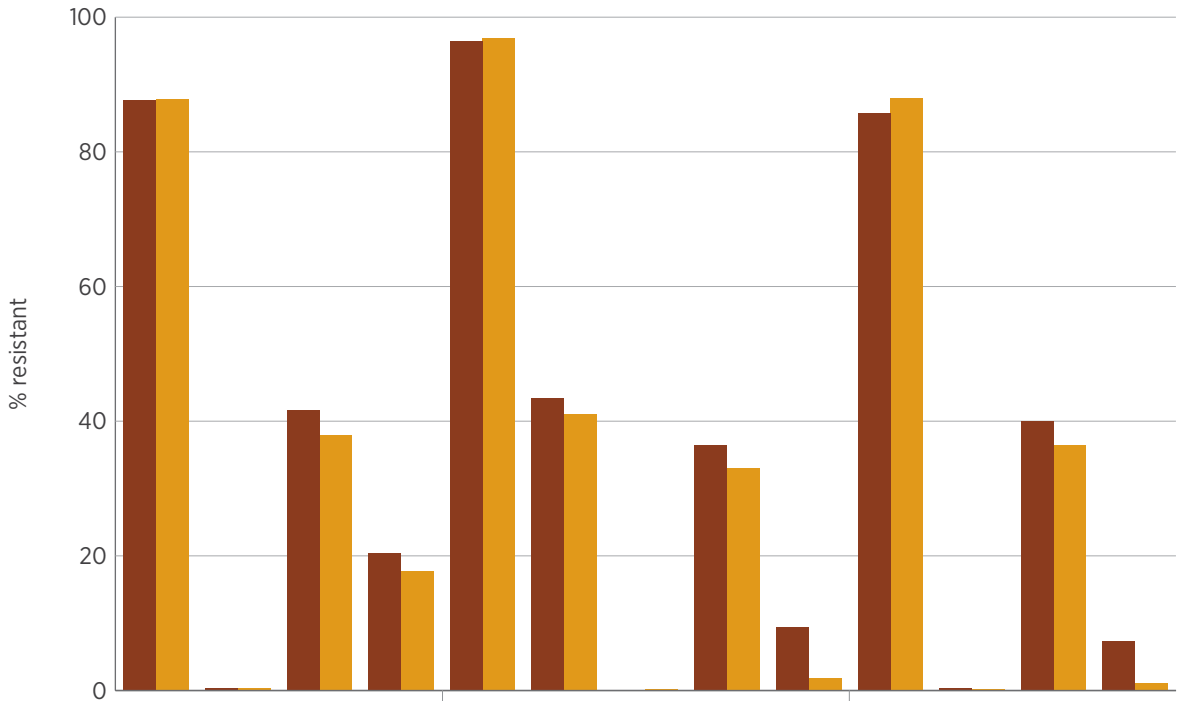
Figure 4.13: *Enterococcus faecalis* resistance, by clinical setting, 2018–19



	AMP	CIP/NOR	NIT	LNZ	VAN	TEI
Private hospitals, %	0.6	24.8	0.2	0.4	0.2	0.7
Public hospitals, %	0.3	22.0	0.7	0.5	0.3	0.1
Aged care homes, %	0.6	nd	0.6	0.0	0.0	0.4
Community, %	0.3	15.5	0.5	0.2	0.4	0.1
Private hospitals, *n*	1,983	479	1,381	1,126	1,681	606
Public hospitals, *n*	27,826	5,777	23,028	17,186	26,499	4,141
Aged care homes, *n*	333	40	329	276	276	263
Community, *n*	3,528	1,522	3,312	2,105	2,251	1,420

AMP = ampicillin; CIP = ciprofloxacin; LNZ = linezolid; nd = no data (either not tested or tested against an inadequate number of isolates); NIT = nitrofurantoin; NOR = norfloxacin; TEI = teicoplanin; VAN = vancomycin
Note: Multi-purpose services are excluded because of an insufficient number of isolates from this setting (<30).
Sources: AGAR and APAS (public hospitals); AGAR, APAS (Qld, SA) and SNP (private hospitals); APAS and SNP (community and aged care homes)

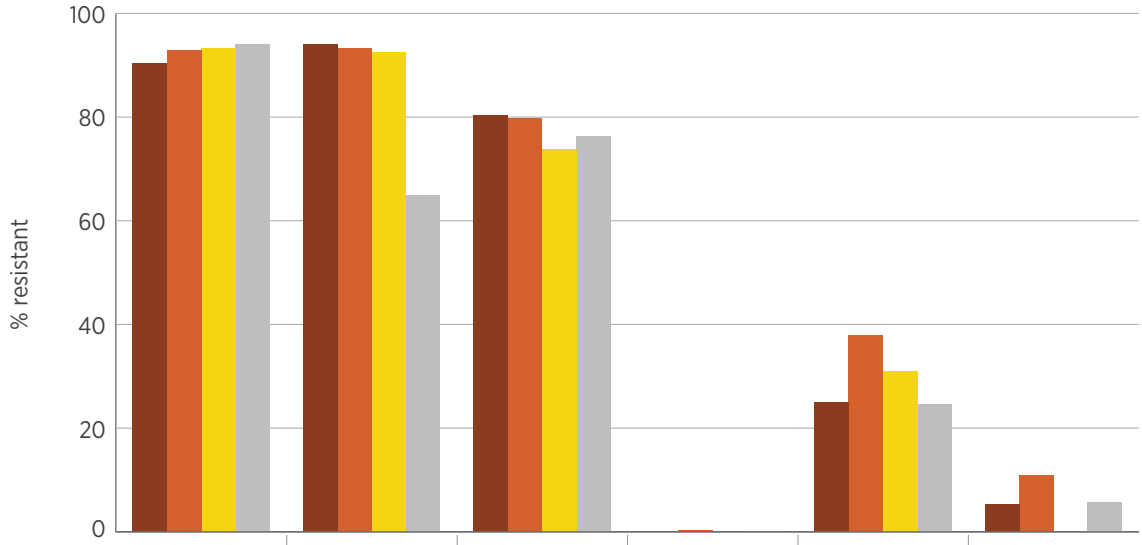
Figure 4.14: *Enterococcus faecium* resistance, by specimen source, 2018–19



	Blood				Urine					Other			
	AMP	LNZ	VAN	TEI	AMP	CIP/NOR	LNZ	VAN	TEI	AMP	LNZ	VAN	TEI
2018, %	87.7	0.3	41.6	20.4	96.5	43.5	0.1	36.4	9.5	85.8	0.4	40.0	7.4
2019, %	87.8	0.4	38.0	17.7	96.9	41.0	0.2	33.1	1.8	88.0	0.2	36.4	1.1
2018, *n*	771	723	777	313	2,908	628	2,294	2,892	465	1,236	1,125	1,251	176
2019, *n*	826	832	835	310	2,828	675	2,163	2,812	392	1,409	1,319	1,423	179

AMP = ampicillin; CIP = ciprofloxacin; LNZ = linezolid; NOR = norfloxacin; TEI = teicoplanin; VAN = vancomycin
Sources: AGAR (national); APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); SNP (Qld, northern NSW)

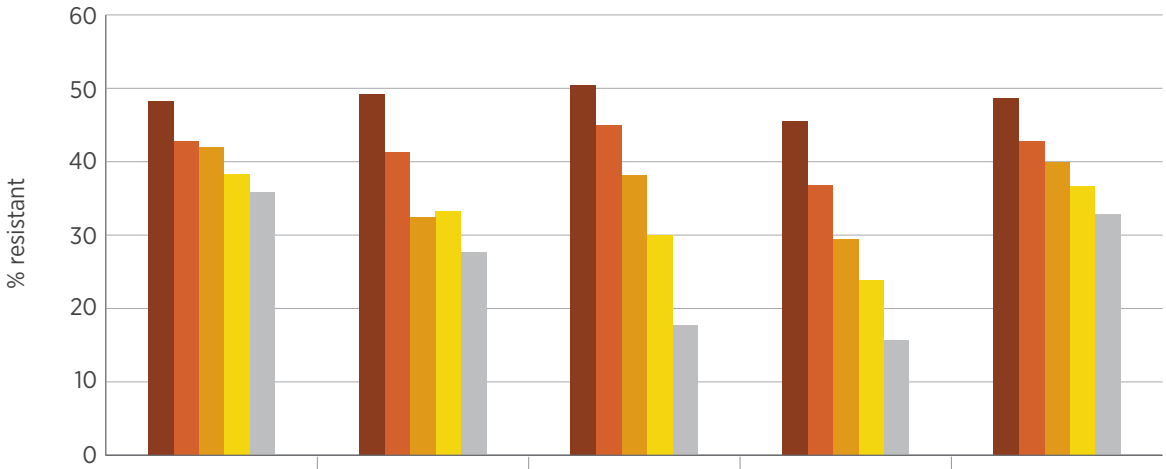
Figure 4.15: *Enterococcus faecium* resistance, by clinical setting, 2018–19



	AMP	CIP/NOR	NIT	LNZ	VAN	TEI
Private hospitals, %	90.4	94.0	80.4	0.0	25.0	5.3
Public hospitals, %	92.9	93.3	79.7	0.3	38.0	10.9
Aged care homes, %	93.2	92.4	73.7	nd	30.9	nd
Community, %	94.1	64.9	76.2	0.0	24.6	5.6
Private hospitals, *n*	705	283	428	403	708	150
Public hospitals, *n*	8,639	1,559	4,409	7,766	8,705	1,570
Aged care homes, *n*	103	79	99	27	94	18
Community, *n*	410	325	366	148	362	71

AMP = ampicillin; CIP = ciprofloxacin; LNZ = linezolid; nd = no data (either not tested or tested against an inadequate number of isolates); NIT = nitrofurantoin; NOR = norfloxacin; TEI = teicoplanin; VAN = vancomycin
Note: Multi-purpose services are excluded because of an insufficient number of isolates from this setting (<30).
Sources: AGAR and APAS (public hospitals); AGAR, APAS (Qld, SA) and SNP (private hospitals); APAS and SNP (community and aged care homes)

Figure 4.16: Percentage of vancomycin-resistant *Enterococcus faecium* by remoteness area, 2015–2019



	Major cities	Inner regional	Outer regional	Remote Australia	All areas combined
2015, %	48.3	49.2	50.4	45.5	48.6
2016, %	42.8	41.3	45.0	36.8	42.8
2017, %	42.0	32.5	38.2	29.5	39.9
2018, %	38.3	33.3	30.0	23.8	36.7
2019, %	35.9	27.7	17.7	15.7	32.9
2015, *n*	1,881	480	254	33	2,670
2016, *n*	2,316	549	240	38	3,184
2017, *n*	2,838	661	306	44	3,877
2018, *n*	2,961	643	267	42	3,946
2019, *n*	2,923	660	265	51	3,926

Note: Remoteness area is based on postcode of patient's place of residence.
Source: APAS (public hospitals)

Rates of resistance to several antimicrobials in Enterococcus faecium *are decreasing nationally, but remain high.*

Key findings: states and territories

The percentages of *Enterococcus* species that were resistant to key antimicrobials are shown in Tables 4.5 and 4.6. In *E. faecium*, there are notable differences in vancomycin resistance between states.

Vancomycin-resistant *E. faecium* is the main AMR issue for *Enterococcus* species. The main type of vancomycin-resistant *E. faecium* circulating in Australia before 2017 was the *vanB* type; however, by 2018, the *vanA* type predominated. In 2019, nationally, *vanA* and *vanB* were circulating equally (Figure 4.17). In NSW, Tasmania and the ACT, the *vanA* type is predominant in blood culture isolates.

Table 4.5: Percentage of *Enterococcus faecalis* resistance (blood culture isolates), by state and territory, 2018–19

Antimicrobial	Year	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Australia, % (*n*)
Ampicillin	2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 (675)
	2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 (698)
Vancomycin	2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 (675)
	2019	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1 (698)
Teicoplanin	2018	0.5	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.3 (675)
	2019	0.9	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.4 (698)
Nitrofurantoin	2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 (668)
	2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 (693)
Linezolid	2018	0.0	0.9	0.0	0.0	1.1	0.0	0.0	0.0	0.3 (675)
	2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 (698)
Total number of isolates tested	2018	211	117	131	57	91	31	11	26	675
	2019	218	128	124	64	80	41	7	36	698

Notes:
1. Resistance was determined using European Committee on Antimicrobial Susceptibility Testing interpretive criteria.
2. Not all antimicrobial agents were reported for all isolates.

Source: AGAR (national)

Table 4.6: Percentage of *Enterococcus faecium* resistance (blood culture isolates), by state and territory, 2018–19

Antimicrobial	Year	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Australia, % (*n*)
Ampicillin	2018	89.5	95.4	74.5	84.2	90.7	91.7	91.7	92.3	89.4 (491)
	2019	92.8	94.5	90.5	86.7	91.1	92.0	69.2	73.7	91.2 (594)
Vancomycin	2018	50.7	61.5	12.7	34.2	18.5	54.2	83.3	42.3	45.0 (491)
	2019	43.5	66.5	15.9	31.1	5.4	40.0	46.2	21.1	41.6 (594)
Teicoplanin	2018	34.2	19.2	5.5	10.5	11.1	16.7	8.3	26.9	20.8 (491)
	2019	32.5	19.5	6.3	11.1	3.6	24.0	0.0	15.8	20.2 (594)
Linezolid	2018	0.0	0.8	0.0	0.0	0.0	0.0	0.0	3.8	0.4 (490)
	2019	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.2 (594)
Total number of isolates tested	2018	152	130	55	38	54	24	12	26	491
	2019	209	164	63	45	56	25	13	19	594

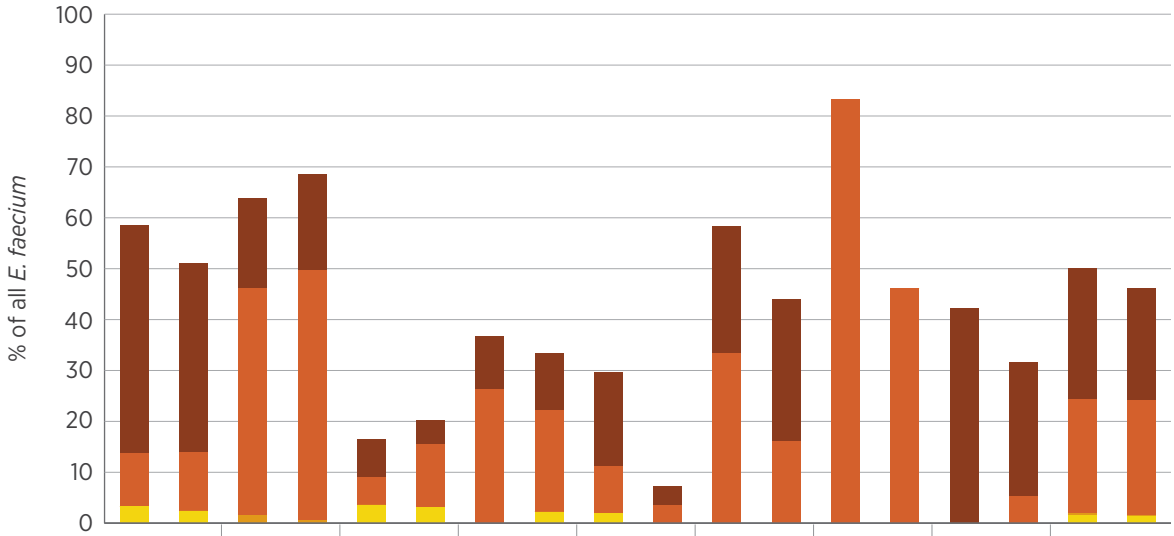
Notes:
1 Resistance was determined using European Committee on Antimicrobial Susceptibility Testing interpretive criteria.
2. Not all antimicrobial agents were reported for all isolates.

Source: AGAR (national)

Data from the AGAR program show that the overall rate of vancomycin resistance has declined slightly since 2015. Over this time, there has been a growth of *vanA* and a decline of *vanB* genotypes. Of note is the small proportion of strains with *vanA* or *vanB* genes that tested as 'susceptible' in the routine susceptibility test. These strains highlight the problem of a hidden reservoir of resistance gene complexes (Figure 4.18).

A small proportion of Enterococcus faecium *strains that have a* vanA *or* vanB *gene are susceptible to vancomycin. These strains may act as a hidden reservoir of resistance gene complexes.*

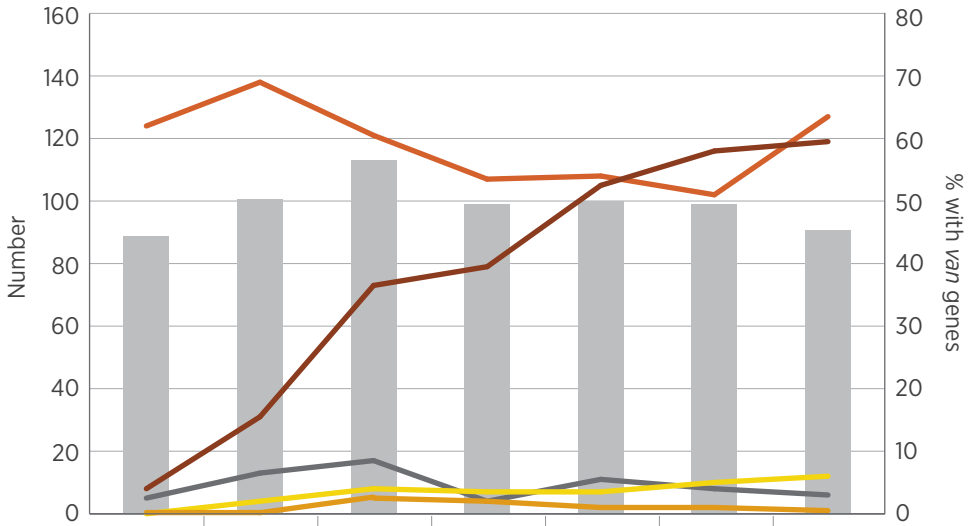
Figure 4.17: *Enterococcus faecium* vancomycin resistance genotype (blood culture isolates), by state and territory and nationally, 2018–19



	NSW		Vic		Qld		SA		WA		Tas		NT		ACT		Australia	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
vanA	44.7	37.3	17.7	18.8	7.3	4.7	10.5	11.1	18.5	3.6	25.0	28.0	0.0	0.0	42.3	26.3	25.7	22.0
vanB	10.5	11.5	44.6	49.1	5.5	12.5	26.3	20.0	9.3	3.6	33.3	16.0	83.3	46.2	0.0	5.3	22.4	22.7
vanA* and *vanB	0.0	0.0	1.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2
Not determined	3.3	2.4	0.0	0.0	3.6	3.1	0.0	2.2	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.3

Note: Total number of isolates: *n* = 491 in 2018; *n* = 596 in 2019.
Source: AGAR (national)

Figure 4.18: *Enterococcus faecium* genotype and vancomycin susceptibility (blood culture isolates), 2013–2019



	2013	2014	2015	2016	2017	2018	2019
van* gene, % of *E. faecium	44.2	50.1	56.3	49.3	49.8	49.3	45.2
***vanA*, vancomycin-resistant**	8	31	73	79	105	116	119
***vanB*, vancomycin-resistant**	124	138	121	107	108	102	127
***vanA* + *vanB*, vancomycin-resistant**	0	0	5	4	2	2	1
***vanA*, vancomycin-susceptible**	0	4	8	7	7	10	12
***vanB*, vancomycin-susceptible**	5	13	17	4	11	8	6
Total, *n*	137	186	224	201	233	238	265

Note: Number of contributors per year – 2013–14, *n* = 27; 2015, *n* = 31; 2016, *n* = 32; 2017–18, *n* = 35; 2019, *n* = 39.
Source: AGAR (national)

Additional findings from targeted surveillance

Data from AGAR are available for 30-day all-cause mortality. The all-cause mortality at 30 days was significantly higher for *E. faecium* infections than for *E. faecalis* infections, possibly as a result of greater comorbidities in patients with *E. faecium* infections. Vancomycin resistance in *E. faecium* appeared to have an even greater association with 30-day all-cause mortality than vancomycin susceptibility in *E. faecium* (Table 4.7).

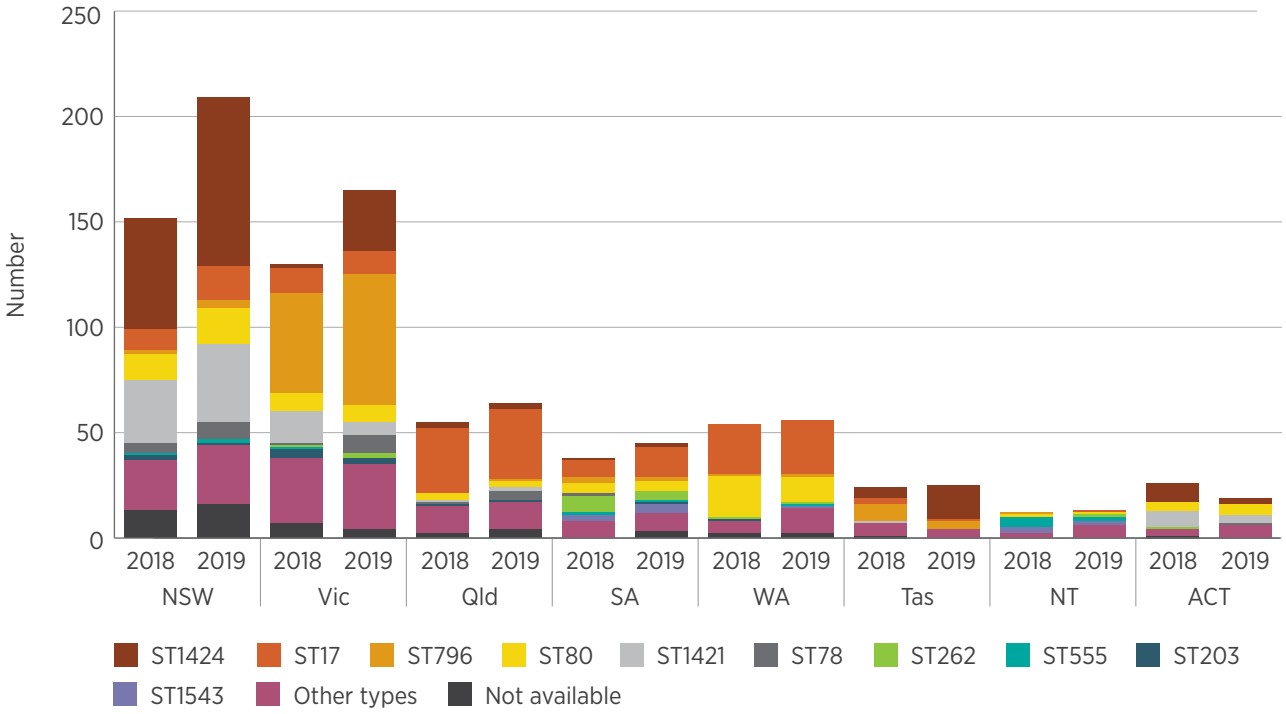
E. faecium isolates were typed using whole-genome sequencing. Different multi-locus sequence types have become established in different states and territories, consistent with rapid local or regional spread rather than national spread (Figure 4.19). This emphasises the importance of local infection prevention and control practices in containment and spread of VRE strains.

Table 4.7: Onset setting and 30-day all-cause mortality for infections with *Enterococcus* (blood culture isolates), 2018–19

Species	Year	Community, *n*	Community mortality, % (*n*)	Hospital, *n*	Hospital mortality, % (*n*)	Total, *n*	Total mortality, % (*n*)
Enterococcus faecalis	2018	371	14.8 (55)	185	14.6 (27)	556	14.7 (82)
	2019	364	12.1 (44)	169	17.2 (29)	533	13.7 (73)
Enterococcus faecium	2018	119	19.3 (23)	293	30.4 (89)	412	27.2 (112)
	2019	141	23.4 (33)	366	27.6 (101)	507	26.4 (134)
Vancomycin-susceptible *E. faecium*	2018	80	20.0 (16)	136	27.2 (37)	216	24.5 (53)
	2019	99	25.3 (25)	193	23.3 (45)	292	24.0 (70)
Vancomycin-resistant *E. faecium*	2018	39	17.9 (7)	157	33.1 (52)	196	30.1 (59)
	2019	40	20.0 (8)	173	32.4 (56)	213	30.0 (64)

Source: AGAR (national)

Figure 4.19: Distribution of *Enterococcus faecium* sequence types (blood culture isolates), by state and territory, 2018–19



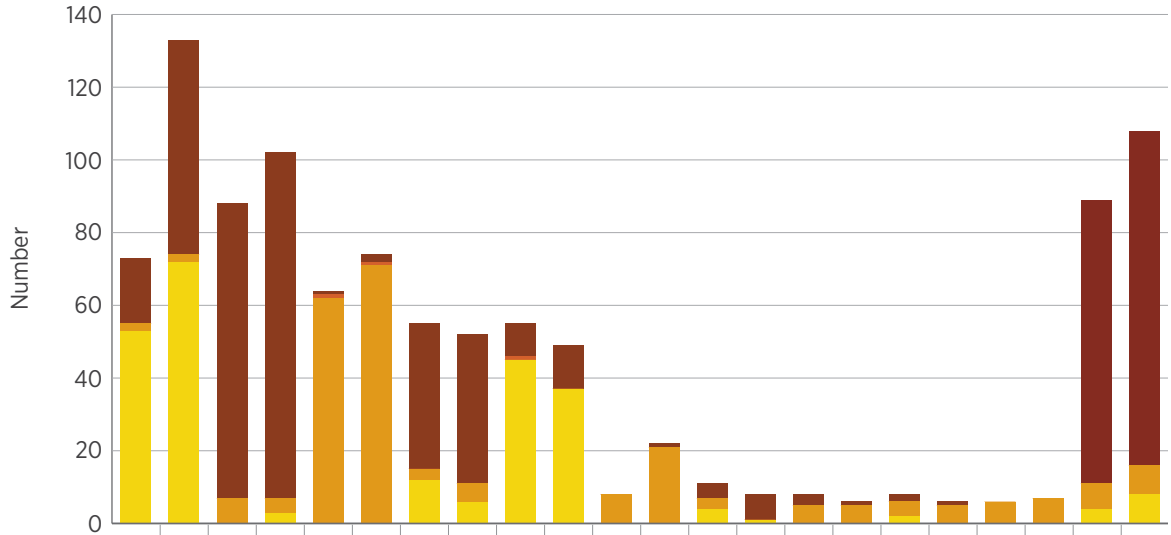
Source: AGAR (national)

Different sequence types of Enterococcus faecium *have become established in different states and territories, consistent with rapid local or regional spread. This emphasises the importance of local infection prevention and control practices in containment and spread of vancomycin-resistant strains.*

Four sequence types – ST17, ST1424 (M-type 3), ST796 and ST1421 (M-type 1) – accounted for 60% of all *E. faecium* in Australia in 2018. In 2019, ST80 replaced ST1421. However, ST1424, ST796 and ST1421 harboured the greatest proportion of *van* genes. Sequence types ST1434 and ST1421 harboured *vanA* genes, while ST796 harboured *vanB* genes (Figure 4.20). This accounts for different VRE teicoplanin susceptibility patterns seen by states and territories in AGAR national reports. ST1424 increased in 2019 compared with 2018. This sequence type was detected in all states and territories except the NT and WA.

Full data from AGAR surveys of *Enterococcus* species can be found on the AGAR website.[3]

Figure 4.20: *Enterococcus faecium* multi-locus sequence types harbouring *vanA* and/or *vanB* genes, 2018–19



	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
	ST1424		ST17		ST796		ST80		ST1421		ST78		ST262		ST555		ST203		ST1543		Other types	
Not *vanA* or *vanB*	18	59	81	95	1	2	40	41	9	12	0	1	4	7	3	1	2	1	0	0	78	92
vanA and *vanB*	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
vanB	2	2	7	4	62	71	3	5	0	0	8	21	3	0	5	5	4	5	6	7	7	8
vanA	53	72	0	3	0	0	12	6	45	37	0	0	4	1	0	0	2	0	0	0	4	8

Source: AGAR (national)

4.5 *Mycobacterium tuberculosis*

This section describes the health impact and treatment of *M. tuberculosis*, and the types, impact and rates of resistance in this species.

Health impact

M. tuberculosis is the bacterium that causes tuberculosis, which has a variety of clinical manifestations, but most commonly presents as lung disease. Once acquired, *M. tuberculosis* can remain quiescent in the body for many years (even decades) as latent tuberculosis. When the body's defences wane, it reactivates and causes active disease. Tuberculosis is a major public health issue in many countries. Australia is fortunate in having one of the lowest rates of tuberculosis in the world; however, continued vigilance is required to maintain or improve this low rate. Approximately 87–89% of all notified cases in Australia occur in people born overseas, who have mostly migrated from high-prevalence countries.

Treatment

M. tuberculosis is not susceptible to most conventional antibacterial agents. Instead, it requires treatment with specially designed antimycobacterial agents. Four of these – isoniazid, rifampicin, ethambutol and pyrazinamide – are the first-line agents and comprise the standard oral treatment regimen for tuberculosis caused by fully susceptible strains. When the strain is susceptible, isoniazid and rifampicin are considered the mainstay of therapy. Combinations of antimycobacterial agents are always required for treatment because resistance to any of them can emerge during treatment. Treatment is required for a minimum of six months.

Types and impact of resistance

Because such a high proportion of Australian cases occur in people born overseas, changes in antimicrobial susceptibility observed in Australia reflect patterns of resistance in these other countries. The most common forms of resistance worldwide are resistance to isoniazid and rifampicin. When strains are resistant to one or both of these agents, other antimycobacterial agents are added to, or substituted into, the treatment combination. For most of these additional agents, side effects are more likely or more severe. Longer courses of treatment are needed for resistant strains.

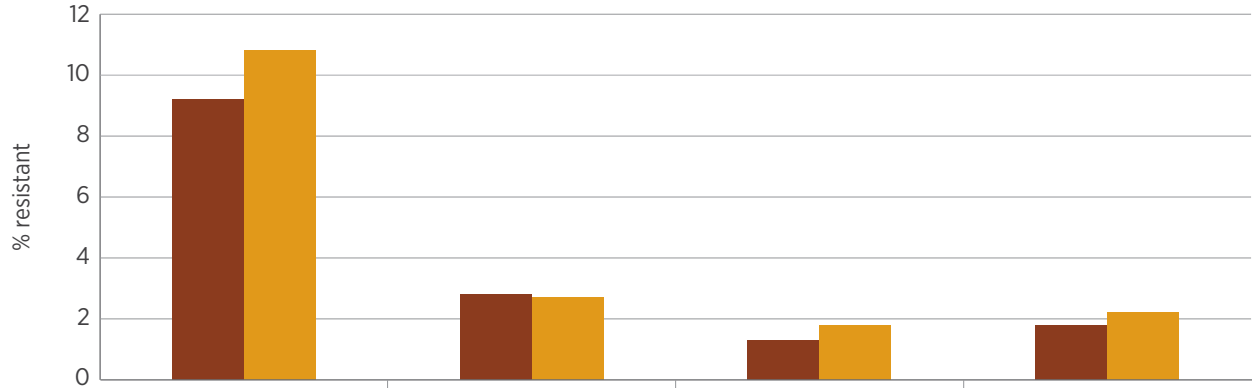
Strains that are resistant to isoniazid and rifampicin, with or without resistance to the other two first-line agents, are considered to be multidrug-resistant tuberculosis (MDR-TB). If these strains are also resistant to fluoroquinolones and at least one injectable agent (amikacin, capreomycin, kanamycin), they are considered to be extensively drug-resistant tuberculosis (XDR-TB). Treatment success is significantly lower, and costs are significantly higher, for MDR-TB, and even more so for XDR-TB.

Key findings: national

In 2018, 1,440 cases of tuberculosis were notified nationally (5.8 cases per 100,000 population). In 2019, 1,510 cases were notified (6.0 cases per 100,000 population).[4] Of these, 1,098 cases in 2018 and 1,088 cases in 2019 had positive laboratory cultures and susceptibility test results. Overall rates of resistance to the four first-line agents and selected additional agents are shown in Figure 4.21.

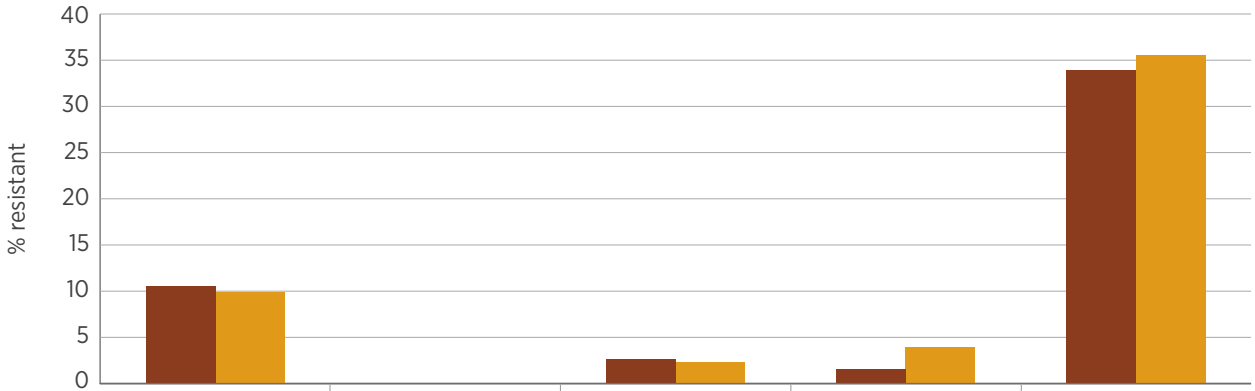
Figure 4.21: *Mycobacterium tuberculosis* resistance to individual first-line agents and selected additional agents, 2018–19

First-line agents



	INH	RIF	EMB	PZA
2018, %	9.2	2.8	1.3	1.8
2019, %	10.8	2.7	1.8	2.2
2018, *n*	1,075	1,091	1,073	1,016
2019, *n*	1,057	1,071	1,052	1,022

Selected additional agents (tested mostly when resistance to first-line agents is detected)



	FLQ	KAN	CAP	AMK	ETO/PTH
2018, %	10.6	0.0	2.7	1.6	33.9
2019, %	9.9	0.0	2.3	3.9	35.6
2018, *n*	66	49	75	64	62
2019, *n*	81	59	87	77	73

AMK = amikacin; CAP = capreomycin; EMB = ethambutol; ETO = ethionamide; FLQ = fluoroquinolones; INH = isoniazid; KAN = kanamycin; PTH = prothionamide; PZA = pyrazinamide; RIF = rifampicin

Notes:

1. First-line agents were tested against (almost) all strains. Selected additional agents were tested against isolates with resistance to first-line agents or from patients with severe adverse reactions to first-line agents.
2. Fluoroquinolones tested were ciprofloxacin, ofloxacin, moxifloxacin or levofloxacin.

Source: NNDSS (national)

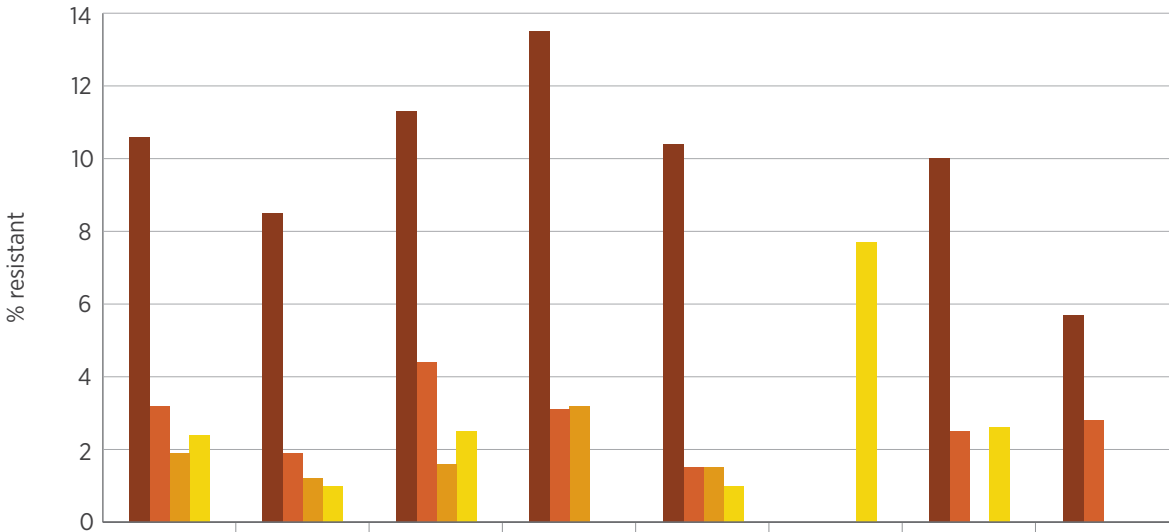
Key findings: states and territories

There was some variation in resistance rates to first-line agents across the states and territories in 2018 and 2019 (Figure 4.22 and *AURA 2021: Supplementary data*). Although the pyrazinamide resistance rate appears higher in Tasmania, this is based on few isolates from that state (6 for 2018 and 10 for 2019).

National trends

Overall, rates of resistance have not changed significantly during the past decade. The proportion of MDR-TB strains (resistance to at least isoniazid and rifampicin) over the past four years remains steady – average 2.3%, range 2.1% (2017) to 2.5% (2018) (Figure 4.23). XDR-TB strains remain rare (<0.1%), with one report in 2018 and one in 2019.

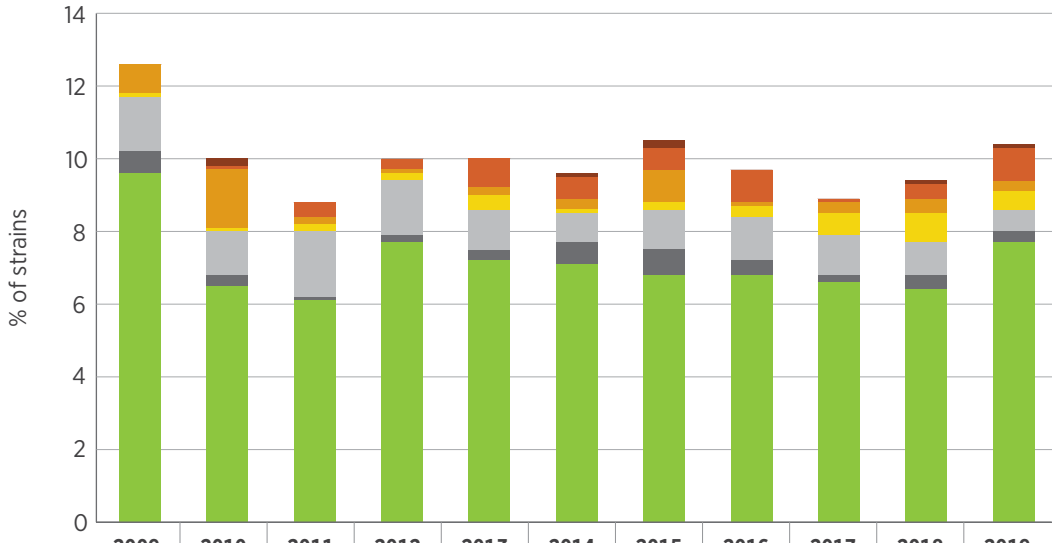
Figure 4.22: *Mycobacterium tuberculosis* resistance to first-line agents, by state and territory, 2018–19



	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
Isoniazid, %	10.6	8.5	11.3	13.5	10.4	0.0	10.0	5.7
Rifampicin, %	3.2	1.9	4.4	3.1	1.5	0.0	2.5	2.8
Ethambutol, %	1.9	1.2	1.6	3.2	1.5	0.0	0.0	0.0
Pyrazinamide, %	2.4	1.0	2.5	nd	1.0	7.7	2.6	0.0
Total, *n*	762	694	339	98	201	16	40	36

nd = no data (tested against an inadequate number of isolates)
Note: For clarity of presentation, data for 2018 and 2019 have been combined. Raw data for the individual years are available in *AURA 2021: Supplementary data*.
Source: NNDSS (national)

Figure 4.23: Resistance and multi-drug resistance patterns in *Mycobacterium tuberculosis*, 2009–2019



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Strains tested, *n*	969	1,028	1,057	976	921	1,023	965	1,037	1,066	1,098	1,088
XDR-TB, %	0.0	0.2	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.1	0.1
Isoniazid + rifampicin + ethambutol + pyrazinamide*, %	0.0	0.1	0.4	0.3	0.8	0.6	0.6	0.9	0.1	0.4	0.9
Isoniazid + rifampicin + pyrazinamide*, %	0.8	1.6	0.2	0.1	0.2	0.3	0.9	0.1	0.3	0.4	0.3
Isoniazid + rifampicin + ethambutol*, %	0.1	0.1	0.2	0.2	0.4	0.1	0.2	0.3	0.6	0.8	0.5
Isoniazid + rifampicin*, %	1.5	1.2	1.8	1.5	1.1	0.8	1.1	1.2	1.1	0.9	0.6
Rifampicin only, %	0.6	0.3	0.1	0.2	0.3	0.6	0.7	0.4	0.2	0.4	0.3
Isoniazid only, %	9.6	6.5	6.1	7.7	7.2	7.1	6.8	6.8	6.6	6.4	7.7

XDR-TB = extensively drug-resistant tuberculosis

* Multidrug-resistant tuberculosis strains

Note: Rifampicin resistance may be detected genotypically or phenotypically. Data supplied to AURA does not provide this level of detail.

Source: NNDSS (public and private hospitals, and health services)

4.6 *Neisseria gonorrhoeae*

This section describes the health impact and treatment of *N. gonorrhoeae*, and the types, impact and rates of resistance in this species.

Health impact

N. gonorrhoeae causes gonorrhoea, an infection that is largely sexually transmitted, and most commonly manifests as urethritis in men and cervicitis in women. Many infections in women are asymptomatic, but, in some women, the infection ascends to the uterus and fallopian tubes, which can cause infertility if not treated promptly. Women who become infected in late pregnancy can spread the infection to the newborn at the time of delivery. With the advent of nucleic acid testing for gonococcal infection, most cases are now diagnosed using these techniques, and specimens for culture are not collected. About 25% of gonococcal infections in Australia are diagnosed by culture and have antimicrobial susceptibility testing performed.

Treatment

Most gonorrhoea is treated empirically, and treatment does not depend on the results of culture and susceptibility testing. The most important reason for this is that immediate empirical treatment is the most effective tool for preventing further transmission. Thus, treatment is based on standard treatment protocols, which are informed by the prevalence of resistance determined by national surveillance programs.

The most important agent for treating gonorrhoea is the third-generation cephalosporin ceftriaxone. This is effective as a single dose in uncomplicated infections such as urethritis or cervicitis. Ceftriaxone has superseded penicillin and ciprofloxacin for first-line treatment, because resistance to these latter agents has emerged. Since 2014, azithromycin, an antimicrobial agent, was added to ceftriaxone for combination therapy for gonococcal disease to contain the emergence of ceftriaxone resistance.

Types and impact of resistance

Resistance to ceftriaxone is an emerging concern globally. Failures of ceftriaxone treatment have been documented in Australia in strains that have reduced susceptibility to it (that is, MICs above those of the wild type).

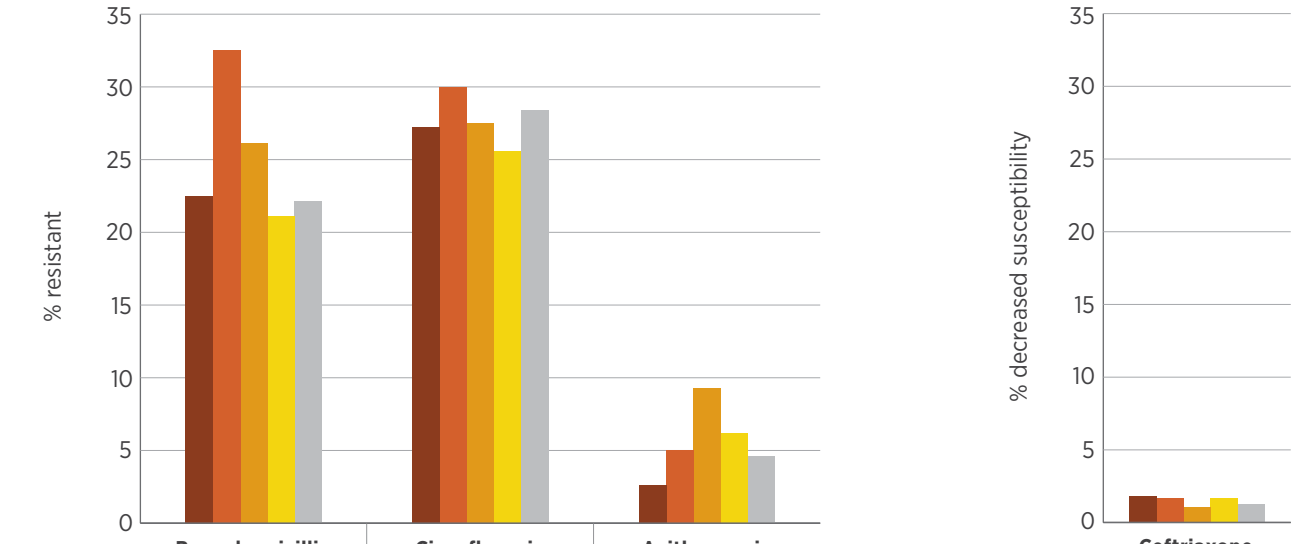
Key findings: national

In 2018, 30,886 cases of gonococcal infection were notified nationally (a rate of 123.7 per 100,000 population).[4] Of these cases, 9,006 had positive laboratory cultures that were submitted for susceptibility testing. In 2019, 34,270 cases were notified (a rate of 135.2 per 100,000 population[5]); of these cases, 9,668 had positive laboratory cultures submitted for susceptibility testing. Most other cases have been diagnosed without culture, using nucleic acid testing.

Overall rates of resistance to the main agents used for treatment are shown in Figure 4.24. In these and subsequent data, all ceftriaxone percentages refer to decreased susceptibility (ceftriaxone MIC ≥0.06 mg/L).

In 2017, the first evidence of sustained spread of multidrug-resistant gonorrhoea was reported internationally[6], followed in 2018 by coincident reports from Australia and the United Kingdom of the first extensively drug-resistant *N. gonorrhoeae* isolates.[7,8] The emergence of gonococcal AMR in Australia has long been influenced by the introduction of multidrug-resistant strains from overseas.[9,10] While the background rate of isolates with decreased susceptibility to ceftriaxone in Australia has remained low,

Figure 4.24: *Neisseria gonorrhoeae* resistance, 2015–2019



	Benzylpenicillin	Ciprofloxacin	Azithromycin
2015	22.5	27.2	2.6
2016	32.5	30.0	5.0
2017	26.1	27.5	9.3
2018	21.1	25.6	6.2
2019	22.1	28.4	4.6

	Ceftriaxone
2015	1.8
2016	1.7
2017	1.1
2018	1.7
2019	1.3

Note: Decreased susceptibility to ceftriaxone is defined as a minimum inhibitory concentration above that of the wild type; wild-type strains have no acquired resistance mechanisms.
Source: NNN Australian Gonococcal Surveillance Programme (public and private hospitals, and health services)

and relatively stable, since the introduction of dual therapy for gonorrhoea in 2014, vigilance in continuing culture-based surveillance to detect novel resistant strains is imperative.[11]

Multi- and extensively drug-resistant Neisseria gonorrhoeae *have been reported in Australia and elsewhere. Clinicians are urged to take a travel history and to send specimens for bacterial culture and antimicrobial susceptibility testing.*

Resistance to azithromycin (MIC ≥1.0 mg/L) in *N. gonorrhoeae* declined from 9.3% in 2017 to 6.2% in 2018, and 4.6% in 2019. Isolates with high-level resistance to azithromycin (MIC value ≥256 mg/L) are identified sporadically in Australia, and were reported in 2018 (*n* = 9) and 2019 (*n* = 8).

Resistance to azithromycin (MIC ≥1.0 mg/L) in Neisseria gonorrhoeae *declined from 9.3% in 2017 to 6.2% in 2018, and 4.6% in 2019.*

Key findings: states and territories

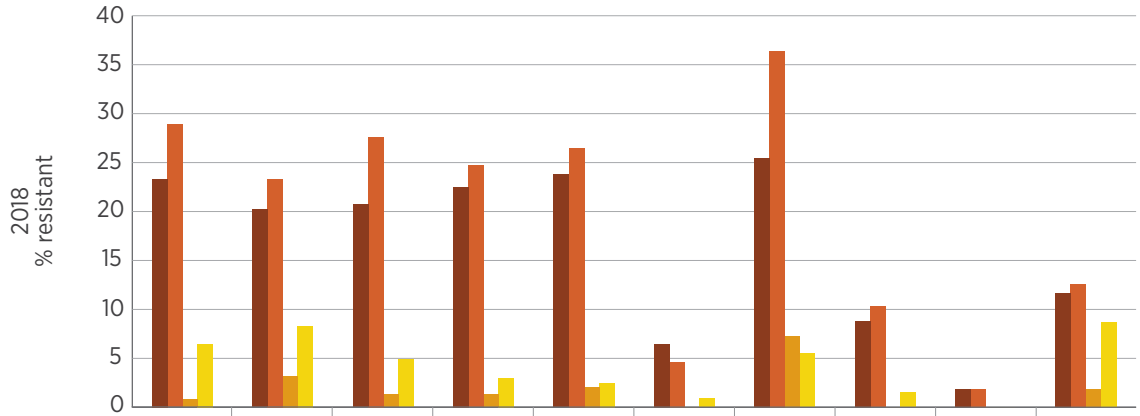
There was some variation in resistance rates to first-line agents across states and territories in both 2018 and 2019 (Figure 4.25). Most noticeable are the low rates of resistance in the remote areas of the NT and WA. A high proportion of the population in these parts of the country are Aboriginal and Torres Strait Islander peoples. Rates of decreased susceptibility to ceftriaxone were 1.7% in 2018 and 1.3% in 2019.[5] There was an overall decline in azithromycin resistance, most notably in Victoria, where resistance decreased from 13.5% in 2017 to 8.3% in 2018, and 6.2% in 2019. The decline in azithromycin resistance might be attributable to changes in circulating clones.

National trends

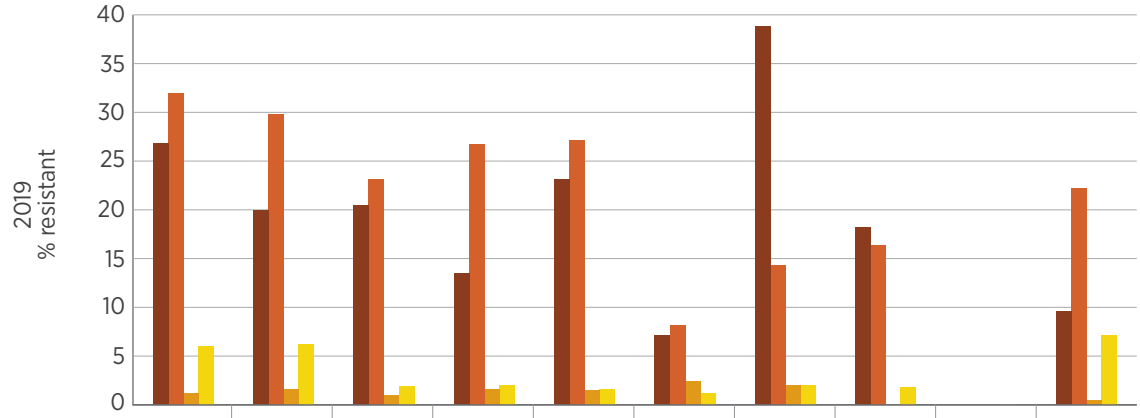
In the past 17 years, resistance rates to the four first-line agents have evolved in different ways (Figure 4.26). Resistance to benzylpenicillin and ciprofloxacin trended upwards from 2003 to 2008, then declined somewhat, to stabilise at about 30%; however, this is not low enough to consider reintroducing these agents into standard treatment protocols. By 2015, there was early evidence of a downward trend. Rates of reduced susceptibility to ceftriaxone are low; reduced susceptibility increased until 2013 but appears to now be in decline.

Detailed reports of susceptibility data on *N. gonorrhoeae* from 1995 to 2019 can be found in the Australian Gonococcal Surveillance Programme annual reports.[5]

Figure 4.25: *Neisseria gonorrhoeae* resistance, by state and territory, 2018–19



	NSW	Vic	Qld	SA*	WA (non-remote)	WA remote	Tas	NT (non-remote)	NT remote	ACT
Benzylpenicillin, %	23.3	20.2	20.7	22.5	23.8	6.5	25.5	8.8	1.9	11.7
Ciprofloxacin, %	28.9	23.3	27.6	24.7	26.5	4.6	36.4	10.3	1.9	12.6
Ceftriaxone (decreased susceptibility), %	0.8	3.2	1.3	1.3	2.1	0.0	7.3	0.0	0.0	1.9
Azithromycin, %	6.5	8.3	4.9	3.0	2.5	0.9	5.5	1.5	0.0	8.7
Isolates, *n*	3,535	2,619	1,375	231	652	108	55	68	157	206



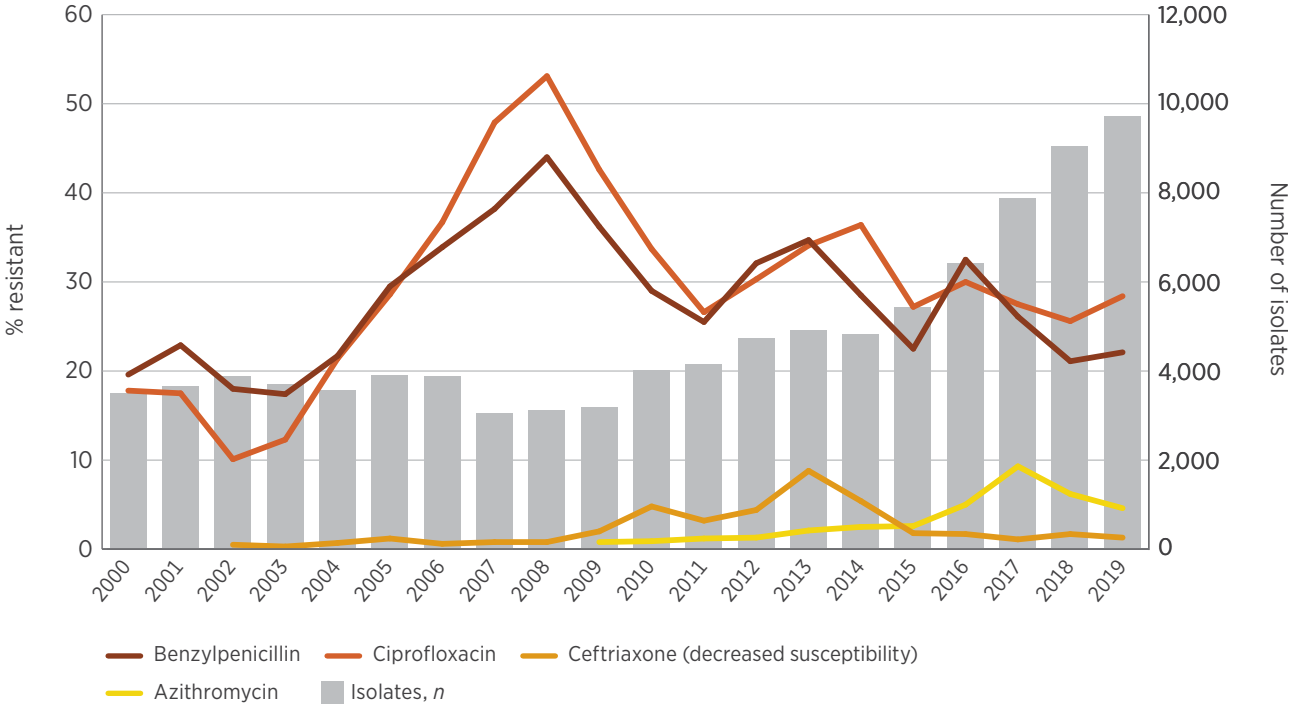
	NSW	Vic	Qld	SA	WA (non-remote)	WA (remote)	Tas	NT (non-remote)	NT (remote)	ACT
Benzylpenicillin, %	26.8	20.0	20.5	13.5	23.1	7.1	38.8	18.2	0.0	9.6
Ciprofloxacin, %	32.0	29.8	23.1	26.7	27.1	8.2	14.3	16.4	0.0	22.2
Ceftriaxone (decreased susceptibility), %	1.2	1.6	1.0	1.6	1.5	2.4	2.0	0.0	0.0	0.5
Azithromycin, %	6.0	6.2	1.9	2.0	1.6	1.2	2.0	1.8	0.0	7.1
Isolates, *n*	3,610	2,616	1,677	554	753	85	49	55	71	198

* Number of isolates resistant to both penicillin and ciprofloxacin = 120

Note: Decreased susceptibility to ceftriaxone is defined as a minimum inhibitory concentration above that of the wild type; wild-type strains have no acquired resistance mechanisms.

Source: NNN Australian Gonococcal Surveillance Programme (national)

Figure 4.26: Trends in resistance and multidrug-resistance patterns, and decreased susceptibility to ceftriaxone, in *Neisseria gonorrhoeae*, 2000–2019



Note: Decreased susceptibility to ceftriaxone is defined as a minimum inhibitory concentration above that of the wild type; wild-type strains have no acquired resistance mechanisms.
Source: NNN Australian Gonococcal Surveillance Programme (public and private hospitals, and health services)

4.7 *Neisseria meningitidis*

This section describes the health impact and treatment of *N. meningitidis*, and the types, impact and rates of resistance in this species.

Health impact

Infection with *N. meningitidis* can cause septicaemia and meningitis, known as invasive meningococcal disease. Although this is a very uncommon infection in Australia, it is considered a medical emergency because it can progress rapidly to serious disease and death. Invasive meningococcal disease can be associated with outbreaks in environments in which there is close prolonged contact, especially in the household. *N. meningitidis* is also rarely associated with localised disease, such as conjunctivitis, arthritis or pneumonia.

In Australia, two meningococcal vaccines are included in the National Immunisation Program. Infants and adolescents receive a vaccine against meningococcal serogroups A, C, W and Y. Aboriginal and Torres Strait Islander infants also receive a vaccine against serogroup B. Because vaccines do not cover all serogroups, not all meningococcal infection is vaccine preventable.

Treatment

Because invasive meningococcal disease is potentially life-threatening, most invasive infection is treated empirically. The most important antimicrobials for treatment are ceftriaxone (or cefotaxime) and benzylpenicillin. Close contacts of patients with invasive meningococcal disease are given antimicrobial prophylaxis to prevent infection by clearing nasopharyngeal colonisation.

The most important antimicrobials for prophylaxis are rifampicin, ciprofloxacin and ceftriaxone.

Types and impact of resistance

There is currently no international consensus on the definition of reduced susceptibility or resistance to benzylpenicillin in *N. meningitidis*. In most test systems, wild-type strains (that is, strains with no acquired resistance mechanism) have MICs of ≤0.25 mg/L.

Resistance to benzylpenicillin has been slow to develop in Australia. Non-wild-type strains that have reduced susceptibility to penicillin are now found regularly, but are not yet associated with treatment failure. Occasional strains are reported by the Australian Meningococcal Surveillance Programme with resistance to rifampicin or reduced susceptibility to ciprofloxacin. These two agents are used for clearance of carriage after treatment.

Key findings: national

In 2018, 281 cases of meningococcal infection were notified nationally (a rate of 1.1 per 100,000 population).[4] From these cases, 212 isolates were submitted for susceptibility testing. In 2019, 207 cases of meningococcal infection were notified nationally (a rate of 0.8 per 100,000 population).[4] From these cases, 167 were submitted for susceptibility testing. The number of notifiable cases has decreased by 45% since 2017. Figure 4.27 shows the national rates of resistance to the four key agents used for treatment or prophylaxis.

The rates of reduced susceptibility and resistance to benzylpenicillin have declined since 2017 (44.9% and 5.1%, respectively), to 21.0% and 0.6%, respectively, in 2019. Ceftriaxone resistance was not seen in 2018 or 2019.

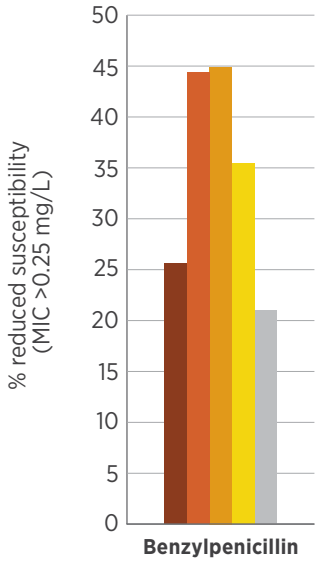
The number of notifiable cases of invasive meningococcal disease has decreased by 45% since 2017. Resistance in these isolates remains low.

National trends

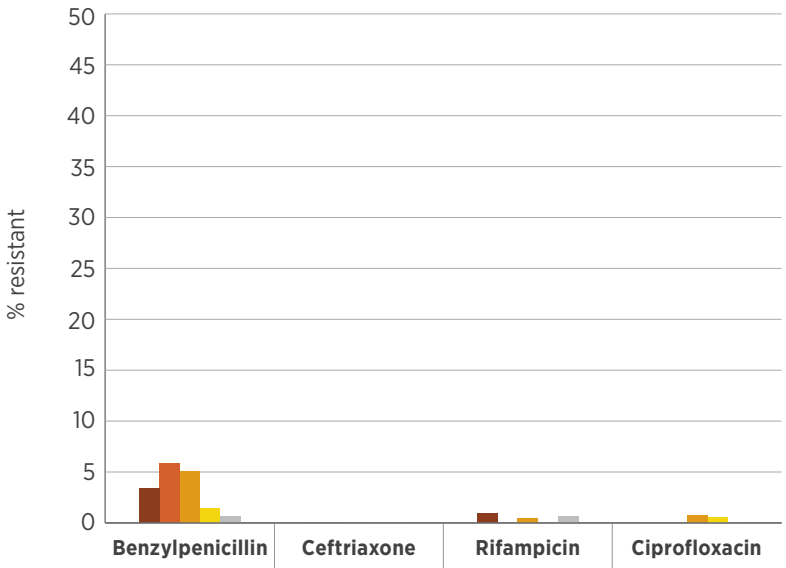
For the past 20 years, there has been little change in the (very low or zero) rates of resistance to any of the four key agents, except for benzylpenicillin (Figure 4.28). For benzylpenicillin, in this context, resistance is defined as an MIC ≥1 mg/L. Resistance peaked in 2016 at 5.8% (all serogroup W) and declined from 2017 (5.1%) through 2018 (1.4%) to 0.6% in 2019. Rates of reduced susceptibility to benzylpenicillin (defined in this report as strains with an MIC >0.25 mg/L) have also shown a steady decrease, from 45% in 2016 and 2017 to 35% in 2018 and 21.0% in 2019 (Figure 4.29). This decrease can be attributed to the declining incidence of the resistant serogroup W clone.

Detailed reports of susceptibility data for *N. meningitidis* from 1997 to 2019 can be found in the Australian Meningococcal Surveillance Programme annual reports.[12]

Figure 4.27: *Neisseria meningitidis* resistance, 2015–2019



	Benzylpenicillin
2015 (*n* = 117)	25.6
2016 (*n* = 189)	44.4
2017 (*n* = 274)	44.9
2018 (*n* = 212)	35.4
2019 (*n* = 167)	21.0



	Benzylpenicillin	Ceftriaxone	Rifampicin	Ciprofloxacin
2015	3.4	0.0	0.9	0.0
2016	5.8	0.0	0.0	0.0
2017	5.1	0.0	0.4	0.7
2018	1.4	0.0	0.0	0.5
2019	0.6	0.0	0.6	0.0

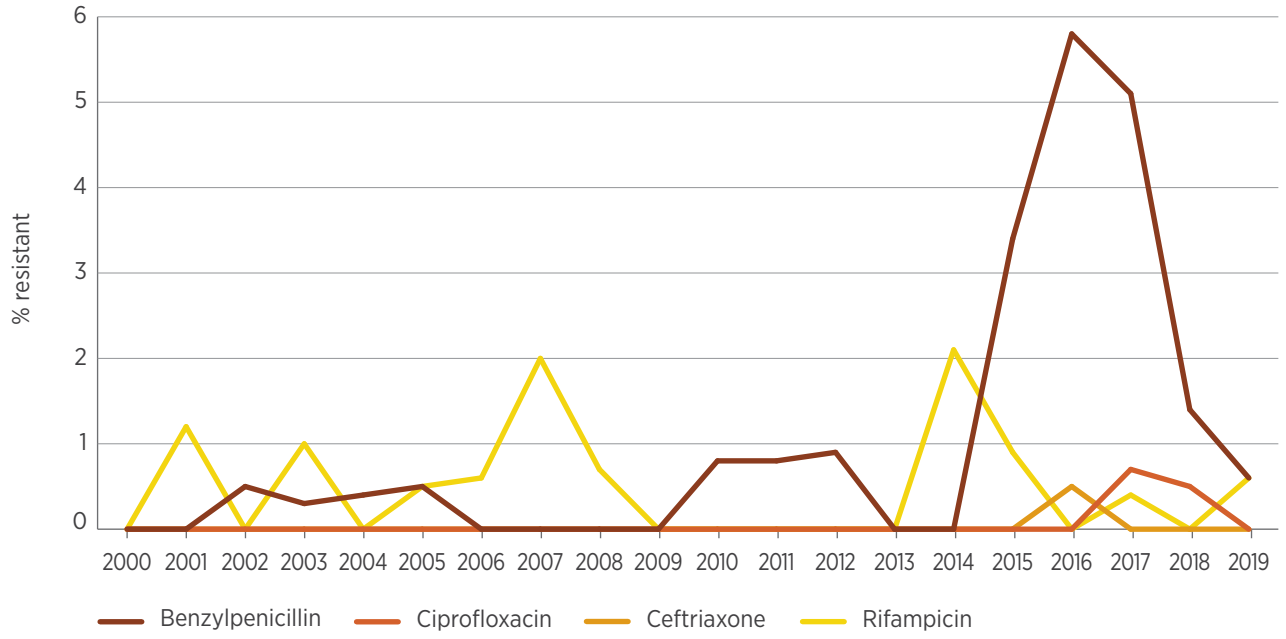
MIC = minimum inhibitory concentration

Notes:

1. Reduced susceptibility or resistance to benzylpenicillin; in most test systems, wild-type strains (i.e. with no acquired resistance mechanism) have MICs of ≤0.25 mg/L.
2. Resistance to benzylpenicillin is defined as an MIC ≥1 mg/L.

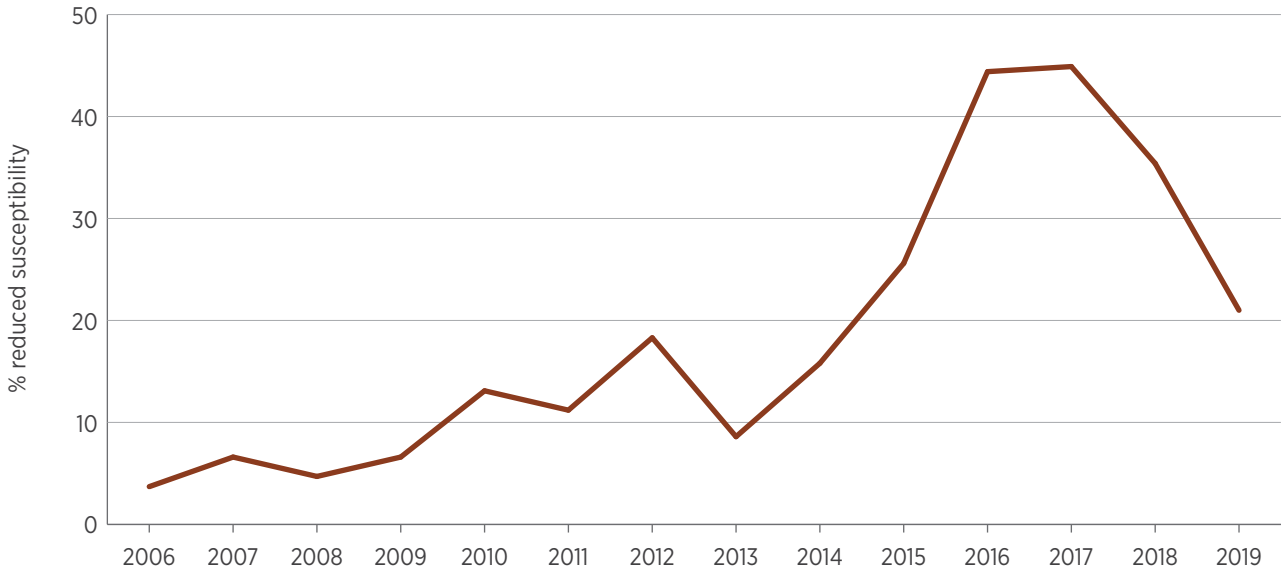
Source: NNN Australian Meningococcal Surveillance Programme (public and private hospitals, and health services)

Figure 4.28: Trends in resistance in *Neisseria meningitidis*, 2000–2019



Note: Resistance to benzylpenicillin is defined as a minimum inhibitory concentration of ≥1 mg/L.
Source: NNN Australian Meningococcal Surveillance Programme (public and private hospitals, and health services)

Figure 4.29: Trends in benzylpenicillin reduced susceptibility in *Neisseria meningitidis*, 2006–2019



Note: Reduced susceptibility is defined as a minimum inhibitory concentration of >0.25 mg/L.
Source: NNN Australian Meningococcal Surveillance Programme (public and private hospitals, and health services)

4.8 *Pseudomonas aeruginosa*

This section describes the health impact and treatment of *P. aeruginosa*, and the types, impact and rates of resistance in this species.

Health impact

P. aeruginosa is an opportunistic, nosocomial pathogen that primarily affects hospitalised or immunocompromised patients. It is a ubiquitous organism found in moist environments. It is naturally resistant to many chemicals, including most common antimicrobials and some antiseptics. As a result, it frequently causes infections in patients who are receiving antimicrobial treatments for other purposes.

P. aeruginosa can cause urinary tract infection in patients with catheters or structural abnormalities of the urinary tract. It is also associated with burn and other wound infections, and has a strong propensity to cause chronic persistent airway infection in patients with cystic fibrosis. *P. aeruginosa* also causes septicaemia, especially in neutropenic patients.

Treatment

P. aeruginosa is susceptible to only a few antimicrobials:

- Specialised β-lactams such as piperacillin (with or without tazobactam), ceftazidime and meropenem
- Aminoglycosides such as gentamicin and tobramycin
- Some fluoroquinolones, such as ciprofloxacin.

Urinary tract infections can often be managed with oral fluoroquinolones. More serious infections must be treated with β-lactams, which may be used in combination with aminoglycosides for the most serious infections. The effective β-lactams and aminoglycosides can only be administered intravenously.

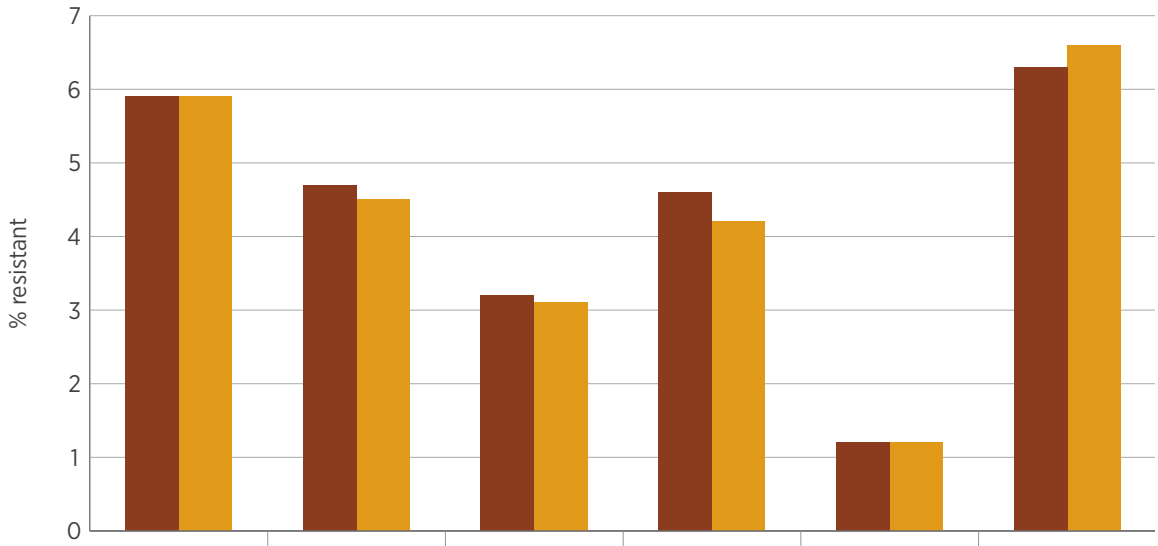
Types and impact of resistance

P. aeruginosa is intrinsically resistant to many antimicrobial classes because of the presence of several efflux pumps in its cell wall and cell membrane. Up-regulation of these efflux pumps results in resistance to the few effective agents; *P. aeruginosa* is well known for its capacity to become resistant during treatment. It can also become resistant to β-lactams through porin loss and the acquisition of β-lactamases. Multidrug-resistant strains with acquired resistance to two or three of the effective antimicrobial classes will require other treatments, such as the potentially toxic antimicrobial colistin.

Key findings: national

Resistance of *P. aeruginosa* to key antimicrobial agents is low overall, as shown in Figure 4.30. Rates of resistance to carbapenems and aminoglycosides were substantially higher in public hospitals than in private hospitals (Figure 4.31), possibly due in part to the influence of isolates from patients with cystic fibrosis who are managed in the public sector. These patients have isolates with higher rates of resistance to all effective agents because they are likely to have been treated multiple times for acute infective exacerbations of cystic fibrosis lung disease.

Figure 4.30: *Pseudomonas aeruginosa* resistance, 2018–19

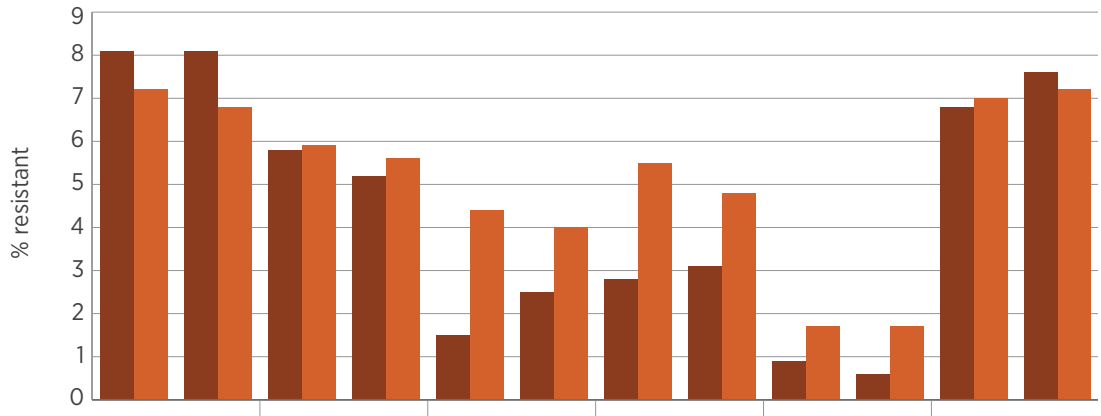


	PTZ	CAZ	MER	GEN	TOB	CIP
2018, %	5.9	4.7	3.2	4.6	1.2	6.3
2019, %	5.9	4.5	3.1	4.2	1.2	6.6
2018, *n*	40,315	40,860	36,808	43,554	34,647	38,225
2019, *n*	43,889	41,678	36,445	44,297	35,219	37,516

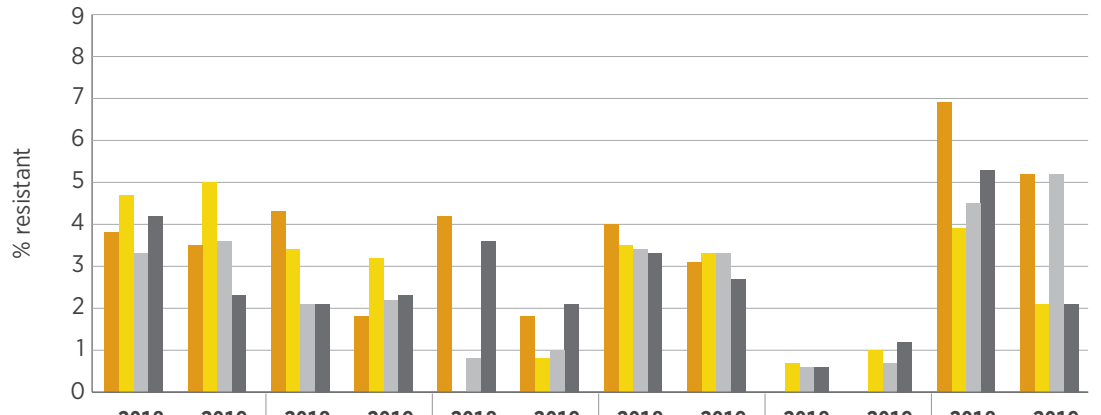
CAZ = ceftazidime; CIP = ciprofloxacin; GEN = gentamicin; MER = meropenem; PTZ = piperacillin–tazobactam; TOB = tobramycin

Sources: AGAR (national); APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); SNP (Qld, northern NSW)

Figure 4.31: *Pseudomonas aeruginosa* resistance, by clinical setting, 2018–19



	2018 PTZ	2019 PTZ	2018 CAZ	2019 CAZ	2018 MER	2019 MER	2018 GEN	2019 GEN	2018 TOB	2019 TOB	2018 CIP	2019 CIP
Private hospitals, %	8.1	8.1	5.8	5.2	1.5	2.5	2.8	3.1	0.9	0.6	6.8	7.6
Public hospitals, %	7.2	6.8	5.9	5.6	4.4	4.0	5.5	4.8	1.7	1.7	7.0	7.2
Private hospitals, *n*	3,232	3,608	3,286	3,611	2,602	805	3,373	3,656	3,186	3,430	2,617	2,961
Public hospitals *n*	22,455	25,462	23,620	24,215	23,676	24,721	25,140	25,717	18,580	18,573	24,103	23,349



	2018 PTZ	2019 PTZ	2018 CAZ	2019 CAZ	2018 MER	2019 MER	2018 GEN	2019 GEN	2018 TOB	2019 TOB	2018 CIP	2019 CIP
Multi-purpose services, %	3.8	3.5	4.3	1.8	4.2	1.8	4.0	3.1	0.0	0.0	6.9	5.2
Aged care homes, %	4.7	5.0	3.4	3.2	0.0	0.8	3.5	3.3	0.7	1.0	3.9	2.1
Community, %	3.3	3.6	2.1	2.2	0.8	1.0	3.4	3.3	0.6	0.7	4.5	5.2
Other, %	4.2	2.3	2.1	2.3	3.6	2.1	3.3	2.7	0.6	1.2	5.3	2.1
Multi-purpose services, *n*	373	425	281	280	236	283	377	422	230	219	335	388
Aged care homes, *n*	1,180	1,040	1,177	1,047	144	124	1,203	1,058	1,158	1,040	178	141
Community, *n*	11,940	12,105	11,962	11,696	9,614	9,679	12,320	12,194	10,968	11,135	9,894	9,443
Other, *n*	353	476	327	431	329	438	360	477	318	427	359	474

CAZ = ceftazidime; CIP = ciprofloxacin; GEN = gentamicin; MER = meropenem; PTZ = piperacillin–tazobactam; TOB = tobramycin
Sources: AGAR and APAS (public hospitals); AGAR, APAS (Qld, SA) and SNP (private hospitals); APAS and SNP (community and aged care homes); APAS (multi-purpose services)

4.9 *Salmonella* species

This section describes the health impact and treatment of *Salmonella* species, and the types, impact and rates of resistance in these species.

Health impact

Salmonella species are important causes of bacterial gastroenteritis. Most cases are acquired through foodborne transmission. Occasionally, gastroenteritis is complicated by septicaemia, although this is usually self-limiting. Two serotypes, *Salmonella* Typhi and *Salmonella* Paratyphi (together called 'typhoidal *Salmonella*'), cause a distinct syndrome called enteric fever, in which the organism is always invasive (causing septicaemia), and causes considerable morbidity and mortality if untreated. *Salmonella* gastroenteritis is endemic in Australia, but almost all cases of enteric fever are seen in returning overseas travellers.

Treatment

Salmonella gastroenteritis is self-limiting. Antimicrobial therapy is generally contraindicated because it does not affect the course of the disease and will prolong intestinal carriage of the organism after disease resolution, increasing the risk of transmission. Antimicrobial therapy is indicated in patients with severe disease or septicaemia (typhoidal *Salmonella* infection, in particular), and patients who have prosthetic vascular grafts. Ciprofloxacin, azithromycin and ceftriaxone are the standard treatments.

Types and impact of resistance

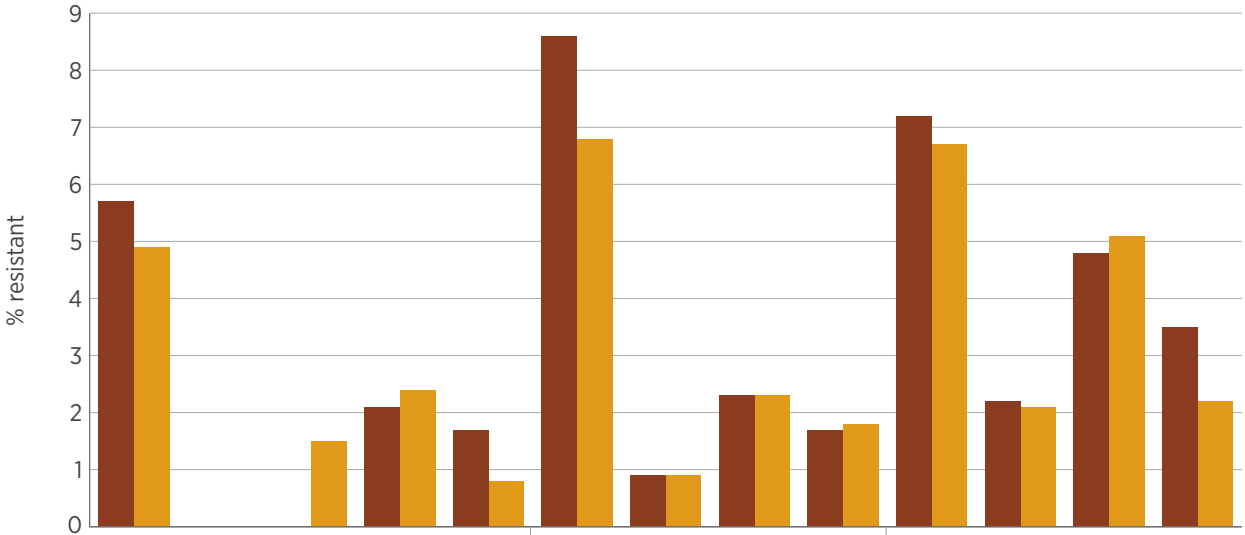
Resistance to older treatment agents, such as ampicillin and chloramphenicol, has been seen for many years. So far, resistance to the newer agents has only been a problem with ciprofloxacin and other fluoroquinolones, such as norfloxacin. This has resulted in the definition of fluoroquinolone resistance recently being reassessed.

Key findings: national

In non-typhoidal *Salmonella* species, rates of resistance were low for ampicillin, ceftriaxone and the fluoroquinolones (Figure 4.32). In contrast, rates of resistance to the fluoroquinolone ciprofloxacin in typhoidal *Salmonella* species were above 78% in 2019 for blood isolates (Figure 4.33). These high rates reflect, in part, recent changes to breakpoints after extensive review by organisations responsible for susceptibility testing interpretive standards.

High rates of resistance to ciprofloxacin in typhoidal Salmonella *species mean that ciprofloxacin should no longer be used as empirical treatment for infections caused by these species.*

Figure 4.32: Non-typhoidal *Salmonella* species resistance, by specimen source, 2018–19

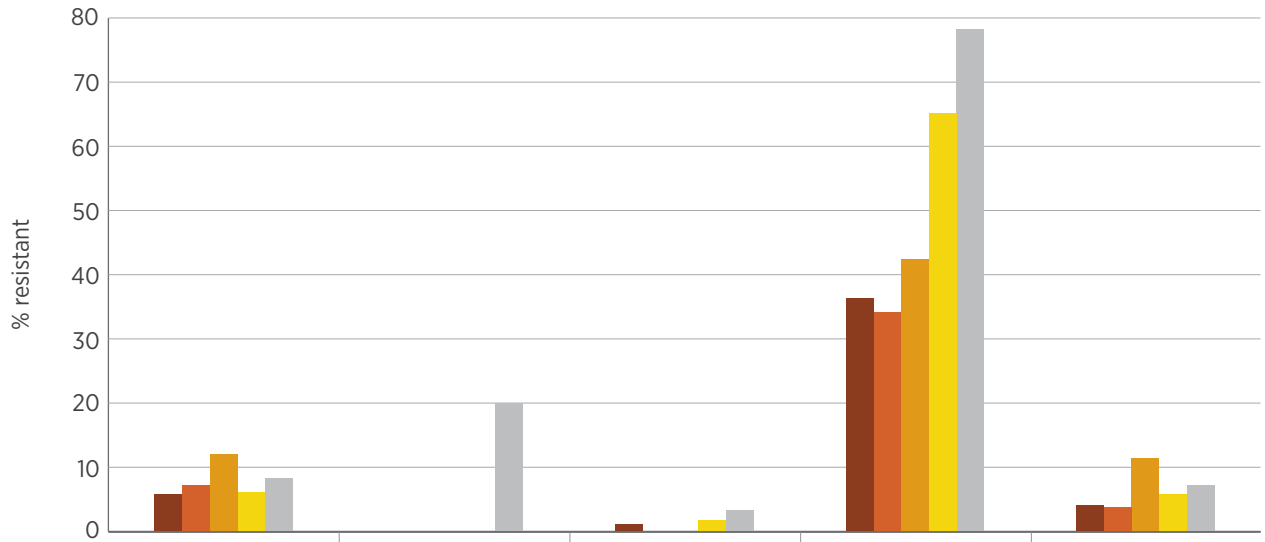


	AMP	AZI	CTR/ CTX	CIP	SXT	AMP	CTR/ CTX	CIP/ NOR	SXT	AMP	CTR/ CTX	CIP/ NOR	TMP
	Blood					Faeces				Other			
2018, %	5.7	nd	0.0	2.1	1.7	8.6	0.9	2.3	1.7	7.2	2.2	4.8	3.5
2019, %	4.9	nd	1.5	2.4	0.8	6.8	0.9	2.3	1.8	6.7	2.1	5.1	2.2
2018, *n*	247	10	246	190	239	2,577	1,686	1,642	2,578	153	90	145	143
2019, *n*	268	23	267	210	260	2,923	1,759	1,800	2,905	150	94	136	134

AMP = ampicillin; AZI = azithromycin; CIP = ciprofloxacin; CTR = ceftriaxone; CTX = cefotaxime; nd = no data (either not tested or tested against an inadequate number of isolates); NOR = norfloxacin; SXT = trimethoprim–sulfamethoxazole; TMP = trimethoprim

Sources: AGAR (national); APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); SNP (Qld, northern NSW)

Figure 4.33: Typhoidal *Salmonella* species resistance (blood culture isolates), 2015–2019



	AMP	AZI	CTR/CTX	CIP	SXT
2015, %	5.9	nd	1.2	36.3	4.1
2016, %	7.2	nd	0.0	34.2	3.8
2017, %	12.1	nd	0.0	42.4	11.5
2018, %	6.1	nd	1.8	65.2	5.8
2019, %	8.3	20.0	3.4	78.3	7.2
2015, *n*	85	9	85	80	74
2016, *n*	83	10	83	73	79
2017, *n*	99	26	99	85	96
2018, *n*	115	9	114	92	104
2019, *n*	145	30	145	143	139

AMP = ampicillin; AZI = azithromycin; CIP = ciprofloxacin; CTR = ceftriaxone; CTX = cefotaxime; nd = no data (either not tested or tested against an inadequate number of isolates); SXT = trimethoprim–sulfamethoxazole
Sources: AGAR (national); APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); SNP (Qld, northern NSW)

4.10 *Shigella* species

This section describes the health impact and treatment of *Shigella* species, and the types, impact and rates of resistance in these species.

Health impact

Shigella species are an uncommon but important cause of gastroenteritis. Genetically, they are almost identical to *E. coli*, and have a similar capacity to acquire multiple antimicrobial resistances. They can also cause outbreaks if there is a common source(s) that infects people, or through person-to-person transmission.

Treatment

Treatment is usually administered when the infection is confirmed to be caused by *Shigella*. The main aim of treatment is to prevent transmission of the organism, rather than to treat symptoms. The antimicrobials of choice are fluoroquinolones (ciprofloxacin and norfloxacin) and trimethoprim–sulfamethoxazole.

Types and impact of resistance

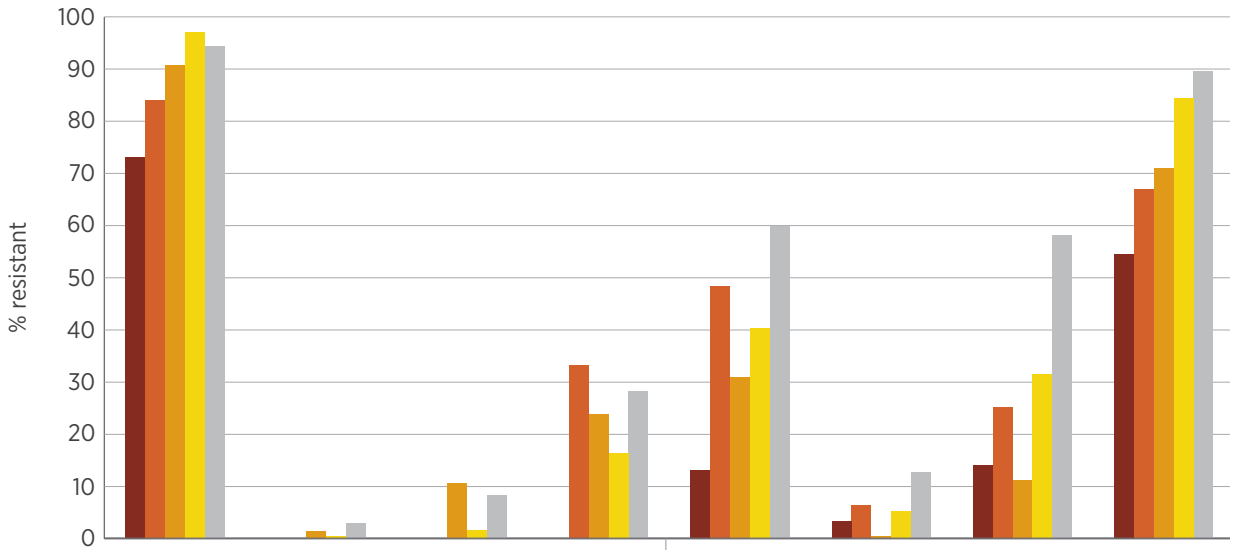
Resistance, including multi-drug resistance to conventional treatments, is well documented in other countries. Azithromycin is considered a suitable option for infections caused by strains that are resistant to standard treatments.

Key findings: national

Resistance to ampicillin was common in *S. flexneri*. The prevalence of resistance to ciprofloxacin and ceftriaxone was very low (Figure 4.34). The presence of any resistance to ciprofloxacin in Australia is of concern, given the capacity of this organism to cause outbreaks.

In 2018 and 2019, *S. sonnei* resistance to ceftriaxone, ciprofloxacin and ampicillin increased rapidly compared with 2017 rates. This coincided with a prolonged outbreak of an ESBL-producing strain ($bla_{\text{CTX-M-27}}$) which was also multidrug-resistant, circulating especially in NSW and Victoria.[13,14]

Figure 4.34: *Shigella* species resistance (faecal isolates), 2015–2019



	S. flexneri				*S. sonnei*			
2015, %	73.1	nd	nd	nd	13.2	3.3	14.1	54.5
2016, %	84.0	nd	nd	33.3	48.3	6.4	25.2	66.9
2017, %	90.7	1.4	10.6	23.8	31.0	0.5	11.3	71.0
2018, %	97.0	0.4	1.6	16.4	40.4	5.2	31.6	84.5
2019, %	94.3	2.9	8.3	28.2	59.9	12.8	58.2	89.6
2015, *n*	26	20	19	20	152	123	149	145
2016, *n*	25	25	29	30	147	109	147	133
2017, *n*	162	146	161	164	229	191	221	231
2018, *n*	268	262	243	268	171	134	171	174
2019, *n*	227	204	218	227	142	94	141	144

AMP = ampicillin; CIP = ciprofloxacin; CTR = ceftriaxone; nd = no data (either not tested or tested against an inadequate number of isolates); SXT = trimethoprim–sulfamethoxazole
Note: Isolates included if fewer than 30 isolates per facility per year.
Sources: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); SNP (Qld, northern NSW)

4.11 *Staphylococcus aureus*

This section describes the health impact and treatment of *S. aureus*, and the types, impact and rates of resistance in this species.

Health impact

S. aureus is a common human pathogen that causes a wide variety of infections. Infections may be minor, such as boils, impetigo and wound infections; moderate, such as cellulitis; or serious, such as bone and joint infections, pneumonia, endocarditis and septicaemia. Infections associated with bacteraemia (positive blood cultures) have a 30-day crude mortality of 15–30%. *S. aureus* is also a common cause of healthcare-associated infections, especially surgical site infections, intravascular line infections with bacteraemia, and infections of prosthetic devices.

According to AGAR data, the overall 30-day all-cause mortality rate for *S. aureus* bacteraemia was 16.7% in 2016 and 14.8% in 2017.[15,16] Thirty-day all-cause mortality was lowest with methicillin-susceptible strains, higher for community-associated bacteraemia, and highest for hospital-associated bacteraemia. Common clinical manifestations of staphylococcal bacteraemia were skin and skin structure infections, bone and joint infections, and device-related infections. Except for right-sided endocarditis, all infections are more common in males.

Treatment

Many staphylococcal skin infections can be managed without antimicrobial therapy, but moderate and serious infections require treatment. The preferred agent for 'susceptible' strains is flucloxacillin (or dicloxacillin), which can be replaced with first-generation cephalosporins such as cefazolin or cefalexin in penicillin-allergic patients.

Types and impact of resistance

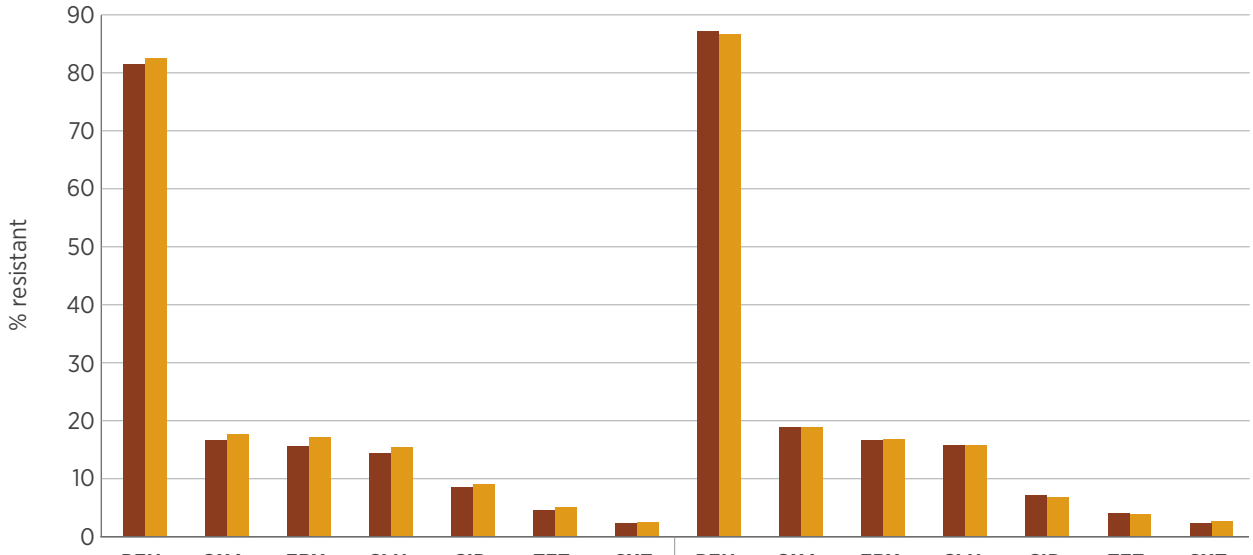
Around 85–90% of *S. aureus* strains in the community are resistant to penicillin; this has been the case for decades. Healthcare-associated strains that are resistant to flucloxacillin and first-generation cephalosporins, commonly called methicillin-resistant *S. aureus* (MRSA), emerged in the 1970s and are now common in many parts of Australia. These healthcare-associated clones are multidrug-resistant and require treatment with reserve antimicrobials such as vancomycin, rifampicin and fusidic acid. Community-associated clones of MRSA are distinct from healthcare-associated clones and emerged in the 1980s. These clones are usually not multidrug-resistant, and moderate infections may be treated with trimethoprim–sulfamethoxazole or clindamycin. All serious MRSA infections require initial treatment with vancomycin. Resistance to vancomycin appears to be uncommon, but is difficult to detect in the diagnostic laboratory. There are very few alternative treatments to vancomycin.

Key findings: national

Overall, more than 81–87% of *S. aureus* isolates were resistant to benzylpenicillin in 2018–19 (Figure 4.35). Oxacillin (methicillin) resistance was stable at 17–19% in isolates from blood and other specimens. There was little difference in rates of resistance between different clinical settings, apart from oxacillin resistance, which was highest in aged care homes and multi-purpose services, suggesting that these are important reservoirs for MRSA (Figure 4.36).

Analyses of APAS data indicate that oxacillin (methicillin) resistance is currently more prevalent in isolates from outer regional, remote and very remote areas of Australia than in major cities and inner regional areas (Figure 4.37).

Figure 4.35: *Staphylococcus aureus* resistance, by specimen source, 2018–19



	Blood							Other						
	PEN	OXA	ERY	CLN	CIP	TET	SXT	PEN	OXA	ERY	CLN	CIP	TET	SXT
2018, %	81.5	16.7	15.6	14.4	8.6	4.6	2.3	87.1	18.9	16.6	15.8	7.1	4.0	2.4
2019, %	82.5	17.7	17.1	15.5	9.0	5.1	2.5	86.6	18.9	16.9	15.7	6.8	3.9	2.6

CIP = ciprofloxacin; CLN = clindamycin; ERY = erythromycin; OXA = oxacillin; PEN = penicillin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines
Sources: AGAR (national), APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); SNP (Qld, northern NSW)

Oxacillin (methicillin) resistance was highest in aged care homes and multi-purpose services, suggesting that these are important reservoirs for methicillin-resistant Staphylococcus aureus *(MRSA).*

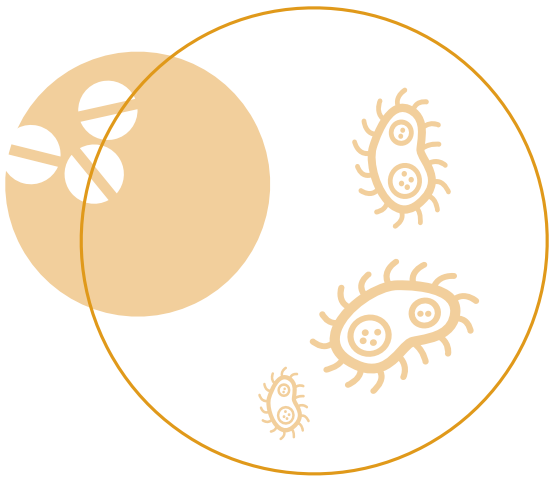
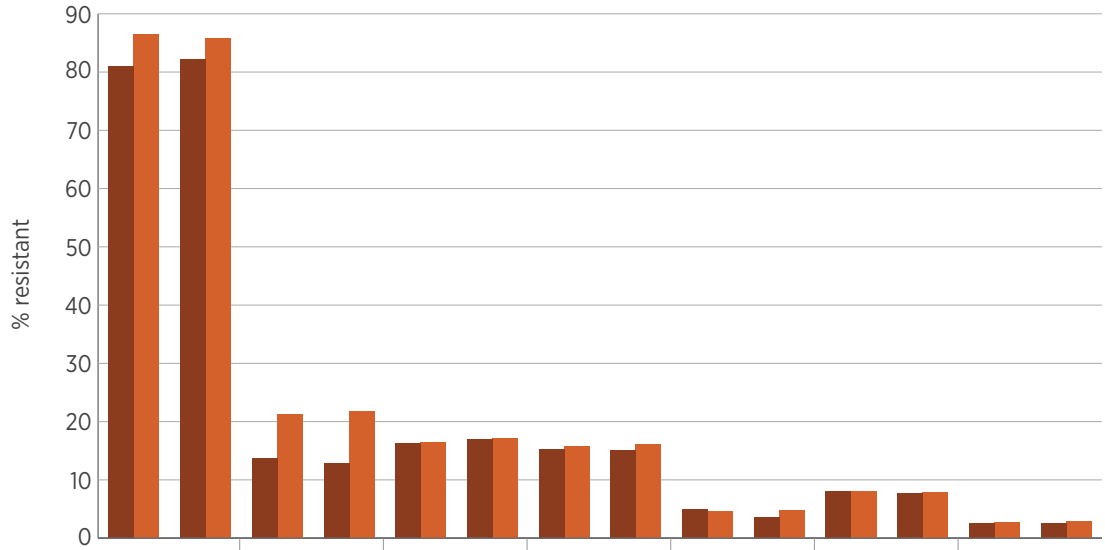
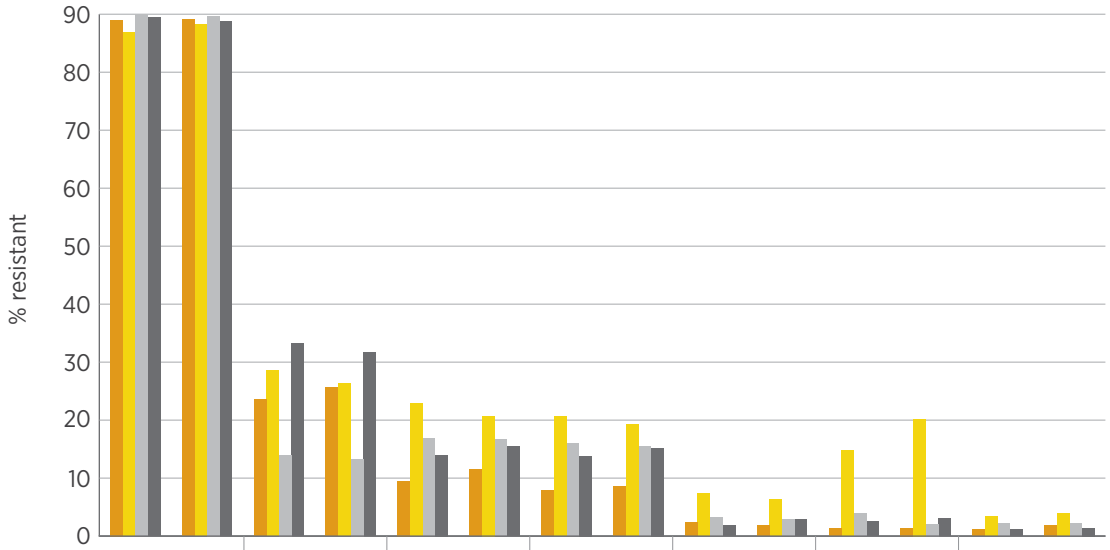


Figure 4.36: *Staphylococcus aureus* resistance, by clinical setting, 2018–19



	2018 PEN	2019 PEN	2018 OXA	2019 OXA	2018 ERY	2019 ERY	2018 CLN	2019 CLN	2018 TET	2019 TET	2018 CIP	2019 CIP	2018 SXT	2019 SXT
Private hospitals, %	80.9	82.1	13.7	12.9	16.3	16.9	15.3	15.1	4.9	3.6	8.1	7.7	2.6	2.5
Public hospitals, %	86.4	85.8	21.3	21.8	16.5	17.2	15.7	16.1	4.6	4.7	8.0	7.9	2.7	2.9

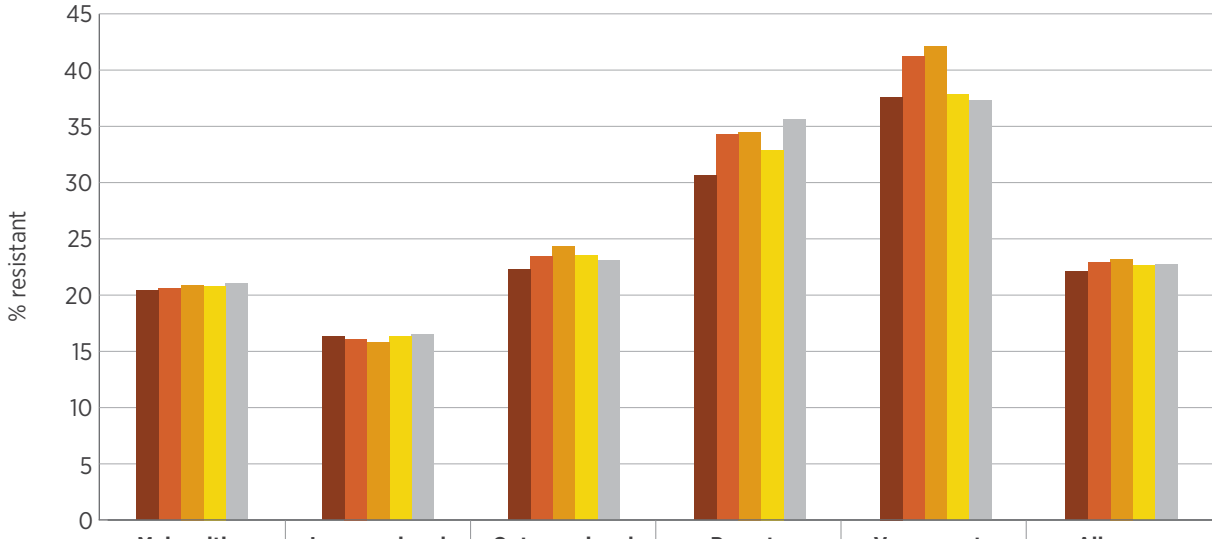


	2018 PEN	2019 PEN	2018 OXA	2019 OXA	2018 ERY	2019 ERY	2018 CLN	2019 CLN	2018 TET	2019 TET	2018 CIP	2019 CIP	2018 SXT	2019 SXT
Multi-purpose services, %	89.0	89.1	23.5	25.6	9.5	11.5	7.9	8.6	2.4	1.8	1.3	1.4	1.2	1.9
Aged care homes, %	86.8	88.2	28.5	26.3	22.8	20.7	20.6	19.3	7.3	6.3	14.8	20.2	3.4	3.9
Community, %	89.9	89.7	14.0	13.3	16.9	16.6	16.0	15.5	3.2	2.8	3.9	2.1	2.2	2.2
Other, %	89.5	88.7	33.2	31.6	14.0	15.5	13.8	15.2	1.8	2.8	2.5	3.0	1.2	1.4

CIP = ciprofloxacin; CLN = clindamycin; ERY = erythromycin; OXA = oxacillin; PEN = penicillin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines

Sources: AGAR and APAS (public hospitals); AGAR, APAS (Qld, SA) and SNP (private hospitals); APAS and SNP (community and aged care homes); APAS (multi-purpose services)

Figure 4.37: Percentage of methicillin-resistant *Staphylococcus aureus* by remoteness area, 2015–2019



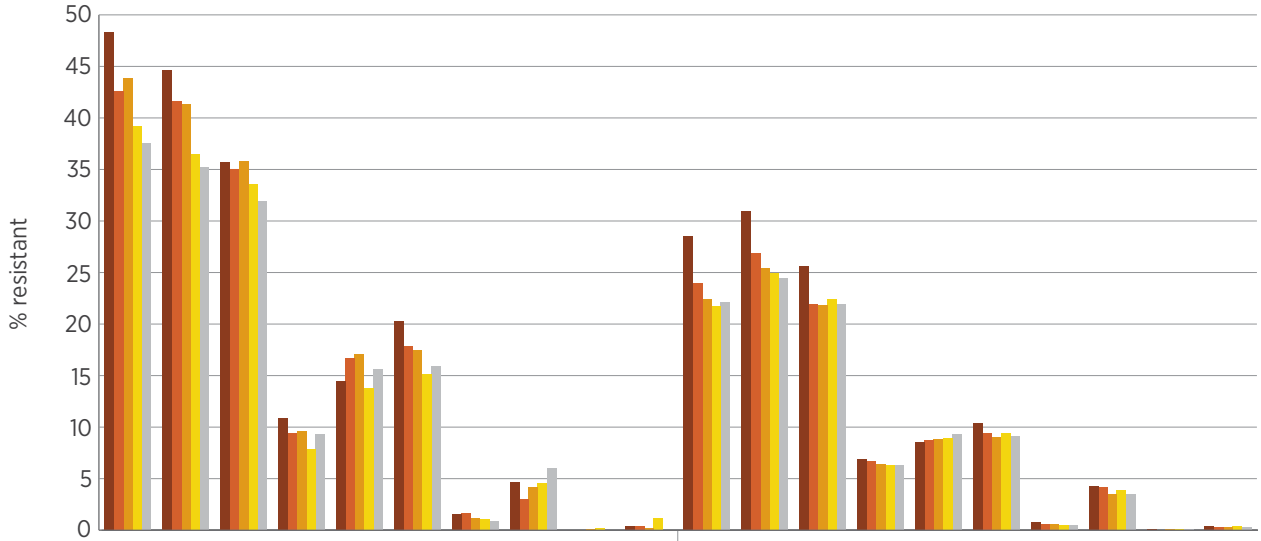
	Major cities	Inner regional	Outer regional	Remote	Very remote	All areas combined
2015, %	20.4	16.3	22.3	30.6	37.6	22.1
2016, %	20.6	16.1	23.4	34.3	41.2	22.9
2017, %	20.9	15.8	24.3	34.5	42.1	23.2
2018, %	20.8	16.3	23.5	32.9	37.8	22.6
2019, %	21.0	16.5	23.1	35.6	37.3	22.7
2015, *n*	46,338	14,077	13,614	5,412	7,031	86,472
2016, *n*	50,427	14,655	14,556	5,877	7,669	93,184
2017, *n*	53,180	15,052	15,135	6,246	7,730	97,343
2018, *n*	52,326	14,412	14,104	5,694	7,260	93,796
2019, *n*	53,496	14,835	14,236	5,852	7,238	95,657

Note: Remoteness area is based on postcode of patient's place of residence.
Source: APAS (national, excluding NT)

Resistance to ciprofloxacin, erythromycin and clindamycin was high in MRSA, especially in blood isolates. A small number of MRSA strains exhibited resistance to linezolid and daptomycin (Figure 4.38). There were noticeable differences in resistance to ciprofloxacin, erythromycin and gentamicin in MRSA strains between clinical settings (Figure 4.39), possibly related to variation in the distribution of healthcare-associated clones compared with community-associated clones (Figures 4.40 and 4.41).

Healthcare-associated clones of MRSA had high rates of resistance to ciprofloxacin, erythromycin and clindamycin, and moderate rates of resistance to trimethoprim–sulfamethoxazole and gentamicin (Figure 4.40). Rates of resistance to other 'anti-MRSA' agents were low. Aged care homes had high rates of MRSA that was resistant to ciprofloxacin and erythromycin (Figure 4.39), a pattern most closely associated with the EMRSA-15 clone (ST22-IV). Rates of resistance to ciprofloxacin, erythromycin and clindamycin were much lower in community-associated clones than in healthcare-associated clones (Figure 4.41).

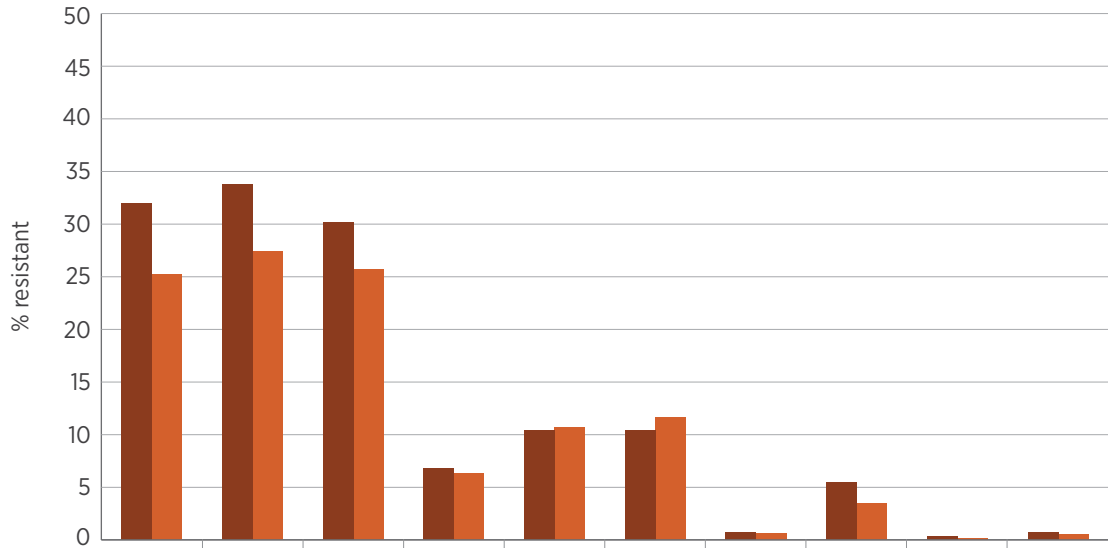
Figure 4.38: Methicillin-resistant *Staphylococcus aureus* resistance to non-β-lactam agents, by specimen source, 2015–2019



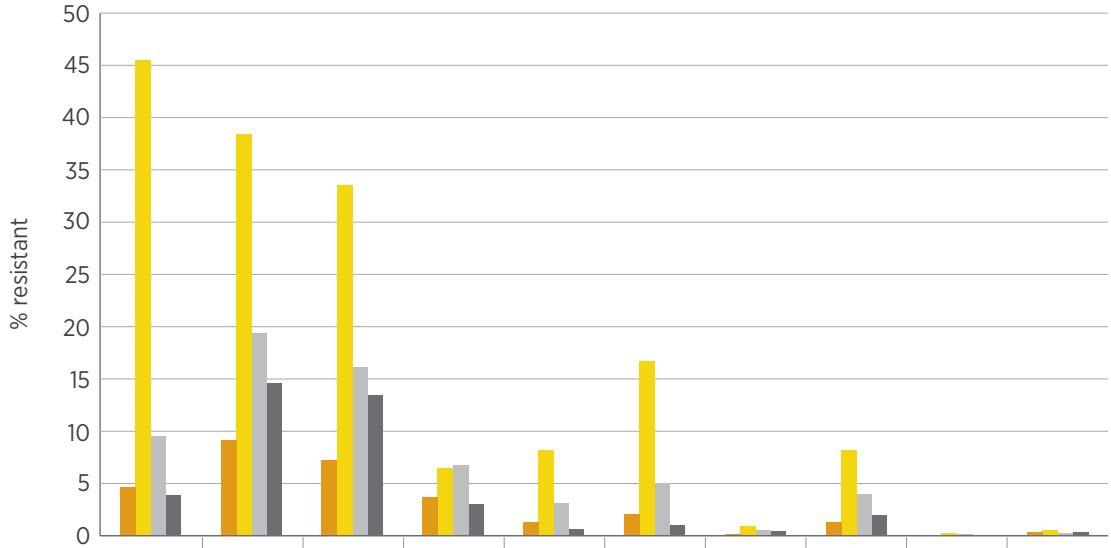
	Blood										Other									
	CIP	ERY	CLN	SXT	GEN	TET	RIF	FUS	LNZ	DAP	CIP	ERY	CLN	SXT	GEN	TET	RIF	FUS	LNZ	DAP
2015, %	48.3	44.6	35.7	10.9	14.4	20.3	1.5	4.6	0.0	0.4	28.5	30.9	25.6	6.9	8.5	10.4	0.8	4.3	0.1	0.4
2016, %	42.6	41.6	35.0	9.4	16.7	17.8	1.6	3.0	0.0	0.4	24.0	26.9	21.9	6.7	8.7	9.4	0.6	4.2	0.0	0.3
2017, %	43.8	41.3	35.8	9.6	17.1	17.5	1.2	4.2	0.1	0.2	22.4	25.4	21.8	6.4	8.8	9.0	0.6	3.5	0.1	0.3
2018, %	39.2	36.5	33.6	7.8	13.8	15.1	1.1	4.5	0.2	1.2	21.7	24.9	22.4	6.3	8.9	9.4	0.5	3.9	0.1	0.4
2019, %	37.5	35.2	31.9	9.3	15.6	15.9	0.9	6.0	0.0	0.0	22.1	24.4	21.9	6.3	9.3	9.1	0.5	3.5	0.1	0.3

CIP = ciprofloxacin; CLN = clindamycin; DAP = daptomycin; ERY = erythromycin; FUS = fusidic acid; GEN = gentamicin; LNZ = linezolid; RIF = rifampicin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines
Sources: AGAR (national); APAS (NSW, Qld, SA, Tas, ACT); SNP (Qld, northern NSW)

Figure 4.39: Methicillin-resistant *Staphylococcus aureus* resistance to non-β-lactam agents, by clinical setting, 2018–19



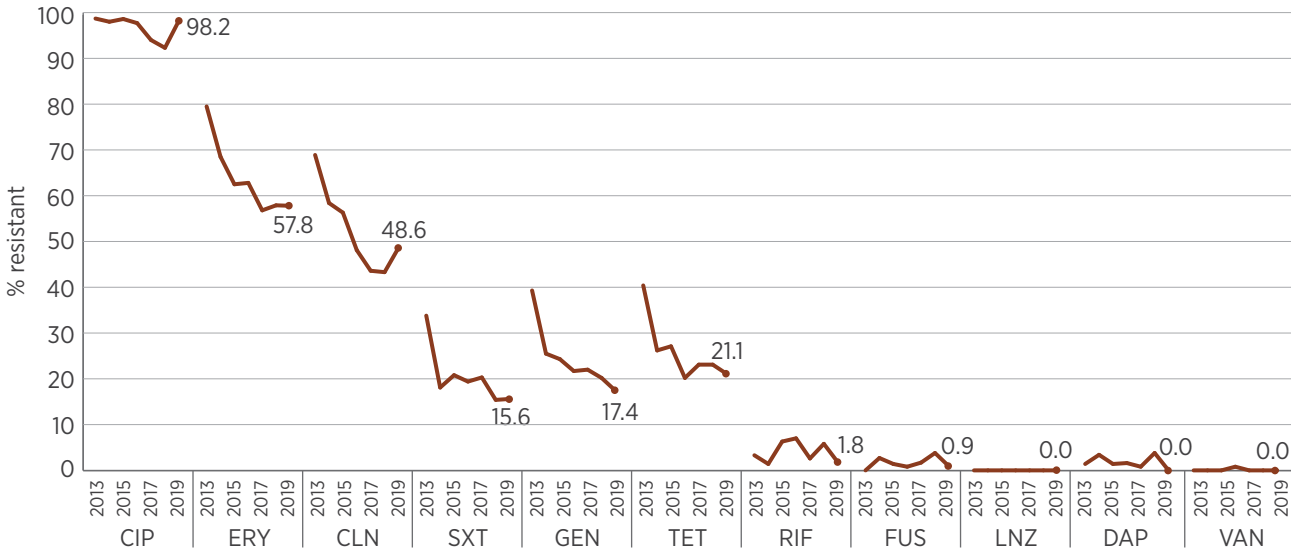
	CIP	ERY	CLN	SXT	GEN	TET	RIF	FUS	LNZ	DAP
Private hospitals, %	32.0	33.8	30.2	6.8	10.4	10.4	0.7	5.5	0.3	0.7
Public hospitals, %	25.2	27.4	25.7	6.3	10.7	11.6	0.6	3.5	0.1	0.5



	CIP	ERY	CLN	SXT	GEN	TET	RIF	FUS	LNZ	DAP
Multi-purpose services, %	4.6	9.1	7.2	3.7	1.3	2.1	0.1	1.3	0.0	0.3
Aged care homes, %	45.5	38.4	33.5	6.5	8.2	16.7	0.9	8.2	0.2	0.5
Community, %	9.5	19.4	16.1	6.7	3.1	5.0	0.5	4.0	0.1	0.2
Other, %	3.9	14.6	13.4	3.0	0.6	1.0	0.4	2.0	0.0	0.3

CIP = ciprofloxacin; CLN = clindamycin; DAP = daptomycin; ERY = erythromycin; FUS = fusidic acid; GEN = gentamicin; LNZ = linezolid; RIF = rifampicin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines
Note: For clarity of presentation, data for 2018 and 2019 have been combined. Raw data for the individual years are available in *AURA 2021: Supplementary data*.
Sources: AGAR and APAS (NSW, Qld, SA, Tas, ACT) (public hospitals); AGAR, APAS (Qld, SA) and SNP (private hospitals); APAS and SNP (community and aged care homes); APAS (multi-purpose services)

Figure 4.40: Trends in resistance (EUCAST) to other antimicrobials of healthcare-associated clones of methicillin-resistant *Staphylococcus aureus* (blood culture isolates), 2013–2019



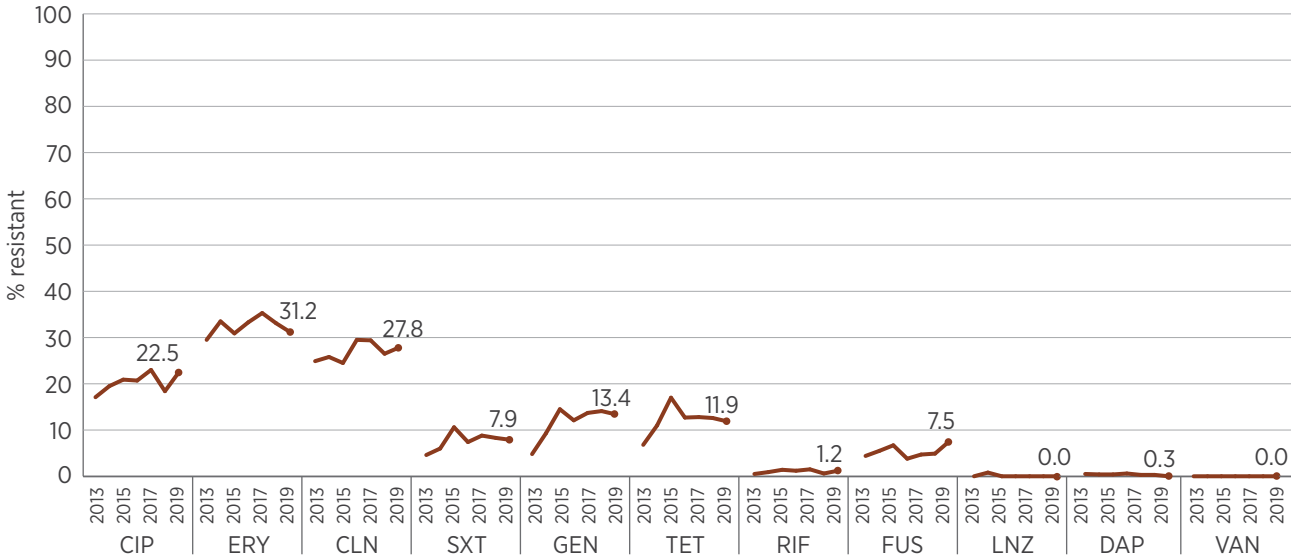
CIP = ciprofloxacin; CLN = clindamycin; DAP = daptomycin; ERY = erythromycin; EUCAST = European Committee on Antimicrobial Susceptibility Testing; FUS = fusidic acid; GEN = gentamicin; LNZ = linezolid; RIF = rifampicin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines; VAN = vancomycin

Notes:

1. Percentage resistance determined using EUCAST 2020 breakpoints for all years. Filled circles indicate values for 2019.
2. Number of contributors per year – 2013–14, *n* = 27; 2015, *n* = 31; 2016, *n* = 32; 2017–18, *n* = 36; 2019, *n* = 39.

Sources: AGAR (national), public and private hospitals

Figure 4.41: Trends in resistance (EUCAST) to other antimicrobials of community-associated clones of methicillin-resistant *Staphylococcus aureus* (blood culture isolates), 2013–2019



CIP = ciprofloxacin; CLN = clindamycin; DAP = daptomycin; ERY = erythromycin; EUCAST = European Committee on Antimicrobial Susceptibility Testing; FUS = fusidic acid; GEN = gentamicin; LNZ = linezolid; RIF = rifampicin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines; VAN = vancomycin

Notes:

1. Percentage resistance determined using EUCAST 2020 breakpoints for all years. Filled circles indicate values for 2019.
2. Number of contributors per year – 2013–14, *n* = 27; 2015, *n* = 31; 2016, *n* = 32; 2017–18, *n* = 36; 2019, *n* = 39.

Sources: AGAR (national), public and private hospitals

Table 4.8 shows the multi-locus sequence types of MRSA clones across Australia. Community-associated clones continue to dominate in staphylococcal bacteraemia, accounting for 80% of all MRSA in 2019. This may be related, in part, to the continued decline of ST239, the multidrug-resistant healthcare-associated clone that was dominant in the eastern states and SA for more than 30 years. The dominant

Table 4.8: Methicillin-resistant *Staphylococcus aureus* clones (blood culture isolates), 2018–19

MRSA clone type	Clone	Clonal complex	% of MRSA (*n*)	
			2018	2019
Healthcare associated	ST22-IV (EMRSA-15)	22	17.7 (80)*	16.4 (89)
	ST239-III (Aus 2/3 EMRSA)	8	3.8 (17)*	3.5 (19)
	ST5-II	5	nc (6)	nc (1)
	ST8-II	8	nc (1)	nc (0)
	Total		*23.0 (104)*	*20.1 (109)*
Community associated	ST93-IV (Qld CA-MRSA)	93	21.9 (99)	24.4 (132)
	ST5-IV	5	9.1 (41)	11.1 (60)
	ST45-V (WA84 MRSA)	45	9.1 (41)	10.1 (55)
	ST1-IV (WA1 MRSA)	1	7.7 (35)	4.8 (26)
	ST30-IV (SWP MRSA)	30	4.6 (21)	2.6 (14)
	ST78-IV (WA2 MRSA)	78	2.9 (13)	2.0 (11)
	ST97-IV	97	3.1 (14)	nc (8)
	ST8-IV	8	nc (8)	2.0 (11)
	ST953-IV	97	nc (5)	1.8 (10)
	ST22-IV (PVL-positive)	22	nc (7)	nc (8)
	ST5-V	5	nc (8)	nc (5)
	ST872-IV	1	nc (7)	nc (5)
	ST72-IV	8	nc (5)	nc (5)
	ST45-IV	45	nc (3)	nc (7)
	ST6-IV	5	nc (3)	nc (6)
	ST59-IV	Not assigned	nc (2)	nc (5)
	ST88-IV	Not assigned	nc (1)	nc (4)
	ST72-V	8	nc (0)	nc (4)
	Other clones	n/a	7.7 (35)	10.5 (57)
	Total		*77.0 (348)*	*79.9 (433)*

MRSA = methicillin-resistant *Staphylococcus aureus*; n/a = not applicable; nc = not calculated (<10 isolates; insufficient numbers to calculate percentage); PVL = Panton–Valentine leucocidin

* Includes two single locus variants

Note: Total numbers of MRSA blood culture isolates were 452 in 2018 and 542 in 2019.

Source: AGAR (national)

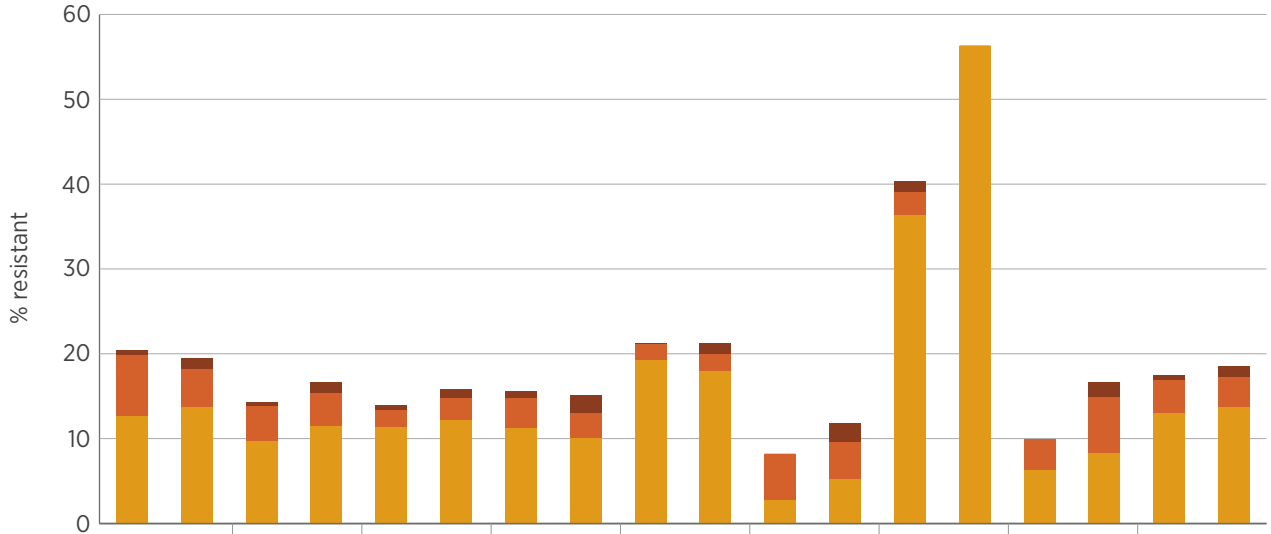
healthcare-associated clone is now EMRSA-15, which has a large reservoir in aged care homes and multi-purpose services.

Community-associated MRSA clones continue to become more widespread nationally, especially ST93, which is now the most common clone found in sepsis. This clone accounted for almost 1 in 4 MRSA isolates in 2019.

Key findings: states and territories

State and territory data are available from the AGAR targeted surveillance program on blood culture isolates. The prevalence and types of MRSA differ significantly between states and territories. In 2019, overall rates ranged from 11.8% in Tasmania to 56.3% in the NT (Figure 4.42 and *AURA 2021: Supplementary data*). Community-associated MRSA clones dominated in all states and territories except Tasmania. Multi-locus sequence type analysis revealed a great diversity of clones across the states and territories (Figure 4.43). The increase in the proportion of ST93 clones observed in blood culture isolates in 2019 was predominantly in WA. In the NT, rates of MRSA exceeded 56% in sepsis isolates.

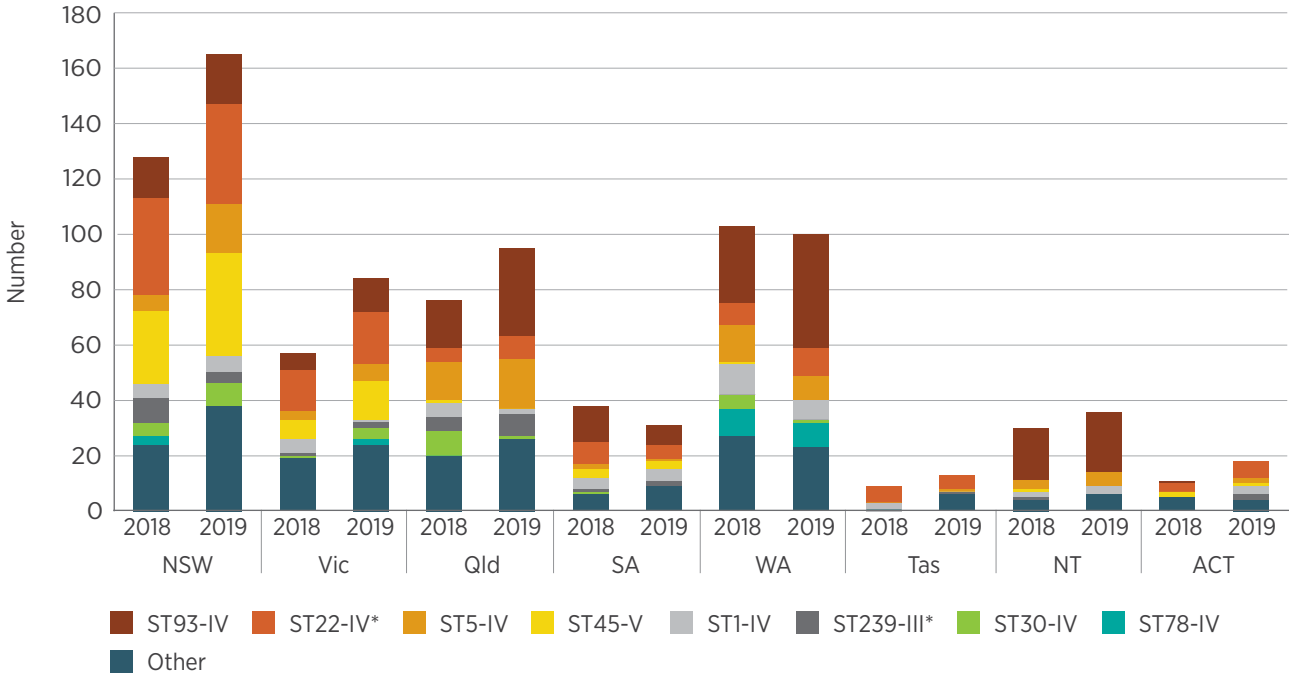
Figure 4.42: Methicillin-resistant *Staphylococcus aureus* as a percentage of all *S. aureus* blood culture isolates, by state and territory, 2018–19



	NSW		Vic		Qld		SA		WA		Tas		NT		ACT		Australia	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
na, %	0.6	1.2	0.5	1.3	0.7	1.1	0.8	2.1	0.2	1.2	0.0	2.2	1.3	0.0	0.0	1.7	0.5	1.3
HA, %	7.1	4.5	4.1	3.8	1.9	2.5	3.5	2.9	1.8	2.0	5.5	4.4	2.6	0.0	3.6	6.6	3.9	3.5
CA, %	12.7	13.7	9.7	11.5	11.4	12.2	11.3	10.1	19.3	18.0	2.7	5.2	36.4	56.3	6.3	8.3	13.0	13.7
na, *n*	4	11	2	7	4	7	2	5	1	6	0	3	1	0	0	2	14	41
HA, *n*	46	41	17	21	11	16	9	7	9	10	6	6	2	0	4	8	104	109
CA, *n*	82	124	40	63	65	79	29	24	94	90	3	7	28	36	7	10	348	433

CA = community associated; HA = healthcare associated; na = isolate not available for typing
Source: AGAR (national)

Figure 4.43: Distribution of methicillin-resistant *Staphylococcus aureus* clones (blood culture isolates), by state and territory, 2018–19



* Healthcare-associated clones
Source: AGAR (national)

The overall 30-day all-cause mortality rate was slightly lower in 2018 (14.2%) and 2019 (14.3%) than in 2017 (14.9%). The rate was higher for hospital-onset bacteraemia than for community-onset bacteraemia (Table 4.9). Thirty-day all-cause mortality was lowest with methicillin-susceptible strains until 2018; however, in 2019, the rate was lower with methicillin-resistant strains. The greatest decline was in bacteraemia caused by community-associated MRSA clones (16.3% in 2018; 11.4% in 2019). The highest 30-day all-cause mortality was for bacteraemia caused by healthcare-associated MRSA clones.

Full data from AGAR surveys of *S. aureus* can be found on the AGAR website.[3]

Table 4.9: Onset setting and 30-day all-cause mortality for infections with *Staphylococcus aureus* (blood culture isolates), 2018–19

***Staphylococcus aureus* strain**	**Year**	**Community, *n***	**Community mortality, % (*n*)**	**Hospital, *n***	**Hospital mortality, % (*n*)**	**Total, *n***	**Total mortality, % (*n*)**
Methicillin-susceptible	2018	1,384	13.0 (180)	383	15.7 (60)	1,767	13.6 (240)
	2019	1,585	14.4 (228)	385	14.0 (54)	1,970	14.3 (282)
Methicillin-resistant	2018	262	16.8 (44)	94	18.1 (17)	356	17.1 (61)
	2019	343	12.8 (44)	114	17.5 (20)	457	14.0 (64)
Community-associated MRSA clones	2018	207	16.9 (35)	56	14.3 (8)	263	16.3 (43)
	2019	253	9.9 (25)	80	16.3 (13)	333	11.4 (38)
Healthcare-associated MRSA clones	2018	50	18.0 (9)	33	21.2 (7)	83	19.3 (16)
	2019	66	19.7 (13)	27	18.5 (5)	93	19.4 (18)
Not determined	2018	5	0.0 (0)	5	40.0 (2)	10	20.0 (2)
	2019	24	25.0 (6)	7	28.6 (2)	31	25.8 (8)
Total	**2018**	**1,646**	**13.6 (224)**	**477**	**16.1 (77)**	**2,123**	**14.2 (301)**
	2019	**1,928**	**14.1 (272)**	**499**	**14.8 (74)**	**2,427**	**14.3 (346)**

MRSA = methicillin-resistant *Staphylococcus aureus*
Source: AGAR (national)

4.12 *Streptococcus agalactiae*

This section describes the health impact and treatment of *S. agalactiae*, and the types, impact and rates of resistance in this species.

Health impact

S. agalactiae, also called group B *Streptococcus* (GBS), occasionally causes infections similar to those caused by *S. pyogenes*. These include skin and soft tissue infections, as well as more serious infections such as septicaemia, and bone and joint infections. Its greatest significance is as the main cause of neonatal septicaemia and meningitis, which is associated with high morbidity and mortality.

Treatment

Screening mothers in late pregnancy for carriage of GBS is now widespread practice in Australia. If the mother tests positive for GBS, antimicrobials are administered to her during delivery to prevent transmission to the baby, regardless of the delivery mode. Benzylpenicillin is the recommended agent for this purpose; cefazolin or lincomycin/clindamycin are recommended for women with penicillin allergy, depending on the type and severity of the allergy.

Types and impact of resistance

Resistance to benzylpenicillin and cefazolin is emerging but still uncommon in Australia, but resistance to erythromycin, lincomycin and clindamycin is common at around 30%. Lincomycin/clindamycin resistance is strongly linked to resistance to macrolides such as erythromycin, which is often used in the laboratory as the test agent to predict resistance to lincomycin/clindamycin.

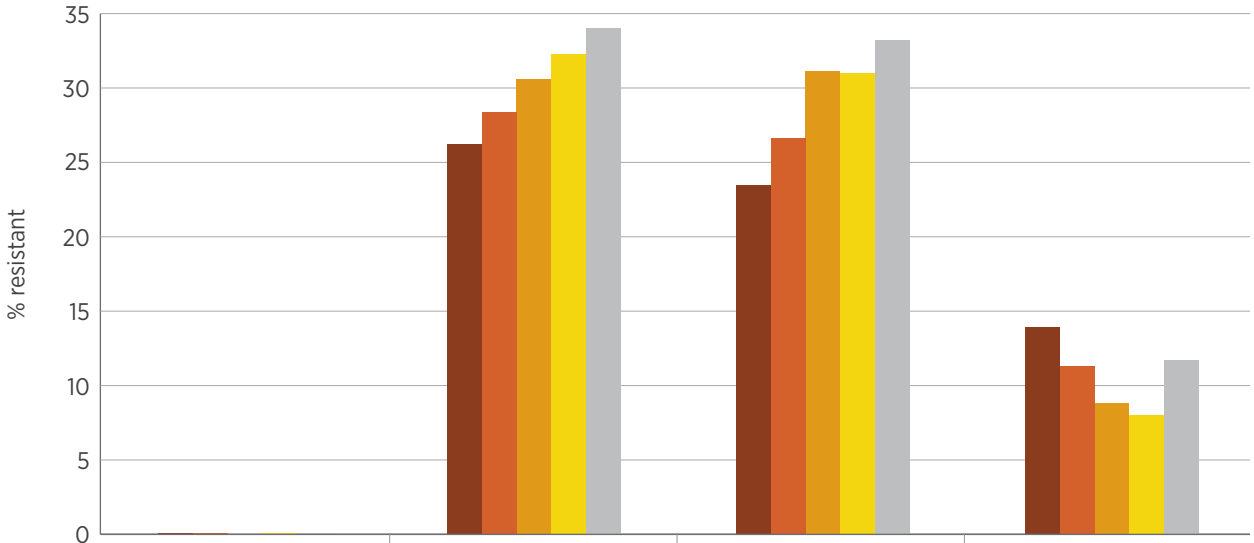
Mothers who carry GBS that is resistant to erythromycin, lincomycin and clindamycin, but who would otherwise be treated with lincomycin or clindamycin, require prophylaxis with vancomycin.

Key findings: national

Resistance to benzylpenicillin was extremely low, but resistance to erythromycin and clindamycin has steadily increased to reach around 33% in 2019 (Figure 4.44). Most of this resistance is of the constitutive MLS_B type. Clindamycin is currently recommended for penicillin-allergic mothers who require intrapartum prophylaxis, but this recommendation will need to be reviewed.

Resistance to clindamycin is increasing in Streptococcus agalactiae*. Recommendations to give clindamycin to penicillin-allergic mothers will need to be reviewed.*

Figure 4.44: *Streptococcus agalactiae* resistance, 2015–2019



	PEN	ERY	CLN	TMP
2015, %	0.1	26.2	23.5	13.9
2016, %	0.1	28.4	26.6	11.3
2017, %	0.0	30.6	31.1	8.8
2018, %	0.1	32.3	31.0	8.0
2019, %	0.1	34.0	33.2	11.7
2015, *n*	12,696	6,613	4,869	1,222
2016, *n*	13,320	7,498	7,025	1,291
2017, *n*	12,916	7,415	7,387	1,364
2018, *n*	12,122	7,670	7,191	1,196
2019, *n*	12,390	7,852	6,404	1,183

CLN = clindamycin; ERY = erythromycin; PEN = penicillin; TMP = trimethoprim
Sources: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); SNP (Qld, northern NSW)

4.13 *Streptococcus pneumoniae*

This section describes the health impact and treatment of *S. pneumoniae*, and the types, impact and rates of resistance in this species.

Health impact

S. pneumoniae is an important pathogen that commonly causes acute otitis media, acute sinusitis and pneumonia. It can also cause septicaemia (especially in young children), acute exacerbation of chronic obstructive pulmonary disease and bacterial meningitis. Its capacity to cause disease is linked to its polysaccharide capsule, of which there are more than 90 serotypes.

In Australia, two pneumococcal vaccines are included in the National Immunisation Program. Infants receive a conjugated vaccine that covers 13 of the most common serotypes, and older Aboriginal and Torres Strait Islander people and those with risk factors receive a polysaccharide vaccine that covers 23 of the most common serotypes. Because vaccines do not cover all serotypes, not all pneumococcal infection is vaccine preventable.

Treatment

Otitis media and sinusitis are normally treated with oral amoxicillin, cefuroxime (in penicillin-allergic patients) or doxycycline (for people older than 8 years). Macrolides and trimethoprim–sulfamethoxazole are sometimes used for oral treatments. Pneumonia and meningitis are generally treated with benzylpenicillin if the strain is proven to be susceptible, or ceftriaxone (or cefotaxime) for penicillin-nonsusceptible strains. Strains causing pneumonia or meningitis that are non-susceptible to penicillin and ceftriaxone (rare) require treatment with reserve antimicrobials such as vancomycin or meropenem.

Types and impact of resistance

Reduced susceptibility to benzylpenicillin is common but can mostly be managed with increased dosing regimens of benzylpenicillin, or amoxicillin when oral treatment is appropriate. However, strains with reduced susceptibility causing meningitis are resistant to treatment with benzylpenicillin because of the relatively poor penetration of this antimicrobial into the subarachnoid space (where the infection is located). Meningitis caused by these strains requires treatment with ceftriaxone (or cefotaxime), unless the strains also have reduced susceptibility to these agents.

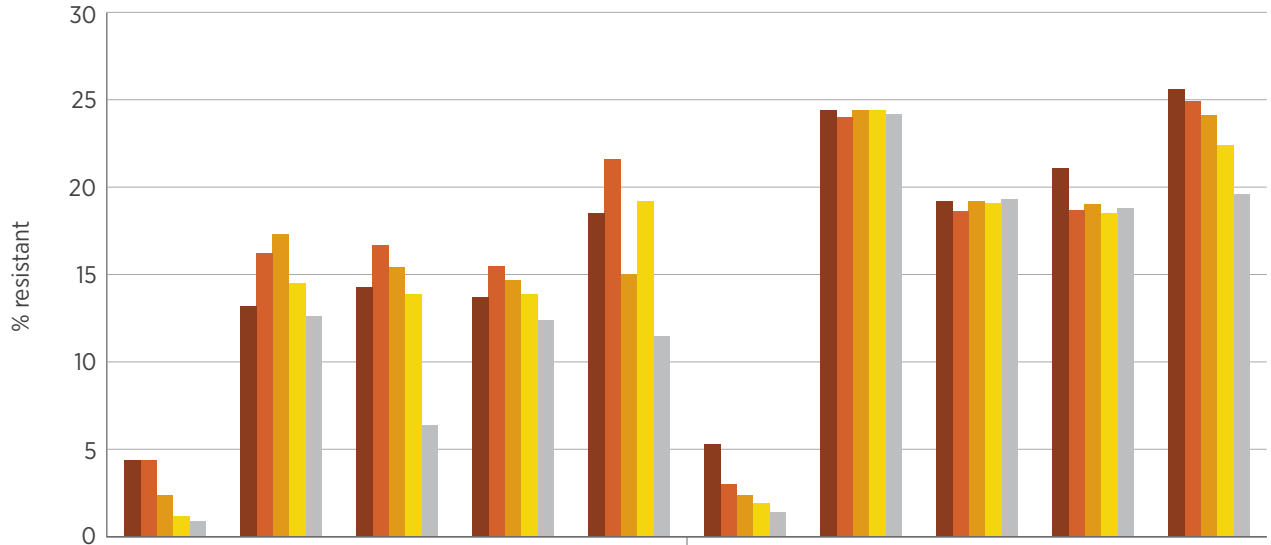
Resistance to tetracycline predicts resistance to doxycycline, the usual agent in this class used for treatment in adolescents and adults, and is a feature of multidrug-resistant strains.

Key findings: national

Resistance to benzylpenicillin has been low and is declining, but overall rates of resistance to macrolides (erythromycin), tetracyclines and trimethoprim–sulfamethoxazole were all above 15% (Figure 4.45) in isolates from specimens other than blood. In isolates from blood, there was a decrease in resistance to penicillins, erythromycin, clindamycin and tetracyclines in 2019.

Rates of resistance were somewhat lower for blood isolates than for isolates from other specimens. This has been noted in studies covering the past two decades and is likely due to different serotypes or clones predominating in invasive compared with non-invasive strains.[17] There were some differences in resistance rates in different clinical settings (Figure 4.46). The reasons for these differences are not clear.

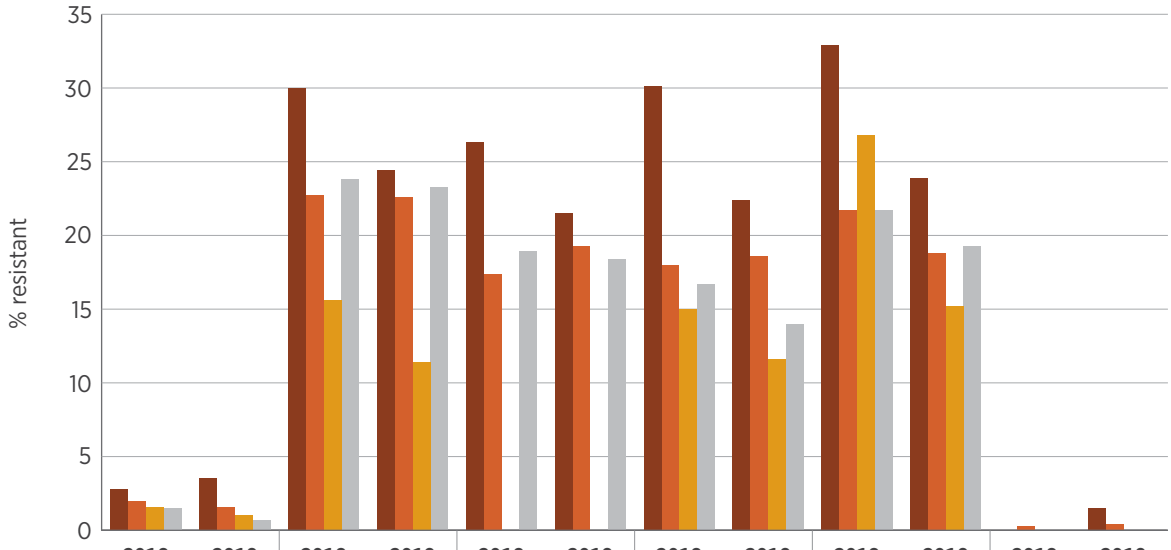
Figure 4.45: *Streptococcus pneumoniae* resistance, by specimen source, 2015–2019



	Blood					Other				
2015, %	4.4	13.2	14.3	13.7	18.5	5.3	24.4	19.2	21.1	25.6
2016, %	4.4	16.2	16.7	15.5	21.6	3.0	24.0	18.6	18.7	24.9
2017, %	2.4	17.3	15.4	14.7	15.0	2.4	24.4	19.2	19.0	24.1
2018, %	1.2	14.5	13.9	13.9	19.2	1.9	24.4	19.1	18.5	22.4
2019, %	0.9	12.6	6.4	12.4	11.5	1.4	24.2	19.3	18.8	19.6
2015, *n*	663	559	70	197	92	5,771	6,126	2,291	2,438	3,087
2016, *n*	756	666	60	362	139	5,507	6,166	2,396	2,124	3,171
2017, *n*	887	747	65	423	207	5,528	5,996	2,454	2,612	3,001
2018, *n*	895	774	101	403	130	5,684	5,724	2,584	3,017	3,465
2019, *n*	1,034	818	125	635	244	6,123	6,151	2,779	3,218	3,824

CLN = clindamycin; ERY = erythromycin; PEN = benzylpenicillin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines
Note: Benzylpenicillin resistance is defined as a minimum inhibitory concentration of >2 mg/L for infections other than meningitis (European Committee on Antimicrobial Susceptibility Testing).
Sources: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); SNP (Qld, northern NSW)

Figure 4.46: *Streptococcus pneumoniae* resistance, by clinical setting, 2018–19



	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
	PEN		ERY		CLN		TET		SXT		CTR	
Private hospitals, %	2.8	3.5	30.0	24.4	26.3	21.5	30.1	22.4	32.9	23.9	0.0	1.5
Public hospitals, %	2.0	1.6	22.7	22.6	17.4	19.3	18.0	18.6	21.7	18.8	0.3	0.4
Multi-purpose services, %	1.6	1.0	15.6	11.4	nd	nd	15.0	11.6	26.8	15.2	nd	nd
Community, %	1.5	0.7	23.8	23.3	18.9	18.4	16.7	14.0	21.7	19.3	0.0	0.0
Private hospitals, *n*	179	201	217	209	160	163	206	196	167	163	69	65
Public hospitals, *n*	4,203	4,614	4,169	4,453	843	849	2,361	2,769	1,646	1,866	1,065	1,232
Multi-purpose services, *n*	62	98	64	79	3	6	40	69	41	33	1	14
Community, *n*	1,977	2,136	1,965	2,112	1,653	1,847	599	614	1,718	1,969	94	104

CLN = clindamycin; CTR = ceftriaxone; ERY = erythromycin; nd = no data (either not tested or tested against an inadequate number of isolates); PEN = benzylpenicillin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines

Notes:

1. Benzylpenicillin resistance is defined as a minimum inhibitory concentration of >2 mg/L for infections other than meningitis (European Committee on Antimicrobial Susceptibility Testing)
2. Aged care homes are excluded because of an insufficient number of isolates from this setting (<30).

Sources: APAS (public hospitals); APAS (Qld, SA) and SNP (private hospitals); APAS and SNP (community); APAS (multi-purpose services)

4.14 *Streptococcus pyogenes*

This section describes the health impact and treatment of *S. pyogenes*, and the types, impact and rates of resistance in this species.

Health impact

S. pyogenes, also called group A *Streptococcus*, is an important human pathogen. It most commonly causes skin and soft tissue infections, and acute pharyngitis, but can cause serious and life-threatening infections such as scarlet fever, septicaemia, bone and joint infections, toxic shock syndrome, necrotising fasciitis and pneumonia. This organism is also associated with two 'post-streptococcal' syndromes: acute glomerulonephritis and rheumatic fever. These syndromes are now rare in most parts of Australia, but are still often seen in remote Aboriginal and Torres Strait Islander communities, contributing to substantial long-term morbidity in these populations.

Treatment

Benzylpenicillin remains the treatment of choice for *S. pyogenes* infections. In patients who are allergic to penicillins, macrolides such as erythromycin and first-generation cephalosporins are treatment options. Patients who have experienced one episode of acute rheumatic fever are prone to further episodes and worsening organ damage; consequently, they are administered long-term prophylaxis (usually over decades) with benzathine penicillin (intramuscularly) or phenoxymethylpenicillin (orally).

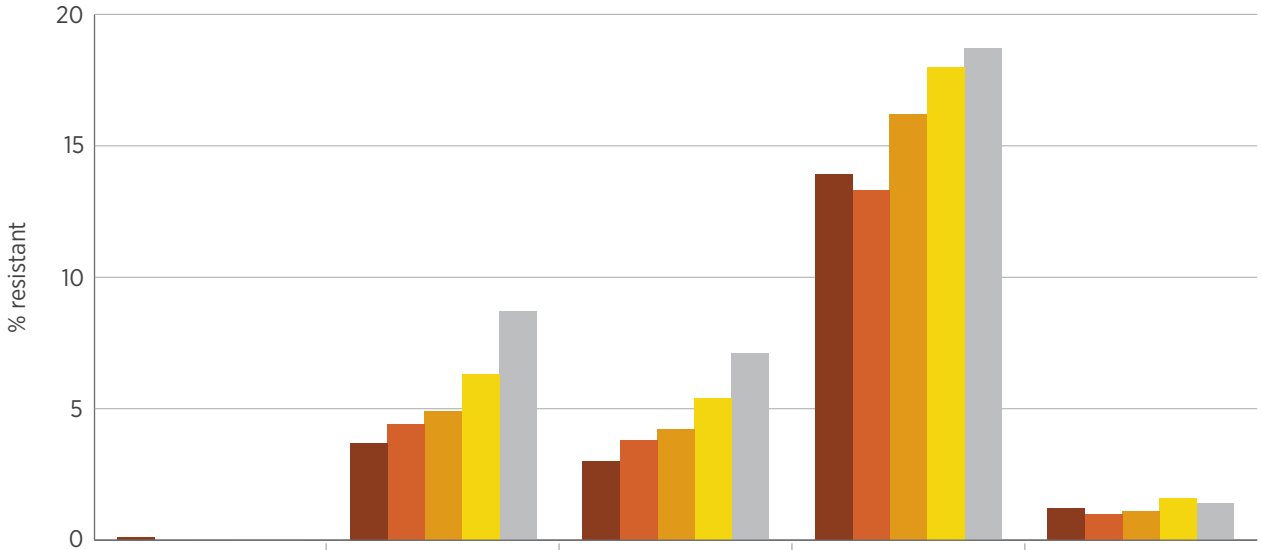
Types and impact of resistance

Confirmed resistance to benzylpenicillin has never been reported anywhere in the world in this species, but the consequences of its emergence would be substantial. It is expected that, based on observations of other species of *Streptococcus*, resistance to benzylpenicillin would also affect susceptibility to first-generation cephalosporins. In contrast, acquired resistance to macrolide antimicrobials has been present in *S. pyogenes* for many years, and levels of resistance seem to fluctuate in line with changes in circulating clones.

Key findings: national

Resistance to key antimicrobial agents is low, apart from tetracyclines, which are rarely used for treatment (Figure 4.47). Resistance to erythromycin (and therefore other macrolides) is low but has been steadily increasing since 2015. There was some variation in macrolide resistance rates among clinical settings, notably in community settings (Figure 4.48).

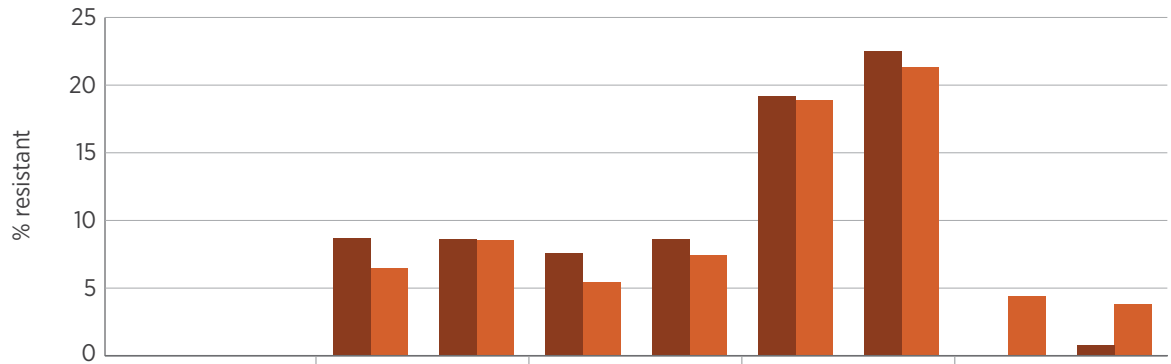
Figure 4.47: *Streptococcus pyogenes* resistance (all specimen sources), 2015–2019



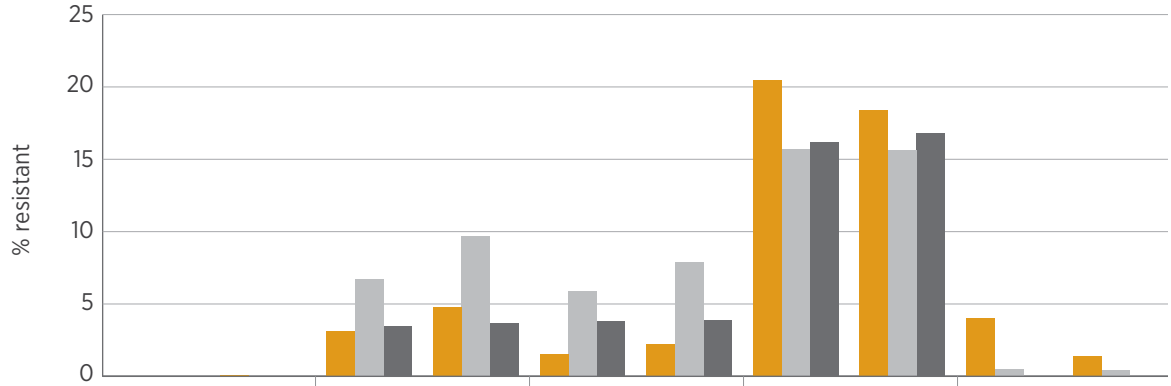
	PEN	ERY	CLN	TET	SXT
2015, %	0.1	3.7	3.0	13.9	1.2
2016, %	0.0	4.4	3.8	13.3	1.0
2017, %	0.0	4.9	4.2	16.2	1.1
2018, %	0.0	6.3	5.4	18.0	1.6
2019, %	0.0	8.7	7.1	18.7	1.4
2015, *n*	22,972	22,820	14,160	9,623	6,421
2016, *n*	26,898	26,713	16,217	11,222	7,959
2017, *n*	30,555	30,374	18,312	12,978	11,528
2018, *n*	26,973	25,140	17,491	13,764	10,491
2019, *n*	26,259	23,961	16,690	13,382	10,577

CLN = clindamycin; ERY = erythromycin; PEN = benzylpenicillin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines
Sources: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); SNP (Qld, northern NSW)

Figure 4.48: *Streptococcus pyogenes* resistance, by clinical setting, 2018–19



	2018 PEN	2019 PEN	2018 ERY	2019 ERY	2018 CLN	2019 CLN	2018 TET	2019 TET	2018 SXT	2019 SXT
Private hospitals, %	0.0	0.0	8.7	8.6	7.6	8.6	19.2	22.5	0.0	0.8
Public hospitals, %	0.0	0.0	6.5	8.5	5.4	7.4	18.9	21.3	4.4	3.8
Private hospitals, *n*	246	264	242	256	210	186	172	191	143	130
Public hospitals, *n*	11,972	11,770	11,122	10,907	5,223	4,863	7,131	7,102	2,886	3,114



	2018 PEN	2019 PEN	2018 ERY	2019 ERY	2018 CLN	2019 CLN	2018 TET	2019 TET	2018 SXT	2019 SXT
Multi-purpose services, %	0.0	0.1	3.1	4.8	1.5	2.2	20.5	18.4	4.0	1.4
Community, %	0.0	0.0	6.7	9.7	5.9	7.9	15.7	15.6	0.5	0.4
Other, %	0.0	0.0	3.5	3.7	3.8	3.9	16.2	16.8	nd	0.0
Multi-purpose services, *n*	583	760	483	627	200	224	507	527	50	221
Community, *n*	12,398	11,624	11,833	10,999	10,197	9,718	4,425	4,058	7,370	6,994
Other, *n*	420	515	312	401	314	382	296	291	29	50

CLN = clindamycin; ERY = erythromycin; nd = no data (either not tested or tested against an inadequate number of isolates); PEN = benzylpenicillin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines

Notes:

1. Aged care homes are excluded because of an insufficient number of isolates from this setting (<30).
2. Other settings are predominantly corrective services.

Sources: APAS (public hospitals); APAS (Qld, SA) and SNP (private hospitals); APAS and SNP (community); APAS (multi-purpose services)

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5

Chapter 5

National Alert System for Critical Antimicrobial Resistances (CARAlert)

Key findings

- Carbapenemase-producing *Enterobacterales* (CPE) was the most commonly reported critical antimicrobial resistance (CAR) in 2020.
- Three carbapenemase types (IMP, NDM and OXA-48-like) accounted for 96% of all *Enterobacterales* with a confirmed carbapenemase, either alone or in combination, in both 2019 and 2020.
- CARs reported from aged care settings were predominantly CPE or daptomycin-nonsusceptible *Staphylococcus aureus*.
- Of CARs reported from bloodstream specimens, 83% were CPE. Oral therapies may not be available for many of these infections, and hospital-based intravenous therapy is the only treatment option.
- There were large increases in multidrug-resistant *Shigella* species (from 104 isolates in 2018 to 331 isolates in 2019), followed by a small decline in 2020 (*n* = 299 isolates).
- There were sporadic reports of ceftriaxone-nonsusceptible *Neisseria gonorrhoeae*.
- *Candida auris* was reported from three states and territories in 2019 and 2020.
- There was a sharp fall in the monthly number of CARs reported from April 2020 onwards, notably in reports of multidrug-resistant *Shigella* species. This fall corresponded with the introduction of COVID-19 restrictions throughout Australia.

This chapter summarises the highlights of data collected through the National Alert System for Critical Antimicrobial Resistances (CARAlert). CARAlert collects data on confirmed critical antimicrobial resistances (CARs). This chapter reports on CARs that were collected between 1 January 2019 and 31 December 2020, and the results reported to CARAlert by 31 January 2021.

5.1 Overview of the CARAlert system

CARAlert was established by the Australian Commission on Safety and Quality in Health Care (the Commission) in March 2016 as a component of the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System. Participating confirming laboratories submit data to CARAlert on priority organisms with critical resistance to last-line antimicrobial agents (Table 5.1). No patient-level data are held in the CARAlert system.

The Commission's AURA team reviewed CARAlert in 2018, in conjunction with relevant experts, and states and territories. The review identified four new CARs that began to be reported to CARAlert from 2019:

- Transferrable resistance to colistin in *Enterobacterales*
- Carbapenemase-producing *Acinetobacter baumannii* complex
- Carbapenemase-producing *Pseudomonas aeruginosa*
- *Candida auris*, which is a multidrug-resistant yeast that has caused outbreaks in many countries.

Twenty-eight confirming laboratories participate in CARAlert. CARAlert generates a weekly summary email alert to report information on confirmed CARs to state and territory health authorities, the Australian Government Department of Health and confirming laboratories. See Appendix 1 for more information on CARAlert processes.

CARAlert data support timely responses to CARs by hospitals, and state and territory health departments. Some states have standalone systems for monitoring selected

Table 5.1: Critical antimicrobial resistances included in CARAlert

Species	Critical antimicrobial resistance
Acinetobacter baumannii complex*	Carbapenemase producing
*Candida auris**	Confirmed identification
Enterobacterales	Carbapenemase producing, and/or ribosomal methyltransferase producing
	Transmissible colistin resistance*
Enterococcus species	Linezolid resistant
Mycobacterium tuberculosis	Multidrug-resistant – resistant to at least rifampicin and isoniazid
Neisseria gonorrhoeae	Ceftriaxone-nonsusceptible or azithromycin-nonsusceptible
Salmonella species	Ceftriaxone-nonsusceptible
Shigella species	Multidrug-resistant
Staphylococcus aureus†	Vancomycin-, linezolid- or daptomycin-nonsusceptible
Streptococcus pyogenes	Penicillin reduced susceptibility
*Pseudomonas aeruginosa**	Carbapenemase producing

* Reported from July 2019

† For CARAlert, *S. aureus* includes *S. argenteus* and *S. schweitzeri*.

CARs, which complement CARAlert, but these are not widespread. Over time, CARAlert data will become increasingly useful to inform a broader range of safety and quality improvement programs.

5.2 Results from CARAlert 2019–20

Critical antimicrobial resistances overall

Between 1 January 2019 and 31 December 2020, a total of 3,551 CARs from 91 originating laboratories across Australia were entered into CARAlert (Table 5.2). There was an average of 164 entries per month in 2019, and 132 entries per month in 2020. The proportion of CARs associated with priority organisms each month is shown in Figure 5.1. CARs by organism and month of collection for 2019–20 are shown in Figure 5.2.

Between 1 January 2019 and 31 December 2020, a total of 3,551 critical antimicrobial resistances from 91 originating laboratories across Australia were entered into CARAlert.

Excluding the four new CARs reported from July 2019, there was an overall increase of 26.8% in CARs reported in 2019 compared with 2018. However, in 2020, there was a 21.3% decrease in reports compared with 2019. There was a sharp fall in the monthly number of CARs reported from April 2020 onwards, notably in reports of multidrug-resistant *Shigella* species. This fall corresponded with the introduction of COVID-19 restrictions throughout Australia.

Carbapenemase-producing *Enterobacterales* (CPE), either alone or in combination with ribosomal methyltransferases (RMTs), was the most frequently reported CAR in 2020 (*n* = 648; 41%); this is a 27% decrease in reports compared with 2019 (*n* = 886; 45%) (Table 5.2). There was a gradual decline in the total number of reports of this CAR from January 2019 (Figure 5.2).

Multidrug-resistant *Shigella* species was the second-ranked CAR in 2020 (*n* = 299; 19%); it was third-ranked in 2019 (*n* = 331; 17%). Monthly reports of this CAR increased 10-fold from August 2018 (*n* = 5) to a peak in April 2019 (*n* = 51), and 75% of reports in 2019 were from Victoria. There was another peak in January 2020, with 61% of reports from New South Wales (NSW), and an abrupt decrease in reports in April 2020.

Azithromycin- or ceftriaxone-nonsusceptible *Neisseria gonorrhoeae* was the most frequently reported CAR in 2017 (*n* = 734; 48%). There has been a steady decline in reports of this CAR since its peak in March 2017. This CAR was the second most frequently reported in 2018 (*n* = 531; 35%) and 2019 (*n* = 435; 22%), and the third most frequently reported in 2020 (*n* = 271; 17%). Reports decreased by 38% in 2020 compared with 2019.

Vancomycin-, linezolid- or daptomycin-nonsusceptible *Staphylococcus aureus* was the fourth most frequently reported CAR in both 2019 (*n* = 161; 8%) and 2020 (*n* = 216; 14%). Reports of this CAR increased by 34% in 2020 compared with 2019. It was the only CAR for which there was an increase in the number of reports in 2020.

All other CARs combined contributed 8–9% of the total number of reports (156/1,969 in 2019; 148/1,582 in 2020).

No reports of *Streptococcus pyogenes* with penicillin reduced susceptibility were submitted in the 2019–20 reporting period. There have been no reports of this CAR since CARAlert commenced.

Table 5.2: Number of critical antimicrobial resistance reports, by state and territory, 1 January 2019 to 31 December 2020

Critical antimicrobial resistance	NSW		Vic		Qld		SA		WA		Tas		NT		ACT		Total		Relative change (%)*
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	
Carbapenemase-producing and/or ribosomal methyltransferase-producing *Enterobacterales*	306	254 ▼	305	197 ▲	183	129 ▼	45	20 ■	28	33 ■	3	3†	7	3†	9	9†	886	648 ■	−26.9
Ceftriaxone-nonsusceptible or azithromycin-non-susceptible *Neisseria gonorrhoeae*	211	174 ▼	159	27 ▼	33	42 ■	0	0†	18	19 ■	1	0†	1	2†	12	7 ■	435	271 ▼	−37.7
Multidrug-resistant *Shigella* species	58	171 ▲	185	57 ▼	65	47 ■	6	3†	7	20 ▲	0	0†	3	1†	7	0†	331	299 ■	−9.7
Vancomycin-, linezolid- or daptomycin-nonsusceptible *Staphylococcus aureus* complex	27	44 ■	53	27 ■	42	108 ▲	0	0†	35	35 ■	0	0†	0	0†	4	2†	161	216 ▲	34.2
Ceftriaxone-nonsusceptible *Salmonella* species	18	8 ▼	2	5†	12	12 ■	3	2†	9	3†	0	0†	1	0†	0	0†	45	30 ■	−33.3
Carbapenemase-producing *Pseudomonas aeruginosa*§	18	23	7	12	1	2†	1	2†	1	3†	0	1†	0	0†	0	1†	28	44	n/a
Carbapenemase-producing *Acinetobacter baumannii* complex§	2	12	24	11	2	1†	0	0†	4	0†	0	0†	0	1†	0	0†	32	25	n/a
Linezolid-nonsusceptible *Enterococcus* species	2	4†	4	6†	1	0†	4	1†	9	7†	1	1†	0	0†	1	0†	22	19 ■	−13.6

continues

Table 5.2: *continued*

Critical antimicrobial resistance	NSW		Vic		Qld		SA		WA		Tas		NT		ACT		Total		Relative change (%)*
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	
Multidrug-resistant *Mycobacterium tuberculosis*	12	8 ■	5	4†	2	1†	1	0†	2	0†	0	0†	1	1†	1	2†	24	16 ■	−33.3
Transferrable resistance to colistin *Enterobacterales*§,#	2	0†	1	9†	0	0†	0	0†	0	0†	0	0†	0	0†	0	0†	3	9†	n/a
Candida auris§	2	2†	0	3†	0	0†	0	0†	1	0†	0	0†	0	0†	0	0†	3	5†	n/a
Total	**658**	**700**	**745**	**358**	**341**	**342**	**60**	**28**	**114**	**120**	**5**	**5**	**13**	**8**	**34**	**21**	**1,970**	**1,582**	**−19.7**
Total minus new CARs introduced in 2019	633	663	713	323	338	339	59	26	108	117	5	4	13	7	34	20	1,904	1,499	−21.3
Relative change (%)*		4.6		−54.7		0.3		−55.9		8.3		−20.0		−46.2		−41.2		−21.3	

n/a = not applicable

* Relative change is the absolute change between 2019 and 2020, expressed as a percentage of 2019 base.

† Insufficient numbers (<10 over both years)

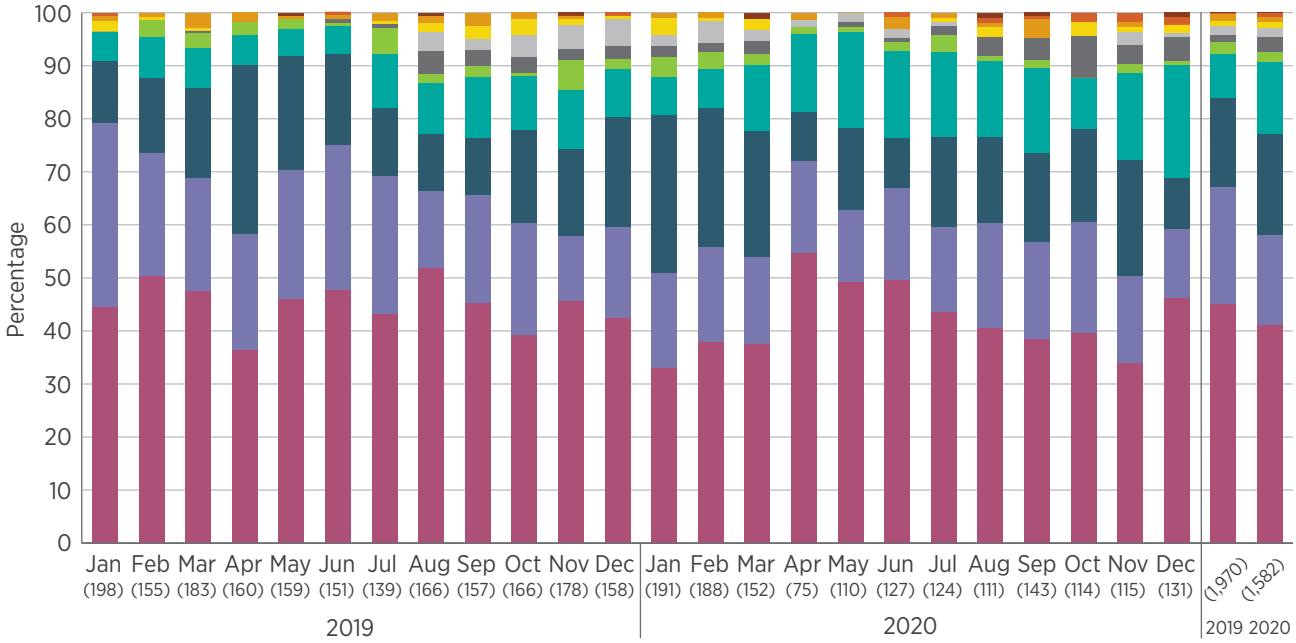
§ New CAR reported from 1 July 2019

\# When not seen in combination with carbapenemase-producing *Enterobacterales*

Note: A change in the proportion of each critical antimicrobial resistance in the state or territory total in 2019 compared with 2020 (Fishers exact test, $P < 0.05$) is indicated against the 2020 total: ▲ significant increase; ▼ significant decrease; ■ no significant difference.

Source: CARAlert (as at 31 January 2021)

Figure 5.1: Critical antimicrobial resistances, by month of collection, 2019–20

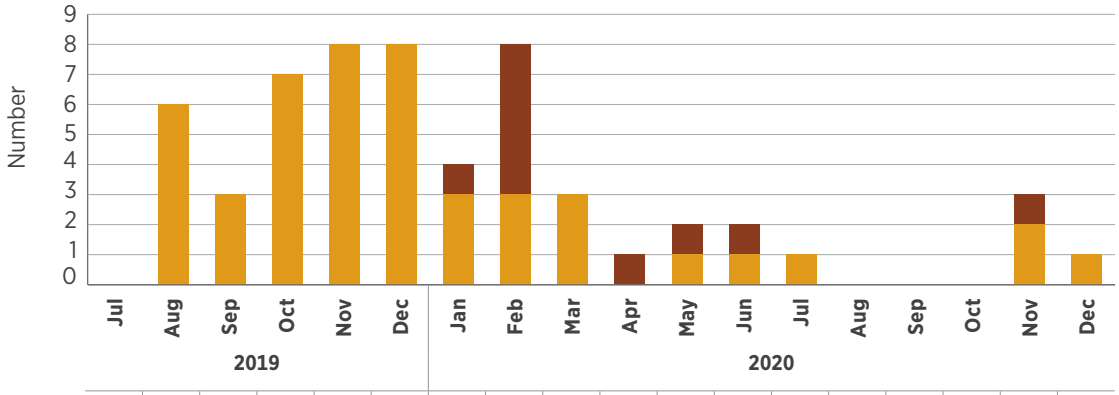


- *Candida auris*
- Transferrable resistance to colistin *Enterobacterales*
- Multidrug-resistant (to at least rifampicin and isoniazid) *Mycobacterium tuberculosis*
- Linezolid-resistant *Enterococcus* species
- Carbapenemase-producing *Acinetobacter baumannii* complex
- Carbapenemase-producing *Pseudomonas aeruginosa*
- Ceftriaxone-nonsusceptible *Salmonella*
- Vancomycin-, linezolid- or daptomycin-nonsusceptible *Staphylococcus aureus* complex
- Multidrug-resistant *Shigella* species
- Ceftriaxone- or azithromycin-nonsusceptible *Neisseria gonorrhoeae*
- Carbapenemase-, and/or ribosomal methyltransferase-producing *Enterobacterales*

Note: Numbers of isolates are in brackets.
Source: CARAlert (as at 31 January 2021)

Figure 5.2: Critical antimicrobial resistances, number of reports, by organism and month of collection, 2019–20

***Acinetobacter baumanni* complex – carbapenemase producing**

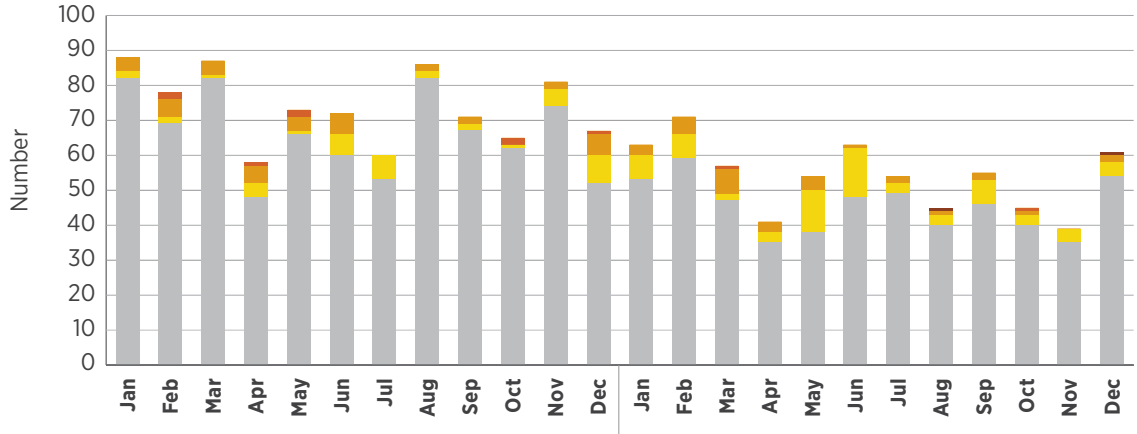


	Jul 2019	Aug 2019	Sep 2019	Oct 2019	Nov 2019	Dec 2019	Jan 2020	Feb 2020	Mar 2020	Apr 2020	May 2020	Jun 2020	Jul 2020	Aug 2020	Sep 2020	Oct 2020	Nov 2020	Dec 2020
Total	0	6	3	7	8	8	4	8	3	1	2	2	1	0	0	0	3	1
Carbapenemase and RMT (*n* = 10)	0	0	0	0	0	0	1	5	0	1	1	1	0	0	0	0	1	0
Carbapenemase (*n* = 47)	0	6	3	7	8	8	3	3	3	0	1	1	1	0	0	0	2	1

RMT = ribosomal methyltransferase

Note: New CAR reported from 1 July 2019.

***Enterobacterales* – carbapenemase, and/or ribosomal methyltransferase producing**



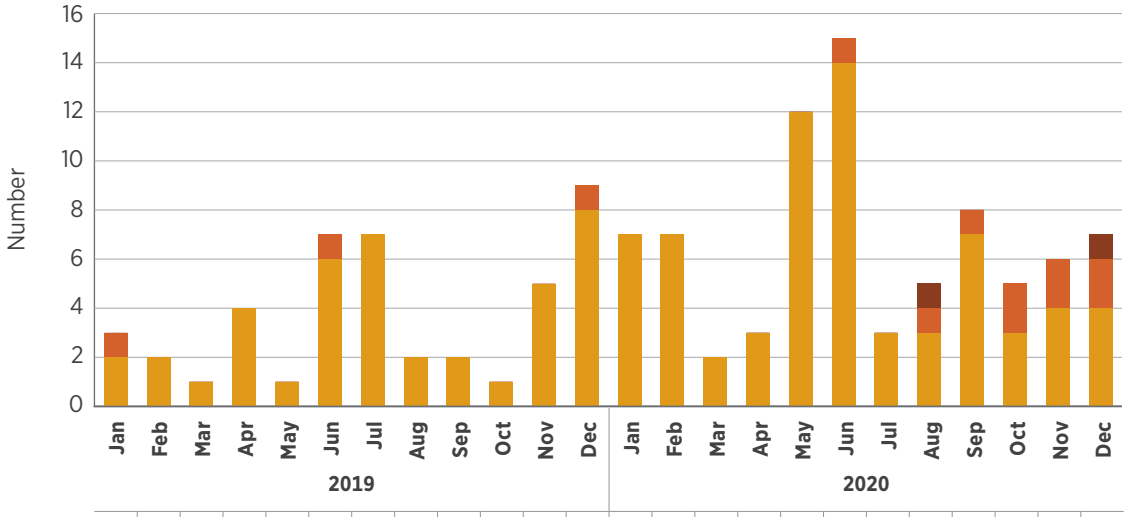
	Jan 2019	Feb 2019	Mar 2019	Apr 2019	May 2019	Jun 2019	Jul 2019	Aug 2019	Sep 2019	Oct 2019	Nov 2019	Dec 2019	Jan 2020	Feb 2020	Mar 2020	Apr 2020	May 2020	Jun 2020	Jul 2020	Aug 2020	Sep 2020	Oct 2020	Nov 2020	Dec 2020
Total	88	78	87	58	73	72	60	86	71	65	81	67	63	71	57	41	54	63	54	45	55	45	39	61
Carbapenemase, RMT and MCR (*n* = 2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
RMT (*n* = 10)	0	2	0	1	2	0	0	0	0	2	0	1	0	0	1	0	0	0	0	0	0	1	0	0
Carbapenemase and RMT (*n* = 71)	4	5	4	5	4	6	0	2	2	0	2	6	3	5	7	3	4	1	2	1	2	1	0	2
Carbapenemase and MCR (*n* = 110)	2	2	1	4	1	6	7	2	2	1	5	8	7	7	2	3	12	14	3	3	7	3	4	4
Carbapenemase (*n* = 1,341)	82	69	82	48	66	60	53	82	67	62	74	52	53	59	47	35	38	48	49	40	46	40	35	54

MCR = transmissible resistance to colistin; RMT = ribosomal methyltransferase

continues

Figure 5.2: *continued*

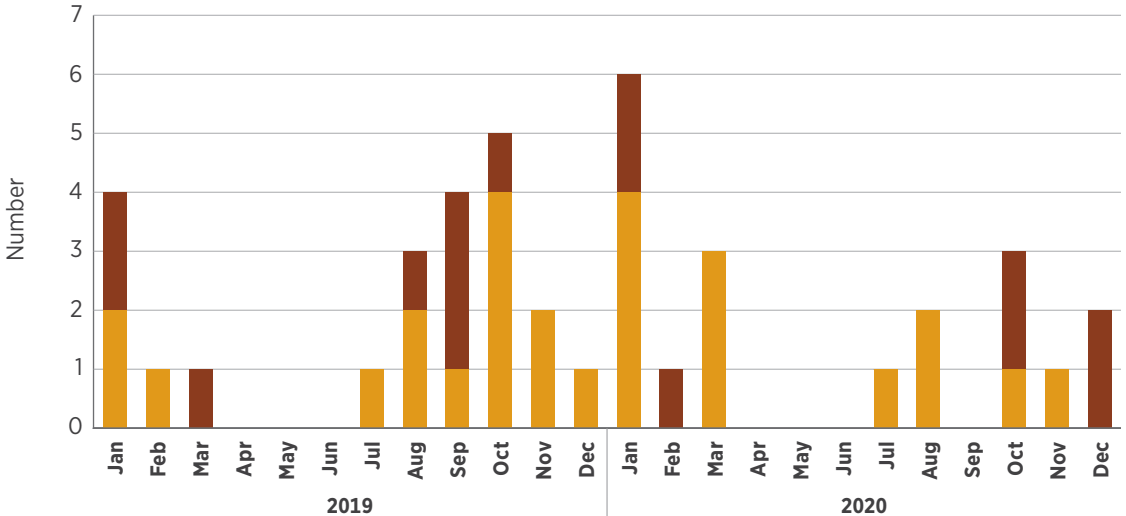
***Enterobacterales* – transmissible resistance to colistin**



	Jan 2019	Feb 2019	Mar 2019	Apr 2019	May 2019	Jun 2019	Jul 2019	Aug 2019	Sep 2019	Oct 2019	Nov 2019	Dec 2019	Jan 2020	Feb 2020	Mar 2020	Apr 2020	May 2020	Jun 2020	Jul 2020	Aug 2020	Sep 2020	Oct 2020	Nov 2020	Dec 2020
Total	3	2	1	4	1	7	7	2	2	1	5	9	7	7	2	3	12	15	3	5	8	5	6	7
MCR, CPE and RMT (*n* = 2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
MCR (*n* = 12)	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	1	2	2	2
MCR and CPE (*n* = 110)	2	2	1	4	1	6	7	2	2	1	5	8	7	7	2	3	12	14	3	3	7	3	4	4

CPE = carbapenemase-producing *Enterobacterales*; MCR = transmissible resistance to colistin; RMT = ribosomal methyltransferase
Note: New CAR reported from 1 July 2019

***Enterococcus* species – linezolid-nonsusceptible**

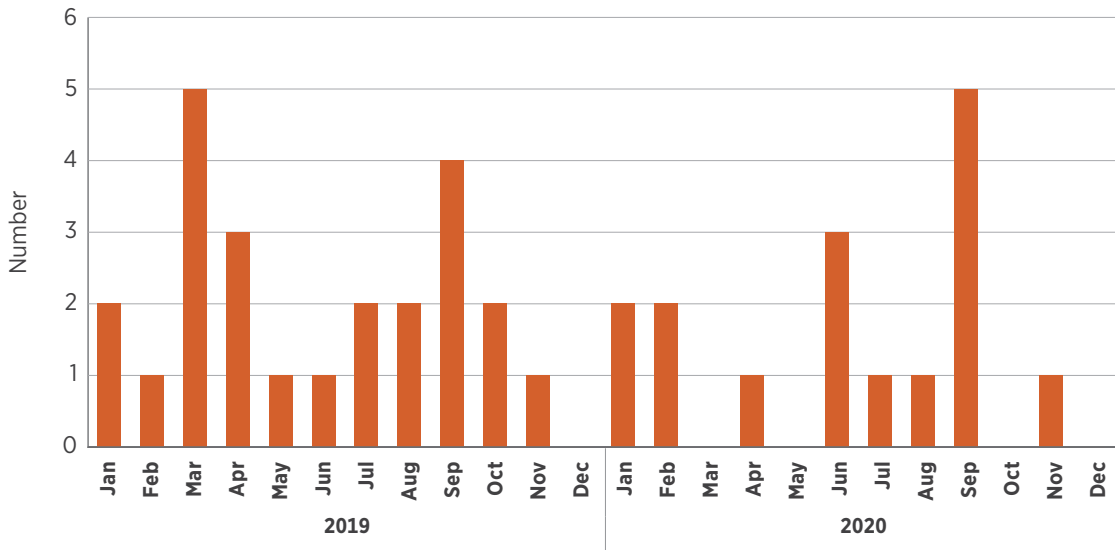


	Jan 2019	Feb 2019	Mar 2019	Apr 2019	May 2019	Jun 2019	Jul 2019	Aug 2019	Sep 2019	Oct 2019	Nov 2019	Dec 2019	Jan 2020	Feb 2020	Mar 2020	Apr 2020	May 2020	Jun 2020	Jul 2020	Aug 2020	Sep 2020	Oct 2020	Nov 2020	Dec 2020
Total	4	1	1	0	0	0	1	3	4	5	2	1	6	1	3	0	0	0	1	2	0	3	1	2
***E. faecium* (*n* = 15)**	2	0	1	0	0	0	0	1	3	1	0	0	2	1	0	0	0	0	0	0	0	2	0	2
***E. faecalis* (*n* = 26)**	2	1	0	0	0	0	1	2	1	4	2	1	4	0	3	0	0	0	1	2	0	1	1	0

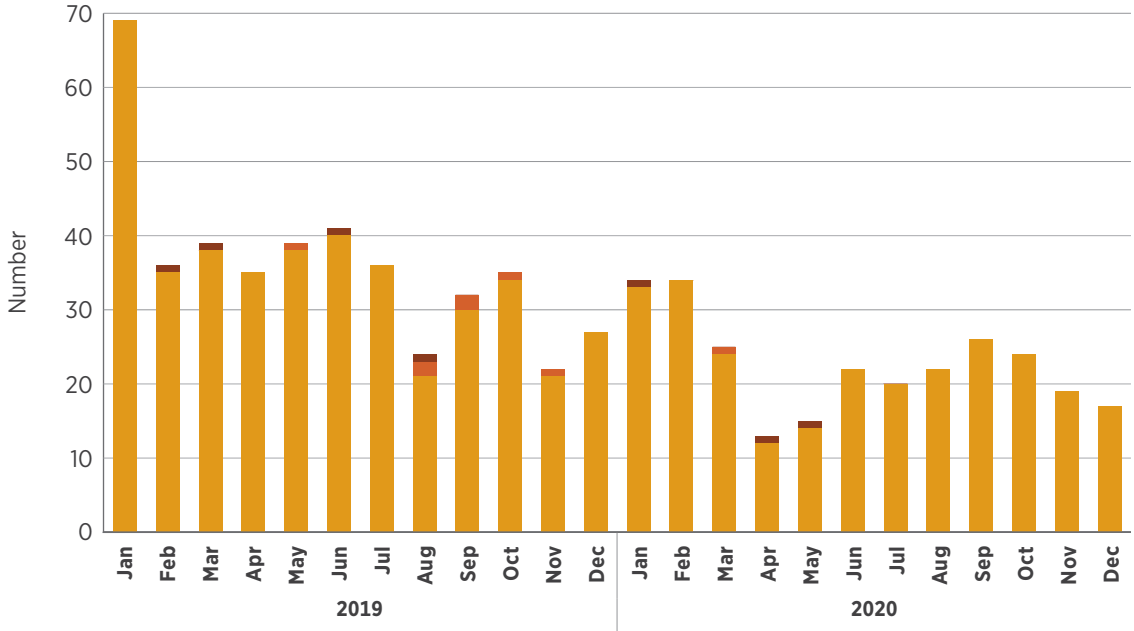
continues

Figure 5.2: *continued*

***Mycobacterium tuberculosis* – multidrug-resistant**



***Neisseria gonorrhoeae* – azithromycin-nonsusceptible or ceftriaxone-nonsusceptible**



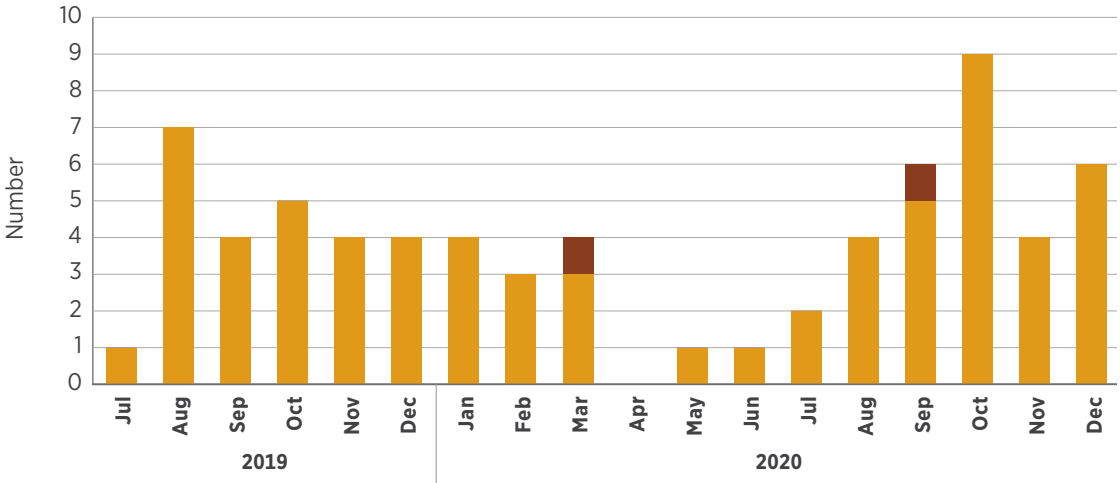
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total	69	36	39	35	39	41	36	24	32	35	22	27	34	34	25	13	15	22	20	22	26	24	19	17
Ceftriaxone-nonsusceptible (*n* = 7)	0	1	1	0	0	1	0	1	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0
Azithromycin-nonsusceptible (HLR, MIC ≥256 mg/L) (*n* = 8)	0	0	0	0	1	0	0	2	2	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0
Azithromycin-nonsusceptible (LLR, MIC <256 mg/L) (n = 691)	69	35	38	35	38	40	36	21	30	34	21	27	33	34	24	12	14	22	20	22	26	24	19	17

HLR = high-level resistance; LLR = low-level resistance; MIC = minimum inhibitory concentration

continues

Figure 5.2: *continued*

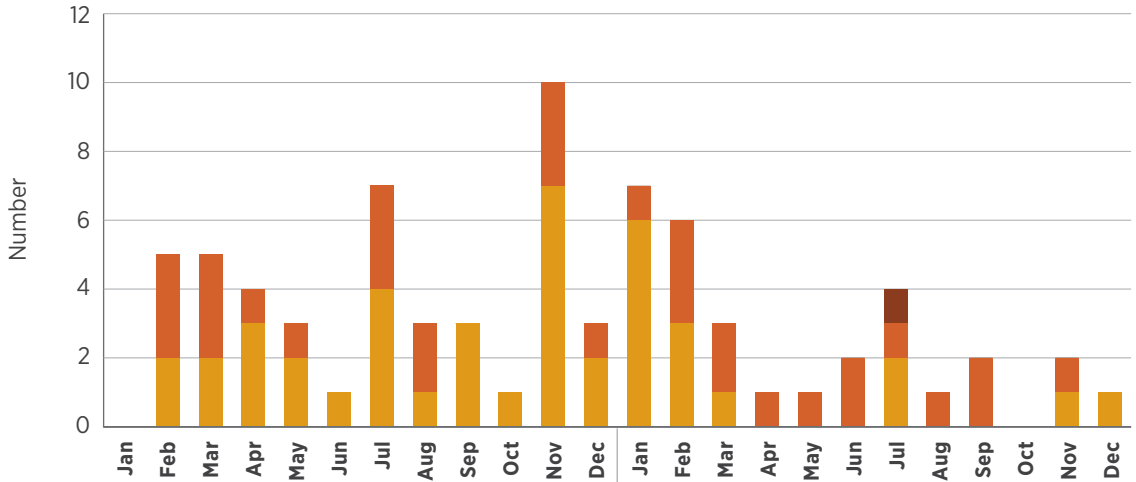
***Pseudomonas aeruginosa* – carbapenemase producing**



	Jul 2019	Aug 2019	Sep 2019	Oct 2019	Nov 2019	Dec 2019	Jan 2020	Feb 2020	Mar 2020	Apr 2020	May 2020	Jun 2020	Jul 2020	Aug 2020	Sep 2020	Oct 2020	Nov 2020	Dec 2020
Total	1	7	4	5	4	4	4	3	4	0	1	1	2	4	6	9	4	6
Carbapenemase and RMT (*n* = 2)	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Carbapenemase (*n* = 67)	1	7	4	5	4	4	4	3	3	0	1	1	2	4	5	9	4	6

RMT = ribosomal methyltransferase
Note: New CAR reported from 1 July 2019.

***Salmonella* species – ceftriaxone-nonsusceptible**



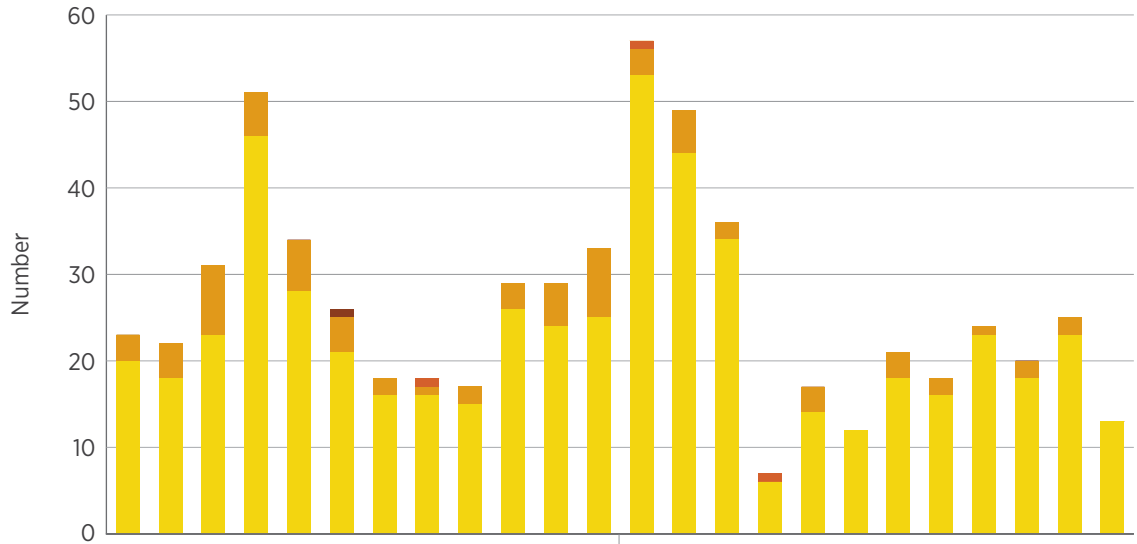
	Jan 2019	Feb 2019	Mar 2019	Apr 2019	May 2019	Jun 2019	Jul 2019	Aug 2019	Sep 2019	Oct 2019	Nov 2019	Dec 2019	Jan 2020	Feb 2020	Mar 2020	Apr 2020	May 2020	Jun 2020	Jul 2020	Aug 2020	Sep 2020	Oct 2020	Nov 2020	Dec 2020
Total	0	5	5	4	3	1	7	3	3	1	10	3	7	6	3	1	1	2	4	1	2	0	2	1
AmpC, ESBL (*n* = 1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
AmpC (*n* = 32)	0	3	3	1	1	0	3	2	0	0	3	1	1	3	2	1	1	2	1	1	2	0	1	0
ESBL (*n* = 42)	0	2	2	3	2	1	4	1	3	1	7	2	6	3	1	0	0	0	2	0	0	0	1	1

ESBL = extended-spectrum β-lactamase

continues

Figure 5.2: *continued*

***Shigella* species – multidrug-resistant**

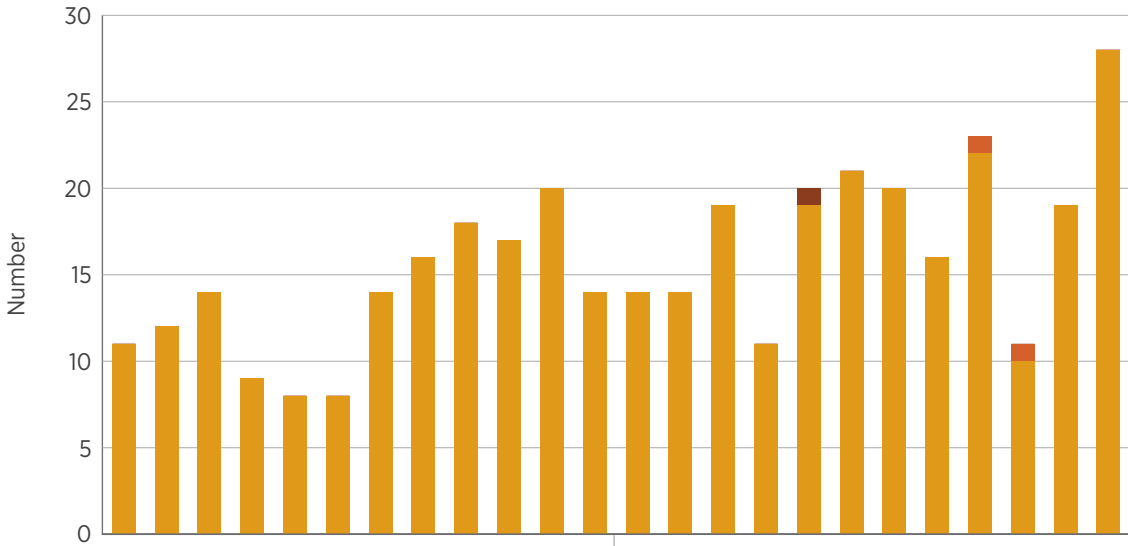


	2019 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2020 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total	23	22	31	51	34	26	18	18	17	29	29	33	57	49	36	7	17	12	21	18	24	20	25	13
***S. dysenteriae* (*n* = 1)**	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
***S. boydii* (*n* = 3)**	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
***S. flexneri* (*n* = 74)**	3	4	8	5	6	4	2	1	2	3	5	8	3	5	2	0	3	0	3	2	1	2	2	0
***S. sonnei* (*n* = 552)**	20	18	23	46	28	21	16	16	15	26	24	25	53	44	34	6	14	12	18	16	23	18	23	13

continues

Figure 5.2: *continued*

***Staphylococcus aureus* – daptomycin-, linezolid- or vancomycin-nonsusceptible**



	Jan 2019	Feb 2019	Mar 2019	Apr 2019	May 2019	Jun 2019	Jul 2019	Aug 2019	Sep 2019	Oct 2019	Nov 2019	Dec 2019	Jan 2020	Feb 2020	Mar 2020	Apr 2020	May 2020	Jun 2020	Jul 2020	Aug 2020	Sep 2020	Oct 2020	Nov 2020	Dec 2020
Total	11	12	14	9	8	8	14	16	18	17	20	14	14	14	19	11	20	21	20	16	23	11	19	28
Linezolid (*n* = 1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Daptomycin and vancomycin (*n* = 2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Daptomycin (*n* = 374)	11	12	14	9	8	8	14	16	18	17	20	14	14	14	19	11	19	21	20	16	22	10	19	28

Note: No *S. argenteus* or *S. schweitzeri* were reported.
Source: CARAlert (as at 31 January 2021)

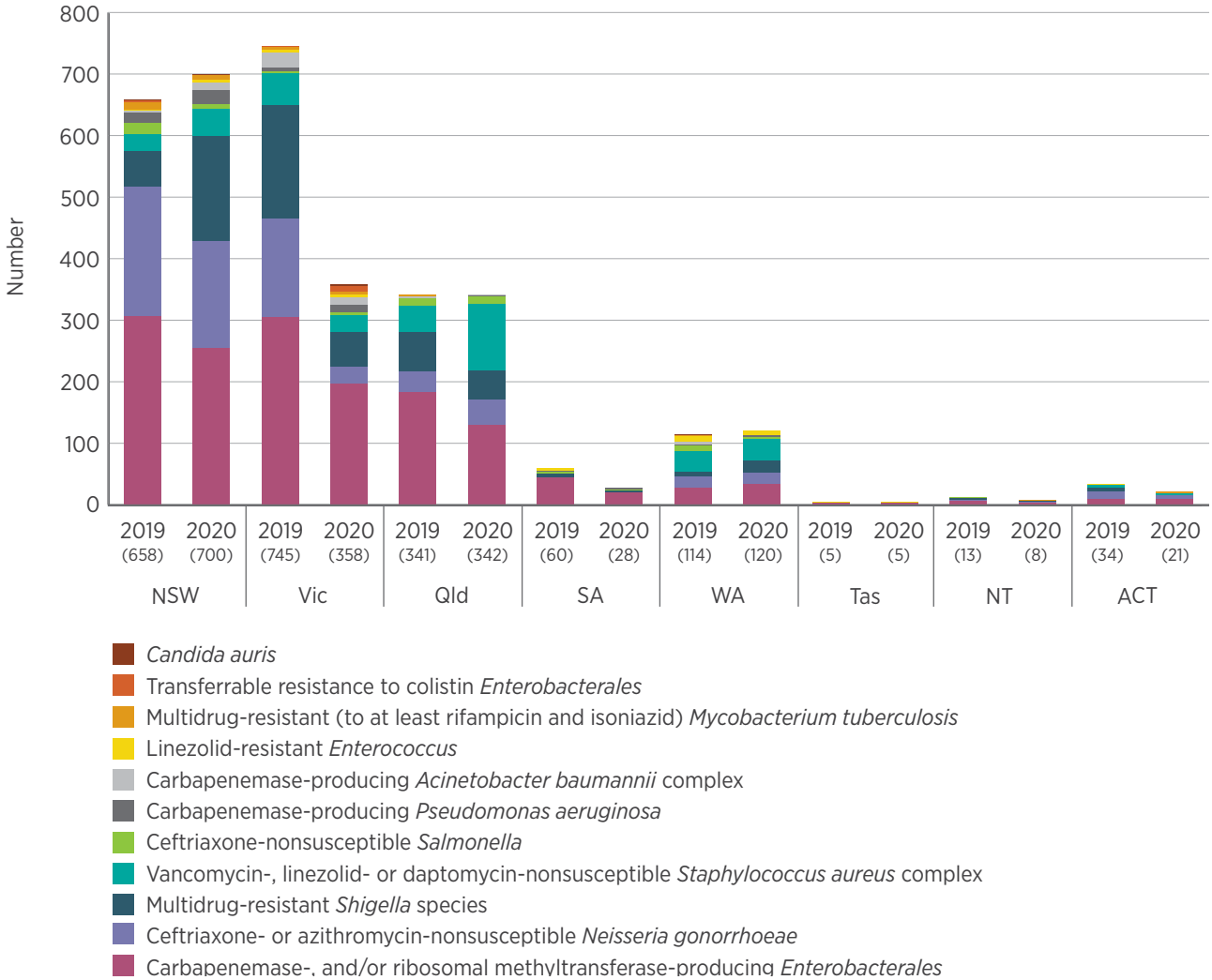
Critical antimicrobial resistances by state and territory

Most CARs (88% in 2019 and 2020) were collected from patients who lived in the most populous states: NSW 33–44% (657/1,969 in 2019; 700/1,582 in 2020), Victoria 23–38% (745/1,969 in 2019; 358/1,582 in 2020) and Queensland 17–22% (341/1,969 in 2019; 342/1,582 in 2020). There were fewer than 15 reports per year from Tasmania and the Northern Territory (NT), and fewer than 35 reports per year from the Australian Capital Territory (ACT) (Figure 5.3). The number of CARs halved in 2020 compared with 2019 for reports from Victoria (*n* = 745 in 2019; *n* = 358 in 2020) and South Australia (SA; *n* = 60 in 2019; *n* = 28 in 2020).

A total of 32 reports were from overseas residents: 12 CPE, seven multidrug-resistant *Shigella* species, seven azithromycin-nonsusceptible *N. gonorrhoeae* (low-level resistance [LLR]; minimum inhibitory concentration [MIC] <256 mg/L), two multidrug-resistant *Mycobacterium tuberculosis*, two carbapenemase-producing *A. baumannii* complex, one ceftriaxone-nonsusceptible *Salmonella* species, and one daptomycin-nonsusceptible *S. aureus*.

CPE were reported from all states and territories. CPE as a proportion of all reported CARs varied by state and territory, and by year. Reports of CPE as a proportion of all CARs in both 2019 and 2020 were highest for SA (75% and 71%, respectively). In 2020,

Figure 5.3: Critical antimicrobial resistances, by patient's state or territory of residence, 2019–20



Note: Numbers of isolates are in brackets.
Source: CARAlert (as at 31 January 2021)

there were decreases in reports of CPE from all states and territories (from 16% in NSW to 57% in SA), except in Western Australia (WA), where there was a 22% increase in reports.

Multidrug-resistant *Shigella* species were reported in all states and territories except Tasmania (2019 and 2020) and the ACT (2020). There was a 2.9-fold increase in reports from both NSW (n = 58 in 2019; n = 171 in 2020) and WA (n = 7 in 2019; n = 20 in 2020). In contrast, there was a three-fold decrease in reports from Victoria (n = 187 in 2019; n = 57 in 2020).

Azithromycin-nonsusceptible or ceftriaxone-nonsusceptible *N. gonorrhoeae* were reported from all states and territories except SA (2019 and 2020) and Tasmania (2020). There was a 38% decrease in the number of reports of this CAR in 2020 compared with 2019 (n = 435 in 2019; n = 271 in 2020). The greatest decreases were in reports from Victoria (n = 159 in 2019; n = 27 in 2020, down 83%) and NSW (n = 211 in 2019; n = 174 in 2020, down 18%). There was an increase in reports from Queensland (n = 33 in 2019; n = 42 in 2020, up 27%).

Daptomycin-nonsusceptible *S. aureus* was reported from five states and territories. In 2020, this CAR accounted for one-third of all CARs reported from Queensland (*n* = 108; 32%) and WA (*n* = 35; 29%). There was a 2.6-fold increase in reports from Queensland in 2020 (*n* = 108) compared with 2019 (*n* = 42).

C. auris was only reported from NSW (*n* = 4), Victoria (*n* = 3) and WA (*n* = 1).

Enterobacterales with transmissible resistance to colistin, when not associated with a carbapenemase, was only reported from Victoria (*n* = 10) and NSW (*n* = 2).

Critical antimicrobial resistances by age group

CARs were isolated from patients of all ages; the median age range was 40–49 years (Figure 5.4). A total of 74–76% (650/878 in 2019; 494/646 in 2020) of CPE were isolated from people aged 50 years and older. Most (91–92%) of azithromycin-nonsusceptible or ceftriaxone-nonsusceptible *N. gonorrhoeae* was reported for people aged 15–49 years; and 82–90% of multidrug-resistant *Shigella* species were in people aged 20–59 years.

Only 4.6–4.9% (90/1,970 in 2019; 76/1,582 in 2020) of all CARs were reported in children aged less than 15 years; CPE, multidrug-resistant *Shigella* species, and ceftriaxone-nonsusceptible *Salmonella* species dominated in this age group, making up 89% of reports in 2019 and 84% in 2020. For the 0–4-year age group, CPE was the most frequently reported CAR (65 reports in two years), followed by multidrug-resistant *Shigella* species (*n* = 20) and ceftriaxone-nonsusceptible *Salmonella* species (*n* = 14).

Critical antimicrobial resistances by specimen type

Around three-quarters of all CARs were from clinical specimens (1,404/1,970, 71% in 2019; 1,240/1,582, 78% in 2020), which are specimens collected for diagnostic purposes rather than for screening. These included urine, wound, blood and other (such as genital or respiratory) specimens (Figure 5.5).

Of CPE isolates:

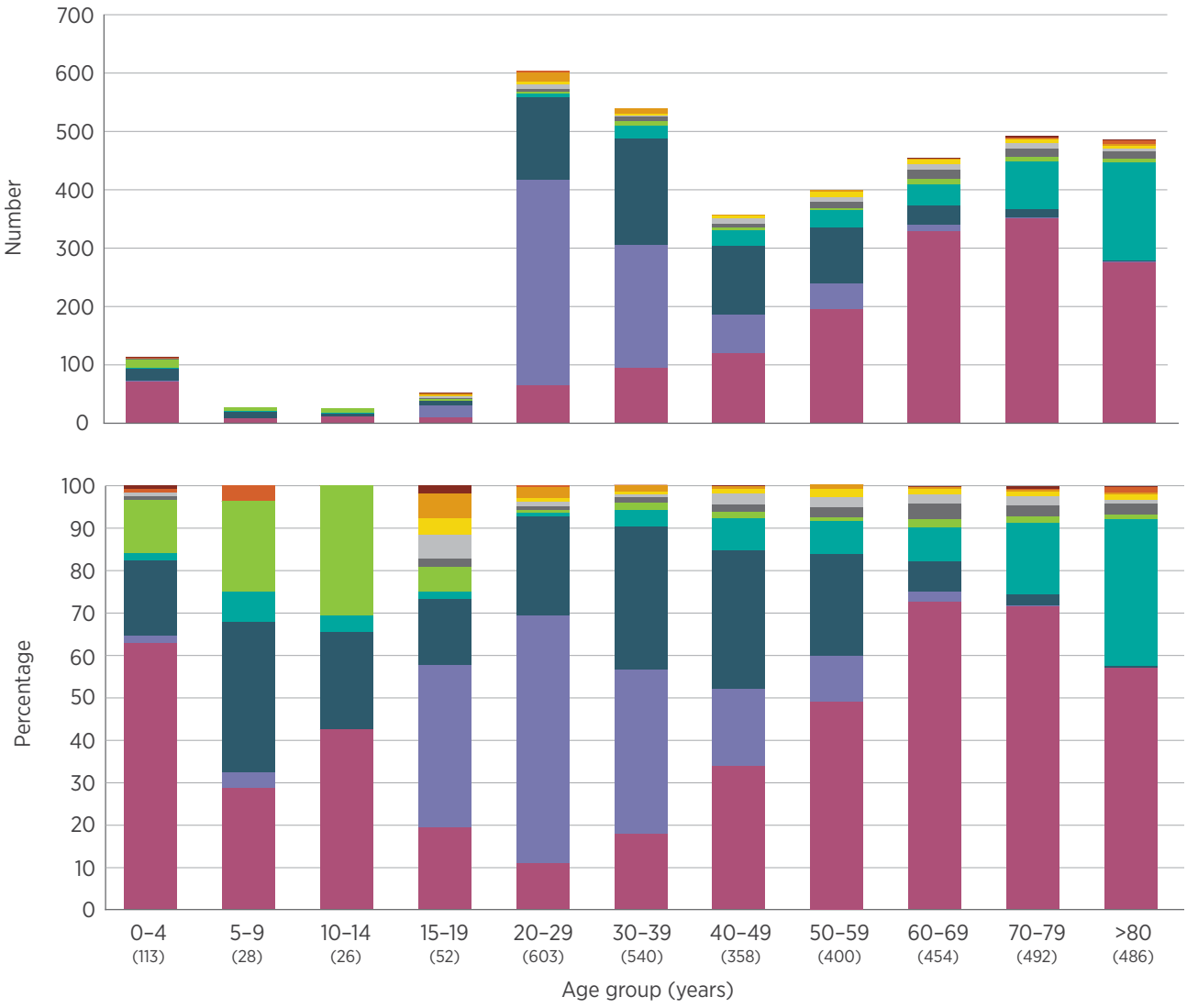
- Approximately half were from clinical specimens (416/886, 47% in 2019; 339/648, 52% in 2020)
- 58–63% of isolates from clinical specimens were from urine (242/416 in 2019; 212/339 in 2020)
- 10–12% of isolates from clinical specimens were from blood cultures (49/416 in 2019; 33/339 in 2020).

CPE comprised 77–88% of all CARs confirmed from blood specimens, highlighting the clinical spectrum of CPE infections compared with other CARs. These infections also have higher mortality rates.[1]

Carbapenemase-producing Enterobacterales (CPE) comprised 77–88% of all critical antimicrobial resistances (CARs) confirmed from blood specimens, highlighting the different clinical spectrum of CPE infections compared with other CARs.

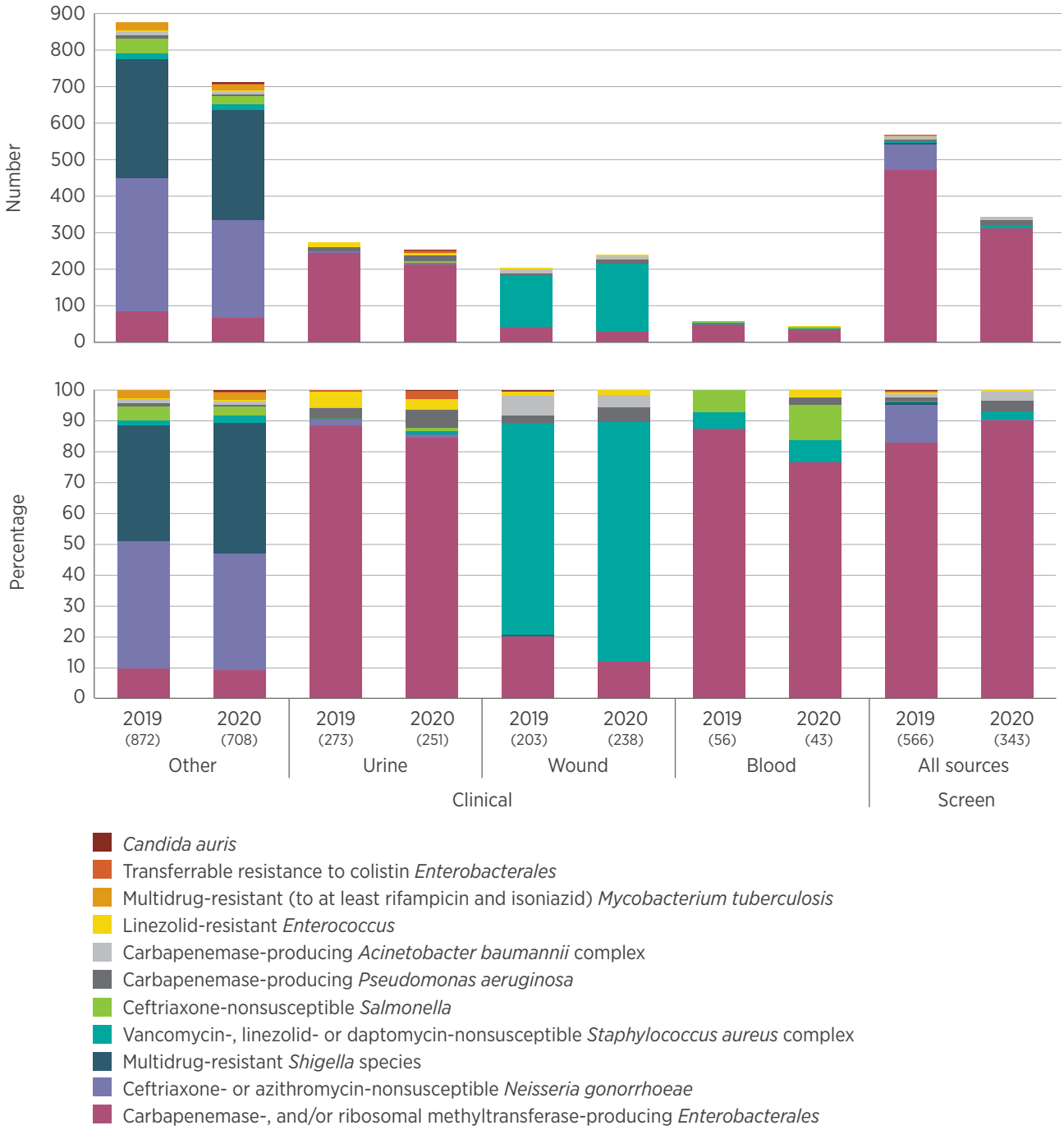
Four other CARs were also reported from blood cultures in 2019 and 2020: ceftriaxone-nonsusceptible *Salmonella* species (*n* = 4 in 2019; *n* = 5 in 2020), daptomycin-nonsusceptible *S. aureus* (*n* = 3 in 2019; *n* = 3 in 2020), linezolid-nonsusceptible *E. faecalis* (*n* = 1 in 2020) and carbapenemase-producing *P. aeruginosa* (*n* = 1 in 2020). Urine is an important specimen for certain CARs, such as CPE, because the urinary tract is a common site of infection.

Figure 5.4: Critical antimicrobial resistances, by age group, 2019–20



Note: Numbers of isolates in each age group are in brackets.
Source: CARAlert (as at 31 January 2021)

Figure 5.5: Critical antimicrobial resistances, by specimen type, 2019–20



Notes:
1. 'Other' refers to specimen types other than urine, wound or blood, such as genital, faecal or respiratory tract.
2. Numbers of isolates are in brackets.

Source: CARAlert (as at 31 January 2021)

Critical antimicrobial resistances by facility type

Excluding azithromycin-nonsusceptible *N. gonorrhoeae*, multidrug-resistant *Shigella* species and multidrug-resistant *M. tuberculosis*, which are generally isolated in the community, a substantial majority of CARs (995/1,137, 88% in 2019; 748/923, 81% in 2020) were detected in either hospitalised patients or hospital outpatients. Smaller proportions were isolated in the community (101/1,137, 9% in 2019; 126/923, 14% in 2020) and in aged care homes (41/1,137, 4% in 2019; 49/923, 5% in 2020) (Figure 5.6).

CPE accounted for 65–75% of those CARs that are mostly healthcare associated. Where the setting was known, 5–8% of CPE reports were from community settings, and 2% were from aged care homes.

For CARs normally associated with community infections, a little more than half were ceftriaxone- or azithromycin-nonsusceptible *N. gonorrhoeae* in 2019 (435/790, 55%); in 2020, multidrug-resistant *Shigella* species were more common (299/586; 51%). Almost one-third of these CARs were detected in either hospitalised patients or hospital outpatients.

In the community, almost three-quarters of reports were ceftriaxone- or azithromycin-nonsusceptible *N. gonorrhoeae* (46–53%) or multidrug-resistant *Shigella* species (21–29%). Almost all reports from aged care homes were daptomycin-nonsusceptible *S. aureus* (54–71%) or CPE (27–41%).

Excluding azithromycin-nonsusceptible Neisseria gonorrhoeae*, multidrug-resistant* Shigella *species and multidrug-resistant* Mycobacterium tuberculosis*, which are generally isolated in the community, the majority of critical antimicrobial resistances (81–88%) were detected in either hospitalised patients or hospital outpatients.*

Critical antimicrobial resistance type by species

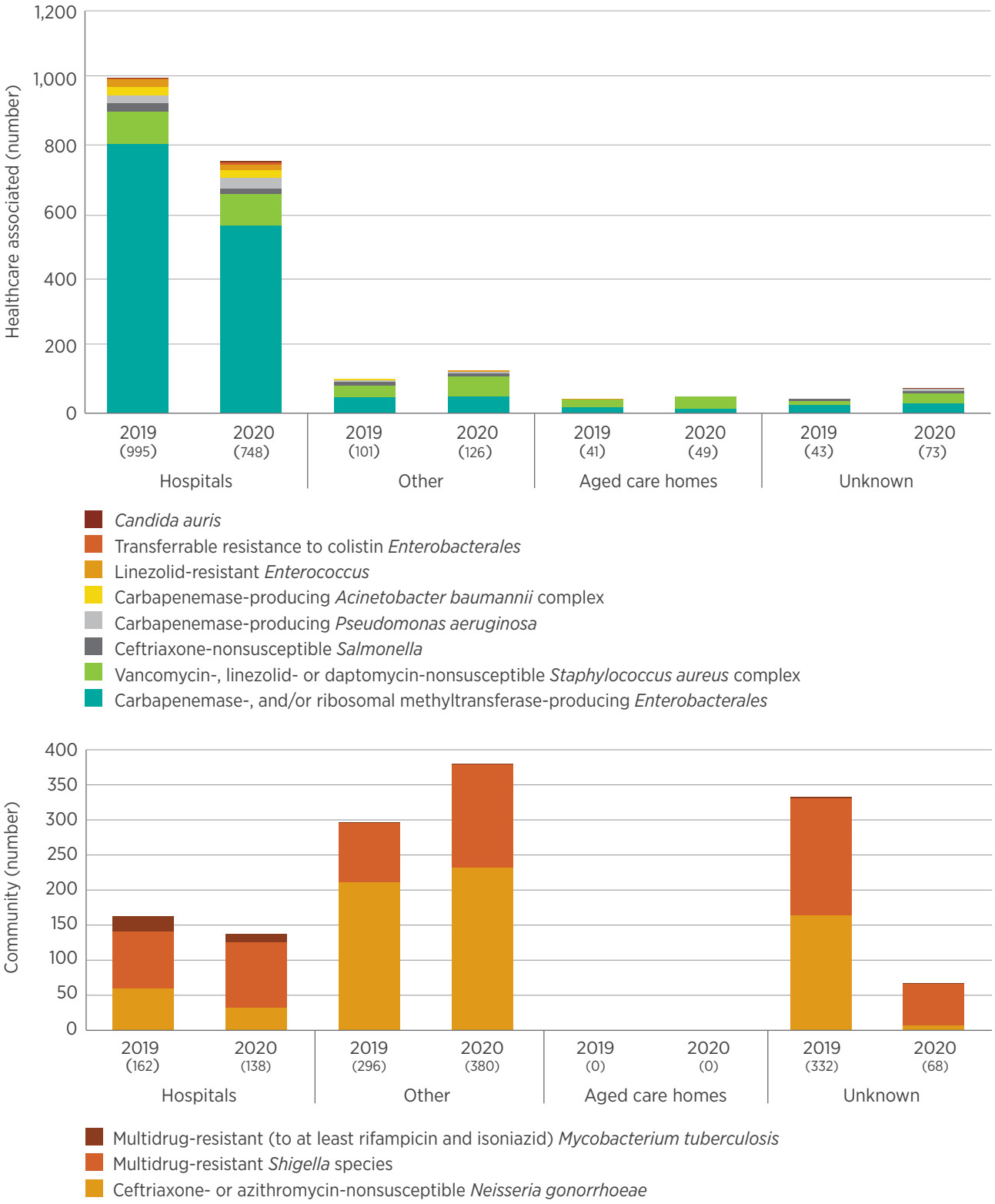
Enterobacterales – carbapenemases

Eight carbapenemase types were reported throughout Australia during 2019 and 2020. There were notable regional differences in the distribution of the top five carbapenemases (Table 5.3).

Three carbapenemase types (IMP, NDM and OXA-48-like) accounted for 96% of all *Enterobacterales* with a confirmed carbapenemase, either alone or in combination, in both 2019 and 2020.

IMP types decreased by 21% in 2020 compared with 2019, although there was a 64% increase in reports from WA. No IMP-producing *Enterobacterales* were reported from SA. IMP types accounted for 78–83% of all CPE reported from Queensland. All the strains that have been genetically sequenced to date (247/505, 49% in 2019; 216/397, 54% in 2020) were $bla_{\text{IMP-4}}$ (n = 436), $bla_{\text{IMP-26}}$ (n = 1) or IMP-4-like (n = 26).

Figure 5.6: Critical antimicrobial resistances, by association and facility type, 2019–20



Notes:
1. 'Other' refers to community (non-hospital and non–aged care home).
2. Numbers of isolates are in brackets.

Source: CARAlert (as at 31 January 2021)

Table 5.3: Top five carbapenemase types, number reported by state and territory, 2019–20

Carbapenemase type	Year	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
IMP	*Total*	*383*	*217*	*249*	*0*	*37*	*1*	*2*	*13*	*902*
	2019	207	134	142	0	14	0	2	6	505
	2020	176	83	107	0	23	1	0	7	397
NDM	*Total*	*126*	*171*	*41*	*50*	*20*	*1*	*8*	*3*	*420*
	2019	75	92	24	37	11	0	5	2	246
	2020	51	79	17	13	9	1	3	1	174
OXA-48-like	*Total*	*53*	*97*	*22*	*13*	*8*	*1*	*0*	*2*	*196*
	2019	30	65	13	6	2	1	0	1	118
	2020	23	32	9	7	6	0	0	1	78
KPC	*Total*	*3*	*12*	*3*	*1*	*0*	*2*	*0*	*0*	*21*
	2019	2	10	3	1	0	2	0	0	18
	2020	1	2	0	0	0	0	0	0	3
IMI	*Total*	*2*	*7*	*2*	*1*	*0*	*0*	*0*	*0*	*12*
	2019	0	4	2	1	0	0	0	0	7
	2020	2	3	0	0	0	0	0	0	5

Note: Number reported by state and territory includes genes detected alone or in combination with another type.
Source: CARAlert (as at 31 January 2021)

NDM types, either alone or in combination, were found in all states and territories. There was a 29% decrease in reports of NDM types in 2020 compared with 2019. In SA, NDM types accounted for more than two-thirds (37/45, 82% in 2019; 13/20, 65% in 2020) of all CPE reported. Four different genes were found in the strains sequenced (104/246, 42% in 2019; 122/174, 70% in 2020): *bla*$_{\text{NDM-5}}$ (118/226; 52%), *bla*$_{\text{NDM-1}}$ (68/226; 30%), *bla*$_{\text{NDM-4}}$ (23/226; 10%) and *bla*$_{\text{NDM-7}}$ (17/226; 8%).

Reports of OXA-48-like CPE decreased by 34% in 2020 compared with 2019. More than 65% (128/196) of the isolates with OXA-48-like types were sequenced. Five genes were reported; the most common was *bla*$_{\text{OXA-181}}$ (56/128; 44%), followed by *bla*$_{\text{OXA-48}}$ (41/128; 32%), *bla*$_{\text{OXA-232}}$ (24/128; 19%), *bla*$_{\text{OXA-244}}$ (6/128; 5%) and *bla*$_{\text{OXA-484}}$ (1/128; 1%).

Fifty-seven per cent of KPC types were from Victoria (12/21), most of which were reported in 2019 (n = 10). There were also reports from NSW (n = 3), Queensland (n = 3), Tasmania (n = 2) and SA (n = 1). Just under two-thirds of the isolates were sequenced (13/21; 62%); almost all were *bla*$_{\text{KPC-2}}$ (12/13). The *bla*$_{\text{KPC-33}}$ gene was detected in a *Klebsiella pneumoniae* isolated from a patient in a Victorian aged care home.

IMI types were reported from four states. Three genes were found in 10 of the sequenced isolates: *bla*$_{\text{IMI-1}}$ (n = 6), *bla*$_{\text{IMI2}}$ (n = 2) and *bla*$_{\text{IMI-6}}$ (n = 2).

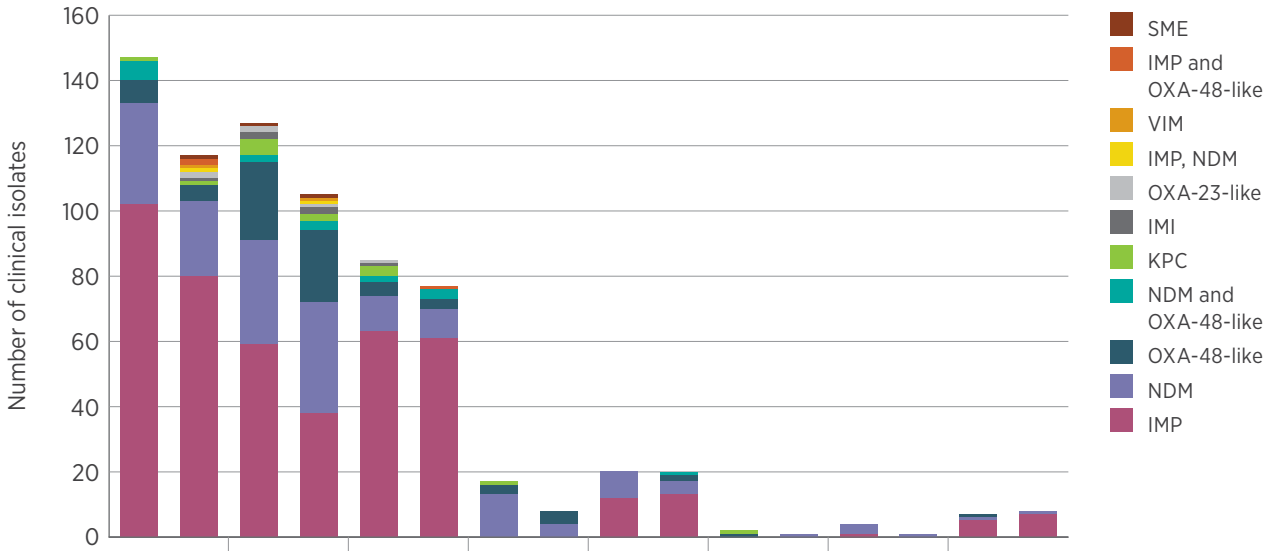
Co-production of carbapenemase was seen at low levels (22/878, 2.5% in 2019; 21/646, 3.3% in 2020). The co-produced genes in 2019–20 were NDM+OXA-48-like (*n* = 33), IMP+NDM (*n* = 6) and IMP+OXA-48-like (*n* = 4).

There were notable variations between states and territories in the carbapenemase types reported from clinical specimens (Figure 5.7). The proportions of CPE overall that were from screening cultures also differed; this may reflect differences in approaches to screening practices.

Carbapenemases were found in 31 species (13 genera) of *Enterobacterales*. IMP types alone accounted for 58–60% (505/878 in 2019; 387/646 in 2020) of all carbapenemases; they were found in 27 different species (Figure 5.8). *Enterobacter cloacae* complex accounted for 52–55% (278/505 in 2019; 203/387 in 2020) of all IMP types and 31–32% (278/878 in 2019; 203/646 in 2020) of all CPE. However, in Queensland, more than half (94/182, 52% in 2019; 72/129, 56% in 2020) of all CPE reported were *E. cloacae* complex containing IMP types.

NDM carbapenemase types were found mainly in *Escherichia coli* (54–59%), and OXA-48-like types in *E. coli* and *K. pneumoniae* (44% for *E. coli*; 43–46% for *K. pneumoniae*). When both NDM and OXA-48-like types were found together, they were mainly in *E. coli* (64–77%).

Figure 5.7: *Enterobacterales*, carbapenemase types from clinical isolates, by state or territory, 2019–20



	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
	NSW		Vic		Qld		SA		WA		TAS		NT		ACT	
Total	304	253	301	197	182	129	45	20	27	33	3	2	7	3	9	9
Clinical, *n*	147	117	127	105	85	77	17	8	20	20	2	1	4	1	7	8
Screen, *n*	157	136	174	92	97	52	28	12	7	13	1	1	3	2	2	1
Screen, %*	51.6	53.8	57.8	46.7	53.3	40.3	62.2	60.0	25.9	39.4	nd	nd	nd	nd	nd	nd

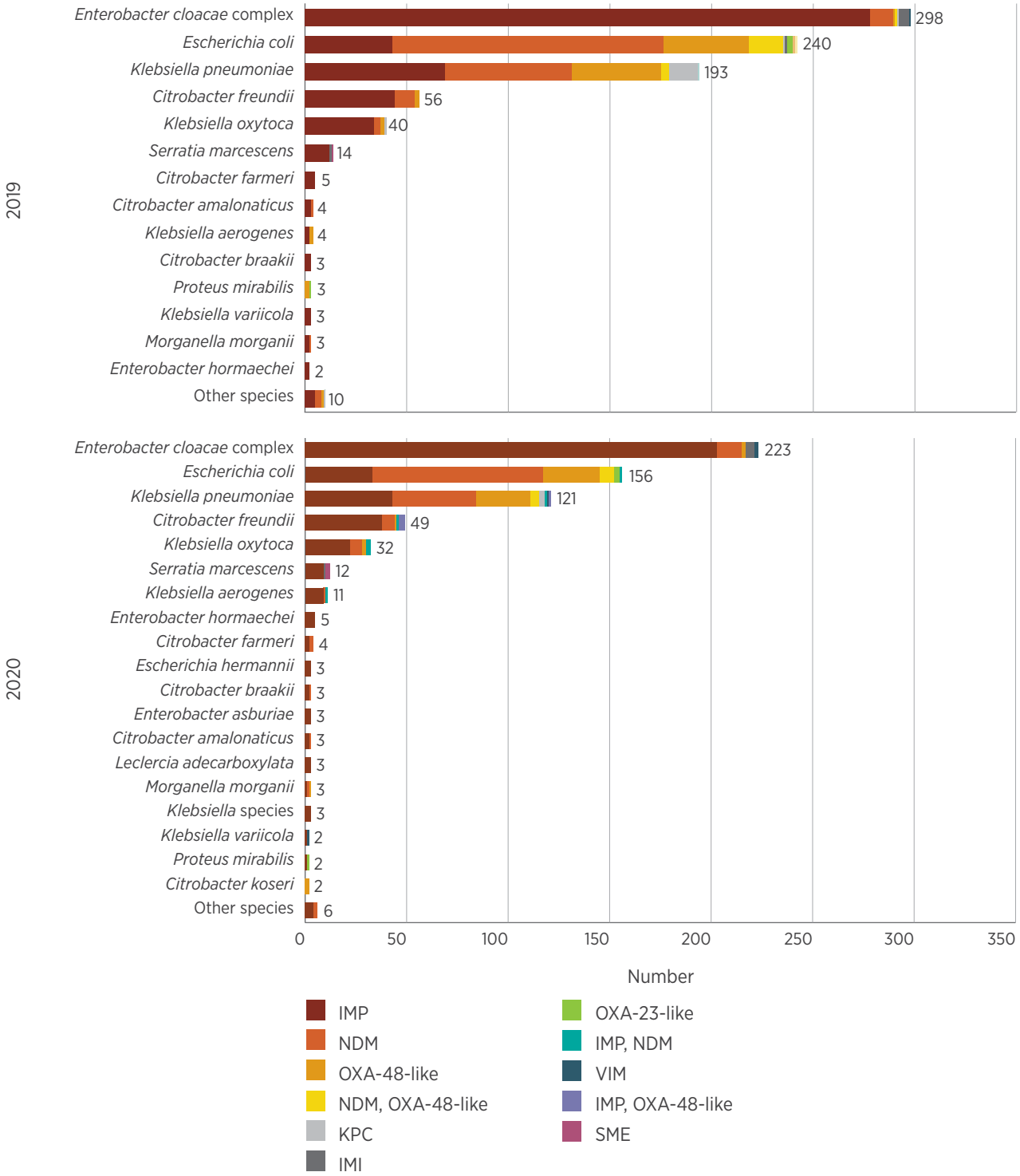
nd = insufficient numbers (<10)

* Number of screening cultures as a proportion of total number of carbapenemase-producing *Enterobacterales* (CPE), where 10 or more CPE were reported per year.

Source: CARAlert (as at 31 January 2021)

Figure 5.8: Carbapenemase-producing *Enterobacterales*, 2019–20

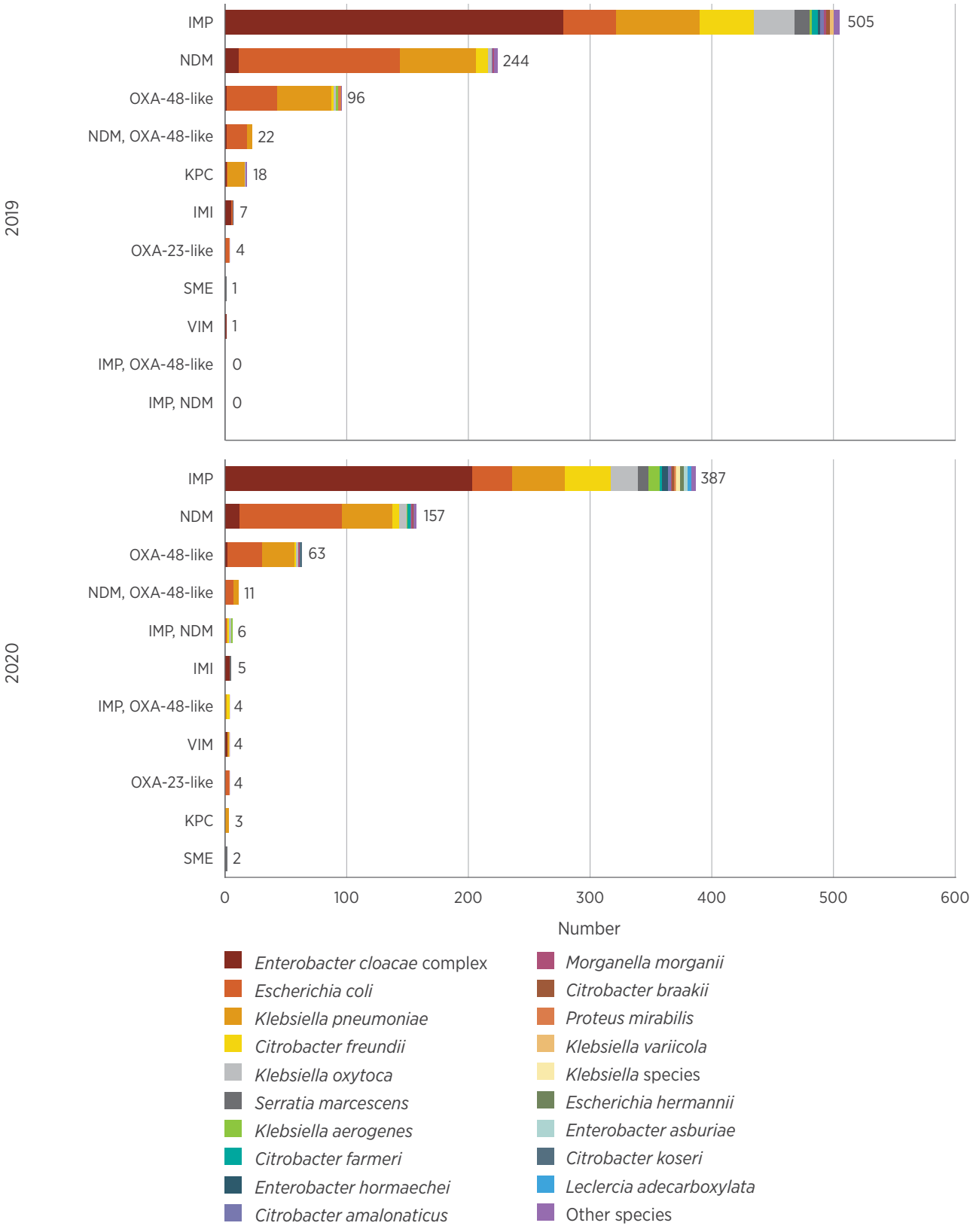
By species and carbapenemase type



continues

Figure 5.8: *continued*

By carbapenemase type and species



Source: CARAlert (as at 31 January 2021)

Enterobacterales – ribosomal methyltransferases

RMTs were detected in 81 isolates of *Enterobacterales*, representing five species; 88% (71/81) of these also had a carbapenemase. The RMTs were mostly found among *K. pneumoniae* (42/81; 52%) and *E. coli* (33/81; 41%). Four RMT genes were found: *rmtB* (*n* = 42; 52%), *armA* (*n* = 22; 27%), *rmtF* (*n* = 9; 11%) and *rmtC* (*n* = 8; 10%).

Enterobacterales – transmissible resistance to colistin

A vast majority of transmissible resistance to colistin (MCR) was reported in isolates that co-produced a carbapenemase (112/124; 90%). Associated carbapenemase types were $bla_{\text{IMP-4}}$ (*n* = 101), $bla_{\text{NDM-1}}$ (*n* = 6), $bla_{\text{NDM-7}}$ (*n* = 2), $bla_{\text{OXA-48}}$ (*n* = 2) and $bla_{\text{IMP-4}}$+$bla_{\text{NDM-7}}$ (*n* = 1). All isolates co-producing a carbapenemase harboured either *mcr-9.1* (*n* = 110) or *mcr-10.1* (*n* = 2). The *mcr-9* gene has recently been found among several species of *Enterobacterales*[2], often on an IncHI2 plasmid, and the expression of *mcr-9* was inducible by sub-inhibitory concentrations of colistin. Preliminary evidence suggests that *mcr-9.1* is frequently not expressed.[1] Three-quarters of the *Enterobacterales* species that co-produced a carbapenemase were *E. cloacae* complex (85/112; 76%).

Twelve isolates with MCR alone were reported since July 2019. Three *E. coli* harboured *mcr-1.1* in 2019; nine *E. cloacae* complex harboured *mcr-10.1* (*n* = 5) or *mcr-9.1* (*n* = 4) in 2020.

Neisseria gonorrhoeae

Almost all (691/706; 98%) of the CAR types associated with *N. gonorrhoeae* were azithromycin-nonsusceptible (LLR). Eight azithromycin-nonsusceptible *N. gonorrhoeae* (high-level resistance) (*n* = 7 in 2019; *n* = 1 in 2020) were reported from all states and territories except SA, NT and the ACT. Seven ceftriaxone-nonsusceptible types (*n* = 4 in 2019; *n* = 3 in 2020) were reported from Victoria (*n* = 4), NSW (*n* = 2) and WA (*n* = 1).

Shigella species – multidrug-resistant

Additional information provided on multidrug-resistance types in *Shigella* was reported from July 2019. Based on ceftriaxone susceptibility, extended-spectrum β-lactamase (ESBL) or plasmid-mediated AmpC (pAmpC) type was notified.

In 2019, just over three-quarters (199/258; 77%) of multidrug-resistant *S. sonnei* were resistant to any three of ampicillin, azithromycin, ciprofloxacin or trimethoprim–sulfamethoxazole, but susceptible to ceftriaxone. However, since October 2019, ceftriaxone resistance was increasingly reported. In 2020, almost 2 in 3 were ESBL producers (177/274; 65%); almost all ESBLs were determined to belong to the CTX-M-9 group (166/170; 98%), specifically $bla_{\text{CTX-M-27}}$ (157/160). Reports of $bla_{\text{CTX-M-27}}$ increased 10-fold in 2020 (*n* = 157) compared with 2019 (*n* = 15), with a prolonged clonal outbreak of ESBL *S. sonnei* associated with men who have sex with men.

The majority of multidrug-resistant *S. flexneri* were ceftriaxone-susceptible (21/26, 81% in 2019; 13/23, 57% in 2020). However, both ESBL (CTX-M) and pAmpC (bla_{DHA}) types were detected in low numbers. Five of six pAmpC were reported from Queensland, and four of eight ESBLs were from WA.

Staphylococcus aureus

Almost all (374/377; 99%) CARs reported for *S. aureus* were daptomycin-nonsusceptible strains. Two linezolid-nonsusceptible strains were confirmed from patients residing in Queensland (2020); one daptomycin- and vancomycin-nonsusceptible *S. aureus* strain was reported from a patient residing in NSW (2020).

Salmonella species – ceftriaxone-non-susceptible (MIC >1 mg/L)

The vast majority of ceftriaxone-nonsusceptible *Salmonella* species were reported from NSW (26/75; 35%), Queensland (24/75; 32%) and WA (12/75; 16%). There were no reports of this CAR from Tasmania or the ACT in 2019–20.

Between 87% and 91% of ceftriaxone-nonsusceptible *Salmonella* reports were from non-typhoidal species (41/45 in 2019; 26/30 in 2020). Typhoidal species were reported from NSW (*n* = 7) and Victoria (*n* = 1).

The ceftriaxone-nonsusceptible *Salmonella* species contained an ESBL (42/75; 56%), pAmpC (32/75; 43%), or both ESBL and pAmpC (1/75). ESBL types dominated reports from all states and territories except Queensland, where 79% (19/24) of reports were pAmpC. Where the variant was determined, the ESBLs were CTX-M types, and pAmpC were all CMY.

Pseudomonas aeruginosa – carbapenemases

All states and territories except the NT reported carbapenemase-producing *P. aeruginosa* since July 2019. Six carbapenemase types (GES, VIM, IMP, NDM, KPC and AIM) were reported. Seventy-seven per cent (55/71) contained GES (*n* = 35; 49%), either alone (*n* = 34) or in combination with IMP (*n* = 1); or VIM (*n* = 20; 28%), either alone (*n* = 19) or in combination with NDM (*n* = 1). Other types reported include IMP (*n* = 6), NDM (*n* = 6) and IMP+NDM (*n* = 1). In 2019, bla_{KPC-2} was reported from two patients residing in NSW. In 2020, bla_{AIM-1} was detected for the first time in a patient residing in SA.

Acinetobacter baumannii – carbapenemases

Carbapenemase-producing *A. baumannii* were reported from five states and territories since July 2019, with no reports from SA, Tasmania or the ACT. Three carbapenemase types (OXA-23-like, NDM and OXA-58) were found. Almost all (56/57; 98%) contained OXA-23-like, either alone (*n* = 48) or in combination with NDM (*n* = 3), or NDM alone (*n* = 5). The bla_{NDM-1} gene was the only NDM variant reported. Ten carbapenemase-producing *A. baumannii* also harboured a ribosomal methyltransferase (*armA*).

5.3 Commentary

Carbapenemase-producing *Enterobacterales*

CPE continue to be dominated by those of the IMP type, found most often in the *E. cloacae* complex. IMP-producing *Enterobacterales* were reported from 132 public and private hospitals throughout Australia in 2019, and 130 in 2020, compared with 120 hospitals in 2018. NDM-producing *Enterobacterales* were reported from all states and territories. There was an increase in reports during 2019, and a decrease during 2020. Although NDM types are generally thought to be acquired overseas, identification of local transmission and appropriate control action are important priorities.

The differences between states and territories in the proportion of screening isolates may indicate local variations in surveillance, infection prevention and control, and screening practices. Local outbreaks during 2019 and 2020 are likely to have required increased infection prevention and control, and surveillance resources in affected hospitals over short periods of time. The impact of outbreaks such as these on other aspects of hospital work and patient flows may be substantial in the absence of timely prevention and control action.

The variation between states and territories in reports of CPE as a proportion of all CARs, and the frequency of reporting of CPE, indicates the need for local decisions about

containment priorities. The Commission's *Recommendations for the control of carbapenemase-producing* Enterobacterales *(CPE): A guide for acute care health facilities*[3] and relevant local guidance provide a framework for responding to CPE.

A total of 4.6% of all CPE reports (71/1,534) occurred in the 0–4-year age group. The mode of acquisition of these CARs is not known; however, CPE outbreaks can occur in the neonatal intensive care unit setting. The long-term impact of this type of resistance on neonates is unknown. Education of clinicians on the risks of neonatal acquisition of antimicrobial-resistant organisms, and review of the appropriateness of antimicrobial use and infection control in the neonatal care setting are encouraged.

Critical antimicrobial resistances in aged care homes

From 2019 to 2020, there was a small increase in the number of CARs reported from aged care homes (*n* = 41 in 2019; *n* = 49 in 2020). In both years, the majority of these were daptomycin-nonsusceptible *S. aureus* (53.7% in 2019; 71.4% in 2020). There were 17 reports of CPE in aged care homes in 2019 and 13 reports in 2020, of which 80% (*n* = 24) were from clinical isolates.

Skin and soft tissue infections are commonly caused by *S. aureus*, which is spread by contact with contaminated surfaces and hands of care workers; this is why environmental cleaning and hand hygiene are so important. *S. aureus* can also be spread from person to person, especially in group living situations such as aged care homes where people with skin infections may inadvertently share personal items such as bed linen, towels or clothing. In aged care homes, skin and soft tissue infections are one of the most common reasons for antimicrobial prescriptions.[4] In some states and territories, the number of reports of this CAR in *S. aureus* from aged care homes was higher than, or similar to, reports from hospitals. These results may reflect variation between laboratories in the testing for, and reporting of, this CAR. More than 70% (41/57) of the reports of this CAR in aged care homes were reported from one Queensland laboratory.

There is a risk of transmission of these CARs in aged care homes and in hospitals due to the frequent movement of aged care home residents between these two settings. Control of CPE requires specific infection prevention and control measures in all care settings, including aged care homes. Compliance with the infection prevention and control requirements of the Aged Care Quality Standards, which include compliance with national guidelines, will support capacity to control and prevent transmission of CPE in aged care homes.[5] In addition, aged care homes should ensure that they implement policies and practices consistent with specific CPE prevention and control guidance.

Multidrug-resistant *Shigella* species

Reports of multidrug-resistant *Shigella* species increased during 2019, peaked in April 2019, and had halved by the third quarter of 2019. The majority of reports in 2019 were from Victoria (38/51; 75%). Reports of this CAR then doubled and peaked again in January 2020, followed by a sharp decrease in April 2020. The majority of reports in 2020 were from NSW (35/57; 61%). This decrease corresponded with the introduction of COVID-19 restrictions in Australia.

Increases in reports of multidrug-resistant *Shigella* species suggest that empirical antimicrobial therapy recommendations for shigellosis may need to be reconsidered. These increases also require ongoing close review by states and territories as there are limited oral antimicrobial options, and

intravenous antimicrobials may be required to treat multidrug-resistant infections. There may also be resource implications for the health system because of increased testing, hospital admissions and transmission in the community. Public health messaging should continue to highlight the risk of sexual transmission of *Shigella* species, particularly in men who have sex with men, and provide guidance on ways to reduce the risk of transmission.

Reports of multidrug-resistant Shigella *species increased during 2019, peaked in April 2019, and had halved by the third quarter of 2019. Reports of this critical antimicrobial resistance then doubled and peaked again in January 2020, followed by a sharp decrease in April 2020. This decrease corresponded with the introduction of COVID-19 restrictions in Australia.*

Neisseria gonorrhoeae

Seven *N. gonorrhoeae* isolates had ceftriaxone non-susceptibility in 2019–20. In 2019 and 2020, there were reports from a number of other countries of *N. gonorrhoeae* strains with resistance to ceftriaxone, and global concerns about the effectiveness of current recommended treatments.[6-8] In Australia, the recommended treatment for *N. gonorrhoeae* is ceftriaxone in conjunction with azithromycin. This regimen was introduced in Australia in 2014 to limit further development of resistance to ceftriaxone.[9]

The low background rate of azithromycin-nonsusceptible *N. gonorrhoeae* (LLR) in Australia is well established. Reports of this CAR declined slightly during 2019 and 2020 in the context of 34,244 notifications of gonococcal infection nationally in 2019, and 29,517 notifications in 2020.[10] The clinical implications of this LLR are not clear. Continuing low numbers of reports of ceftriaxone non-susceptibility in 2019 (n = 4) and 2020 (n = 3), following six reported in 2018, indicate that ongoing monitoring of azithromycin and ceftriaxone non-susceptibility is required because of the importance of emerging changes in susceptibility for treatment guidelines. Use of antibiotics such as azithromycin is also associated with increased resistance in other organisms.[11]

Enterococcus species

Although numbers are low, reports of linezolid-nonsusceptible *Enterococcus* species increased from 2018 to 2019 and were stable in 2020 (n = 14, n = 22 and n = 19, respectively). There were only four reports of this CAR in 2017. *Enterococcus* species commonly cause urinary tract, biliary tract and other intra-abdominal infections, and bloodstream infections. This CAR, in addition to CPE, has the potential to become a significant problem in the future, if it is not prevented and controlled. Australia has a very high reported rate of vancomycin-resistant *E. faecium* compared with European countries.[12] Resistance in enterococci, similar to some CPE and other *Enterobacterales*, is transmitted in hospital environments from patients' bowel flora.

Other CARs remain at very low levels; however, ongoing prevention and control strategies and monitoring are essential to ensure that levels of these CARs continue to remain low in Australia.

5.4 Developments and future plans

The Commission's AURA team will continue to collaborate with relevant experts to enhance CARAlert as new resistances are identified, maintain CARAlert, and review reported CARs in collaboration with states, territories, the Australian Government Department of Health and clinical experts.

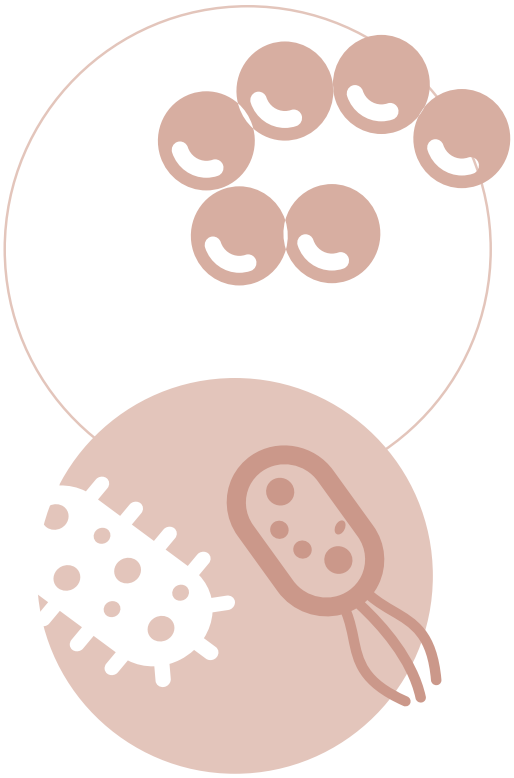
CARAlert data have implications for infection prevention and control programs that are implemented by health service organisations to meet the requirements of the National Safety and Quality Health Service Standards[13] – for example, in relation to CPE. The Commission will work with states and territories on strategies to promote consistency of screening and infection control practices to improve CPE containment.

The response to emerging CARs in aged care homes will be considered in liaison with the Aged Care Quality and Safety Commission, aged care provider organisations and general practitioners. The importance of infection prevention and control, and antimicrobial stewardship in this setting will be promoted, consistent with the mandatory Aged Care Quality Standards, with specific considerations for the response to CPE and other CARs.

Maintaining effective surveillance of resistance in *N. gonorrhoeae* and *Shigella* species, continuing programs for prevention and control of sexually transmissible infections, and implementing outbreak response strategies are all essential to minimise the spread of untreatable gonorrhoea and shigellosis.

The Commission's AURA team will also continue to prepare analyses of antimicrobial resistance data for, and liaise with, Therapeutic Guidelines Limited, the organisation that develops guidance on antimicrobial prescribing in Australia.

Maintaining effective surveillance of resistance in Neisseria gonorrhoeae *and* Shigella *species, continuing programs for prevention and control of sexually transmissible infections, and implementing outbreak response strategies are all essential to minimise the spread of untreatable gonorrhoea and shigellosis.*



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6

Chapter 6
Focus areas

Key findings

Antimicrobial resistance in northern Australia

- The HOTspots resistance surveillance program monitors antimicrobial resistance in the far north of Australia. The program shows that resistance rates of some important pathogens are higher in this region than in other parts of the country. Inclusion of resistance data from the Northern Territory (NT), for the first time, is an important development for the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System, increasingly incorporating data from across Australia and broadening the representativeness of the data.
- Methicillin-resistant *Staphylococcus aureus* is prevalent in northern Australia. In 2019, aggregate rates for northern Australia were 27.7% for blood isolates, compared with 17.7% nationally. Rates were higher for skin and soft tissue isolates (34.7%) than for blood isolates, and higher for community-based isolates (41.1%) than for hospital-based isolates (31.9%). Rates were higher in far north Western Australia (WA; 46.9%) than in the NT (34.6%) and far north Queensland (29.6%).
- In 2018–19, rates of resistance to fluoroquinolones in *Escherichia coli* in northern Australia were similar to national figures (HOTspots, 14.6–14.8%; national, 11.4–13.7%). In contrast, rates of resistance to third-generation cephalosporins (ceftriaxone or cefotaxime) were, in general, higher in northern Australia (8.3–18.2%) than nationally (8.0–11.9%). There have been upward trends in both of these resistances since 2015.
- Rates of erythromycin-resistant *Streptococcus pyogenes* have remained low (<2%) in far north WA, but have risen from 1.2% in 2015 to 8.0% in 2019 in far north Queensland.
- Rates of resistance to erythromycin and tetracycline in *Streptococcus pneumoniae* have been falling in far north WA, but remained stable in far north Queensland over the period 2015–2019.

continues

Impact of COVID-19 on antibiotic use in Australia during 2020

- Pharmaceutical Benefits Scheme data indicate that the COVID-19 pandemic had a profound impact on antimicrobial use in 2020, with a 40% drop in antimicrobials dispensed between March and April; use remained at this lower level for the rest of the year. The change was largely the result of a drop in antimicrobial dispensing for seasonal respiratory viral infections. These infections decreased as a result of COVID-19 community control measures.

International comparisons of antimicrobial resistance

- Although Australia's rates of fluoroquinolone resistance in *Escherichia coli* and *Klebsiella pneumoniae* remain very low compared with most European countries, resistance has increased since the establishment of AURA, when compared with some countries. Rates of resistance to third-generation cephalosporins in these two species in Australia are lower than the European average.
- Compared with European countries, rates of resistance in key gram-positive pathogens are moderate to high in Australia. The prevalence of vancomycin resistance in *Enterococcus faecium* remains higher in Australia than in more than 30 European countries, even though rates have levelled off in recent years.

International comparisons of antimicrobial use

- Australian hospital antimicrobial use, based on defined daily doses per 1,000 occupied bed days, is nearly four times that of the European country with the lowest use, the Netherlands, and considerably higher than that of Canada, which has a comparable healthcare system.
- Australia ranks seventh compared with European countries in its community use of antibacterial agents (defined daily doses per 1,000 people per day).

Clostridioides infection in Australia

- *Clostridioides difficile* infection (CDI) in Australia is characterised by a heterogeneous strain population, dominated by PCR ribotype (RT) 014 – the most common *C. difficile* strain type in humans and pig herds in Australia.
- Over the survey period, the majority of *C. difficile* in Australia did not show reduced susceptibility to antimicrobials recommended for treatment of CDI (vancomycin, metronidazole and fidaxomicin). Fidaxomicin demonstrated superior in vitro activity to vancomycin and metronidazole.
- Resistance to carbapenems and fluoroquinolones was low, and multidrug-resistant *C. difficile* was uncommon. However, clindamycin resistance was common, and one epidemic fluoroquinolone-resistant RT027 strain was detected.
- Continued surveillance of current and emerging *C. difficile* strains and antimicrobial resistance phenotypes is a key component in the strategy to understand and ultimately reduce the burden of CDI on global healthcare systems.

This chapter explores a number of key issues identified through the analyses undertaken for the Antimicrobial Use and Resistance in Australia (AURA) 2021 report of antimicrobial use (AU) and antimicrobial resistance (AMR) surveillance, and through new collaborations. These issues highlight the importance, and value, of surveillance data when analysed with the intent of informing policy and practice to prevent and contain AMR, and to improve patient care. They also indicate responses are required at both local and system levels.

6.1 Antimicrobial resistance in northern Australia

A new area of focus for AURA 2021 is the inclusion of resistance data from across northern Australia, as a result of collaboration with HOTspots, which provides an opportunity for analysis and reporting of resistance in more remote parts of Australia.[1] This focus area incorporates data collected through HOTspots, a component of the HOT North initiative.[2] HOT North is a research program funded by the National Health and Medical Research Council, and led by the Menzies School of Health Research, that aims to improve health outcomes in the tropical north through projects that link organisations, translate research into outcomes and create pathways for health professionals.

Overview of HOTspots structure

The HOTspots program was developed in 2018. The program is overseen by the HOTspots team and the HOTspots advisory committee, which is comprised of infectious diseases physicians, microbiologists and public health experts.

Participating regions comprise two northern regions of far north Western Australia (FN-WA; Kimberley and Pilbara), five regions that make up the Northern Territory (NT; Alice Springs, Barkly, Darwin, East Arnhem and Katherine) and five regions of far north Queensland (FN-Q; Cairns and Hinterland, Mackay, North West, Torres and Cape, Townsville).

Participating pathology services (Western Diagnostic Pathology, PathWest Laboratory Medicine WA, Territory Pathology, Pathology Queensland) provided data on all clinical specimens for which susceptibility testing was performed during the study period (2007–2019). Susceptibility tests were performed using either disc diffusion or commercial semi-automated broth microdilution (VITEK® 2 – bioMérieux, France). Data were generated using Clinical and Laboratory Standards Institute (CLSI) or European Committee on Antimicrobial Susceptibility Testing (EUCAST) breakpoints relevant for each year, depending on the contributing laboratory.

Data from FN-WA and FN-Q were provided with CLSI-interpreted values. FN-Q has reported its data using EUCAST breakpoints. Minimum inhibitory concentration (MIC) data were provided from Territory Pathology; these data were interpreted using CLSI breakpoints. Data from PathWest Laboratory Medicine WA were provided as susceptible or resistant; intermediate was included with resistant for all species. Pathology Queensland included intermediate with resistant, except for reporting penicillin and ceftriaxone susceptibility in *Streptococcus pneumoniae.*

In all laboratories, clindamycin resistance was inferred from erythromycin resistance, and a D-test for inducible-clindamycin resistance was only performed on request. Methicillin resistance in *Staphylococcus aureus* was inferred from resistance to oxacillin in laboratories in WA, cefoxitin in NT laboratories, and oxacillin or cefoxitin in FN-Q laboratories.

Results from HOTspots

HOTspots collected susceptibility data on 14 key pathogens from the relevant laboratory services for the period between between 2007 and 2019. Data were received from non-hospital healthcare settings (community) and public hospital settings (hospital). Specimen source, region and setting for the eight top-ranked isolates are shown in Table 6.1. Data from NT hospitals were not available for *Haemophilus influenzae*, *S. pneumoniae* or *S. pyogenes*.

Staphylococcus aureus

For all regions in northern Australia, the vast majority of samples of *S. aureus* isolates between 2015 and 2019 were from skin and soft tissue infections (FN-Q, 89–91%; FN-WA, 63–91%; NT, 94–96%).

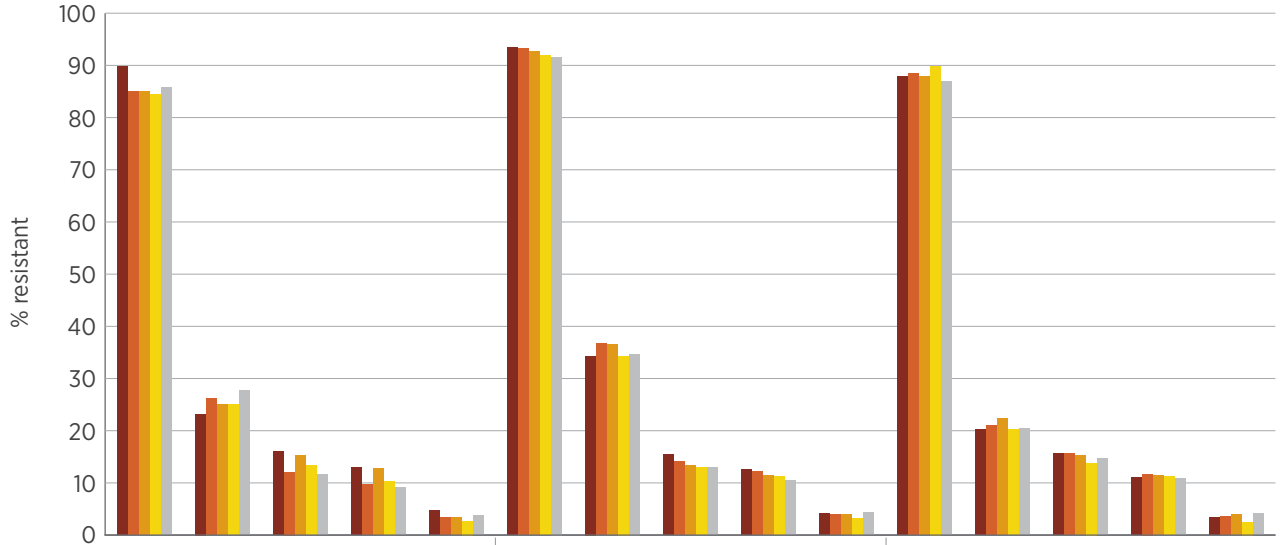
Overall, more than 88–93% of *S. aureus* isolates were resistant to benzylpenicillin in 2015–2019 (Figure 6.1). Oxacillin (methicillin) resistance was higher in specimens from skin and soft tissue infections (34–37%) than in specimens from blood (23–28%). Oxacillin resistance was higher in isolates from the community (Figure 6.2) and in isolates from FN-WA (41–47%) (Figure 6.3). Rates of resistance to erythromycin and clindamycin were more than twice as high in FN-WA and the NT as in FN-Q.

Table 6.1: Top eight organisms, specimen source, by region and setting, 2007–2019

Organism and specimen source	Far north Western Australia		Northern Territory		Far north Queensland		Total
	Community	Hospital	Community	Hospital	Community	Hospital	
Specimen source							
Urine	331,973	3,645	78,028	17,333	6,202	88,769	525,950
Skin and soft tissue	141,654	10,710	94,199	36,609	19,149	113,126	415,447
Respiratory	48,175	1,640	15,778	n/a	1,094	20,914	87,601
Blood	3,558	320	268	2,382	258	10,673	17,459
Species							
E. coli	286,419	3,172	66,362	14,674	5,172	73,314	449,113
S. aureus	132,190	7,159	68,115	31,819	10,393	76,668	326,344
S. pyogenes	23,765	3,805	28,523	n/a	8,524	27,756	92,373
P. aeruginosa	33,390	818	6,974	5,092	656	2,481	49,411
K. pneumoniae	33,107	495	8,556	3,954	854	15,411	62,377
H. influenzae	9,971	414	5671	n/a	644	8,448	25,148
S. pneumoniae	3,888	348	2,786	n/a	358	4,938	12,318
A. baumannii	804	22	678	785	100	2,094	4,483

n/a = not available
Note: Data were available from all contributing pathology services between 1 January 2015 and 31 December 2019.
Sources: Pathology Queensland, 2008–2019 (FN-Q); PathWest Laboratory Medicine WA, 2015–2019 (FN-WA); Territory Pathology, 2012–2019 (NT hospitals), Western Diagnostic Pathology, 2007–2019 (FN-WA community, NT community)

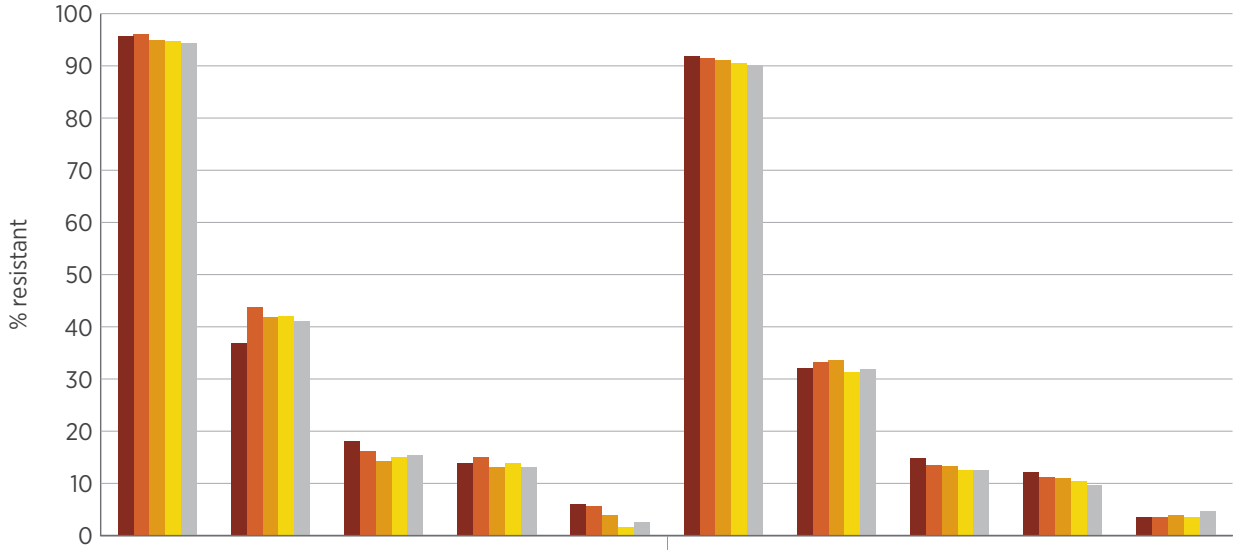
Figure 6.1: *Staphylococcus aureus* resistance in northern Australia, by specimen source, 2015–2019



	Blood					Skin and soft tissue					Other				
	PEN	OXA	ERY	CLN	SXT	PEN	OXA	ERY	CLN	SXT	PEN	OXA	ERY	CLN	SXT
2015, %	89.8	23.2	16.0	12.9	4.7	93.4	34.3	15.5	12.5	4.1	87.8	20.2	15.7	11.0	3.3
2016, %	85.0	26.2	12.1	9.7	3.4	93.3	36.7	14.1	12.2	4.0	88.4	21.0	15.6	11.7	3.5
2017, %	85.0	25.1	15.3	12.8	3.4	92.7	36.5	13.3	11.4	3.9	87.9	22.4	15.2	11.4	3.9
2018, %	84.4	25.1	13.3	10.3	2.7	91.9	34.3	12.9	11.2	3.2	89.9	20.3	13.8	11.2	2.5
2019, %	85.8	27.7	11.6	9.1	3.7	91.6	34.7	13.0	10.4	4.3	86.9	20.4	14.7	10.8	4.1
2015, *n*	362	452	450	449	450	12,977	15,648	15,862	15,723	15,302	1,209	1,235	1,227	1,159	1,180
2016, *n*	361	446	445	445	444	14,954	17,721	18,177	18,133	17,324	1,232	1,259	1,233	1,218	1,215
2017, *n*	354	446	445	445	445	14,969	18,113	18,196	18,229	18,218	1,263	1,284	1,282	1,268	1,289
2018, *n*	334	407	407	407	407	14,402	17,113	17,344	17,388	17,381	1,055	1,078	1,079	1,072	1,086
2019, *n*	394	483	483	483	483	14,558	17,441	17,484	17,599	17,575	1,134	1,201	1,155	1,157	1,163

CLN = clindamycin; ERY = erythromycin; OXA = oxacillin; PEN = penicillin; SXT = trimethoprim–sulfamethoxazole
Source: HOTspots (NT, Qld, WA)

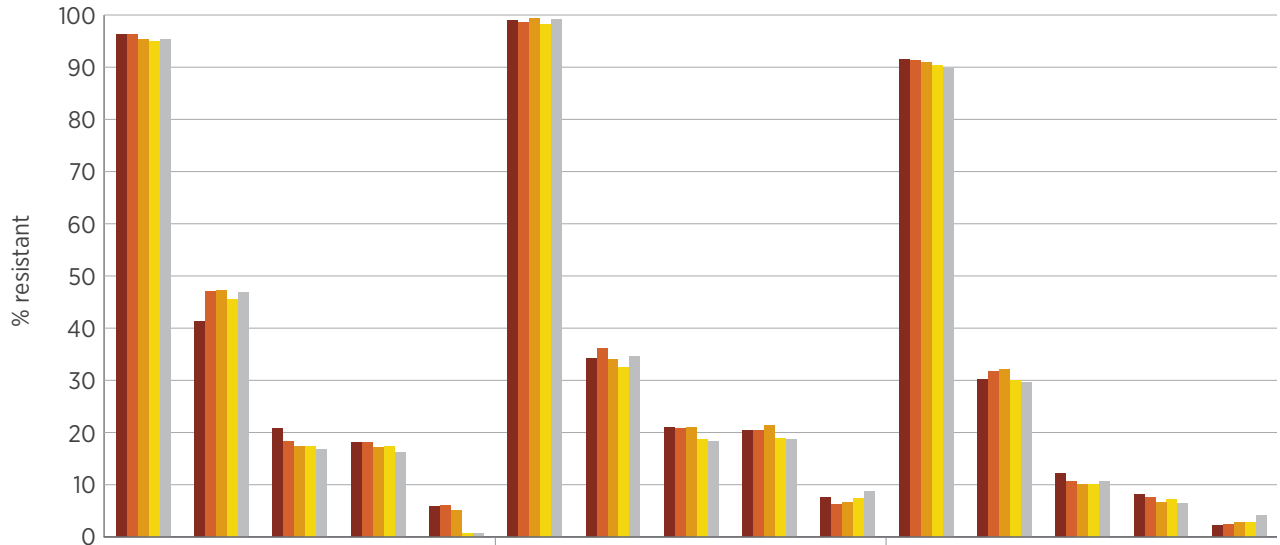
Figure 6.2: *Staphylococcus aureus* resistance in northern Australia, by setting, 2015–2019



	PEN	OXA	ERY	CLN	SXT	PEN	OXA	ERY	CLN	SXT
	Community					Hospital				
2015, %	95.7	36.9	18.1	13.8	6.0	91.8	32.1	14.8	12.1	3.6
2016, %	96.1	43.8	16.2	15.0	5.7	91.4	33.2	13.5	11.2	3.5
2017, %	94.9	41.8	14.2	13.2	4.0	91.2	33.7	13.3	11.0	3.9
2018, %	94.7	42.0	15.1	13.9	1.7	90.6	31.3	12.5	10.5	3.5
2019, %	94.3	41.1	15.4	13.1	2.5	90.1	31.9	12.5	9.7	4.7
2015, *n*	3,735	3,490	3,727	3,526	3,444	10,813	13,845	13,812	13,805	13,488
2016, *n*	4,681	4,156	4,650	4,580	4,194	11,866	15,270	15,205	15,216	14,789
2017, *n*	4,142	3,963	4,120	4,131	4,114	12,444	15,880	15,803	15,811	15,838
2018, *n*	3,819	3,503	3,795	3,813	3,809	11,972	15,095	15,035	15,054	15,065
2019, *n*	3,717	3,567	3,673	3,711	3,701	12,369	15,558	15,449	15,528	15,520

CLN = clindamycin; ERY = erythromycin; OXA = oxacillin; PEN = penicillin; SXT = trimethoprim–sulfamethoxazole
Source: HOTspots (NT, Qld, WA)

Figure 6.3: *Staphylococcus aureus* resistance in northern Australia, by state and territory, 2015–2019



	PEN	OXA	ERY	CLN	SXT	PEN	OXA	ERY	CLN	SXT	PEN	OXA	ERY	CLN	SXT
	Far north Western Australia					Northern Territory					Far north Queensland				
2015, %	96.3	41.3	20.8	18.1	5.8	98.9	34.2	20.9	20.5	7.6	91.4	30.1	12.1	8.1	2.2
2016, %	96.3	47.0	18.3	18.1	6.1	98.6	36.1	20.7	20.5	6.3	91.3	31.7	10.7	7.5	2.4
2017, %	95.3	47.2	17.3	17.1	5.0	99.3	34.1	20.9	21.3	6.7	91.0	32.0	10.1	6.7	2.8
2018, %	95.0	45.6	17.3	17.3	0.6	98.2	32.5	18.7	18.9	7.3	90.4	30.0	10.1	7.1	2.7
2019, %	95.3	46.9	16.8	16.2	0.6	99.2	34.6	18.3	18.6	8.7	89.8	29.6	10.6	6.4	4.1
2015, *n*	3,411	3,337	3,389	3,406	3,527	449	3,311	3,485	3,261	3,480	10,688	10,687	10,665	10,664	9,925
2016, *n*	4,003	3,747	3,941	3,949	3,967	436	3,571	3,839	3,785	3,841	12,108	12,108	12,075	12,062	11,175
2017, *n*	3,855	3,819	3,796	3,850	3,846	279	3,573	3,709	3,708	3,709	12,452	12,451	12,418	12,384	12,397
2018, *n*	3,483	3,378	3,426	3,476	3,471	340	3,252	3,462	3,462	3,462	11,968	11,968	11,942	11,929	11,941
2019, *n*	3,609	3,533	3,482	3,606	3,575	121	3,236	3,309	3,309	3,309	12,356	12,356	12,331	12,324	12,337

CLN = clindamycin; ERY = erythromycin; OXA = oxacillin; PEN = penicillin; SXT = trimethoprim–sulfamethoxazole
Note: Data on penicillin resistance from NT hospitals were not provided.
Source: HOTspots (NT, Qld, WA)

The rates of methicillin-resistant *S. aureus* (MRSA) were relatively steady across all three regions, although there were notable differences in the proportions of community and hospital infections (Figure 6.4). MRSA isolates from the NT were predominantly from hospitals, whereas those from FN-WA were mostly from community settings. In FN-Q, there was a steady decline in the proportion of MRSA from community settings; in 2019, it was lower than MRSA from hospital settings.

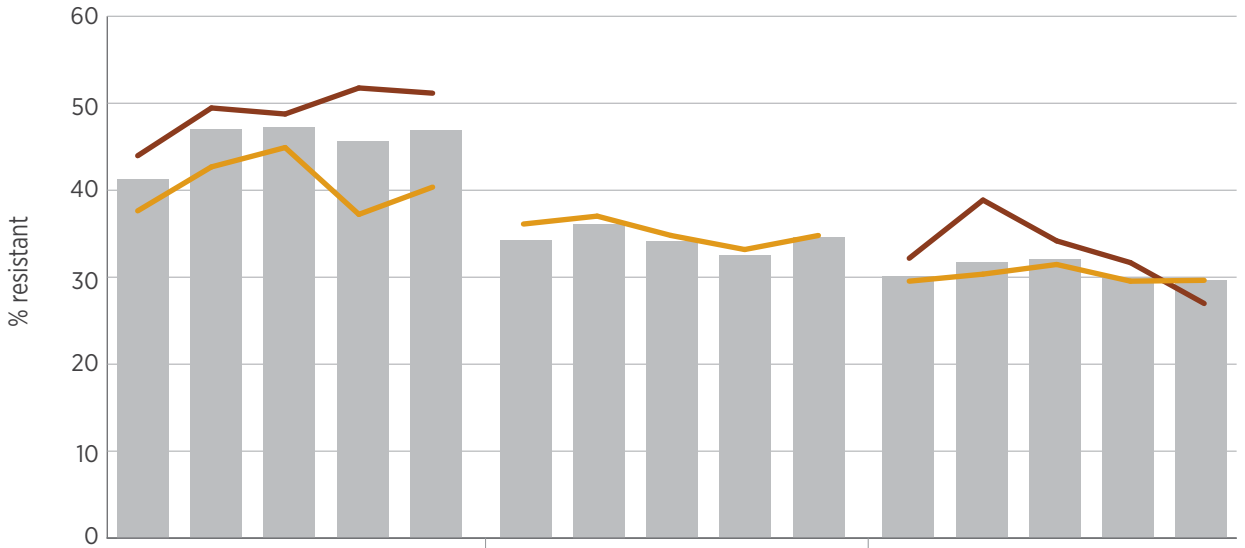
Escherichia coli

For *E. coli*, there were no substantial differences in resistances between specimen sources (Figure 6.5). Since 2015, resistance to ceftriaxone and fluoroquinolones (ciprofloxacin or norfloxacin) has been increasing in *E. coli*.

Rates of resistance to ampicillin/amoxicillin were higher in community settings than in hospitals (Figure 6.6). Rates of resistance to other agents were slightly higher in hospitals. Fluoroquinolone (ciprofloxacin or norfloxacin) resistance in community settings increased from 7.9% in 2015 to 14.1% in 2019.

The highest rates of resistance to ceftriaxone and fluoroquinolones were seen in FN-Q (Figure 6.7).

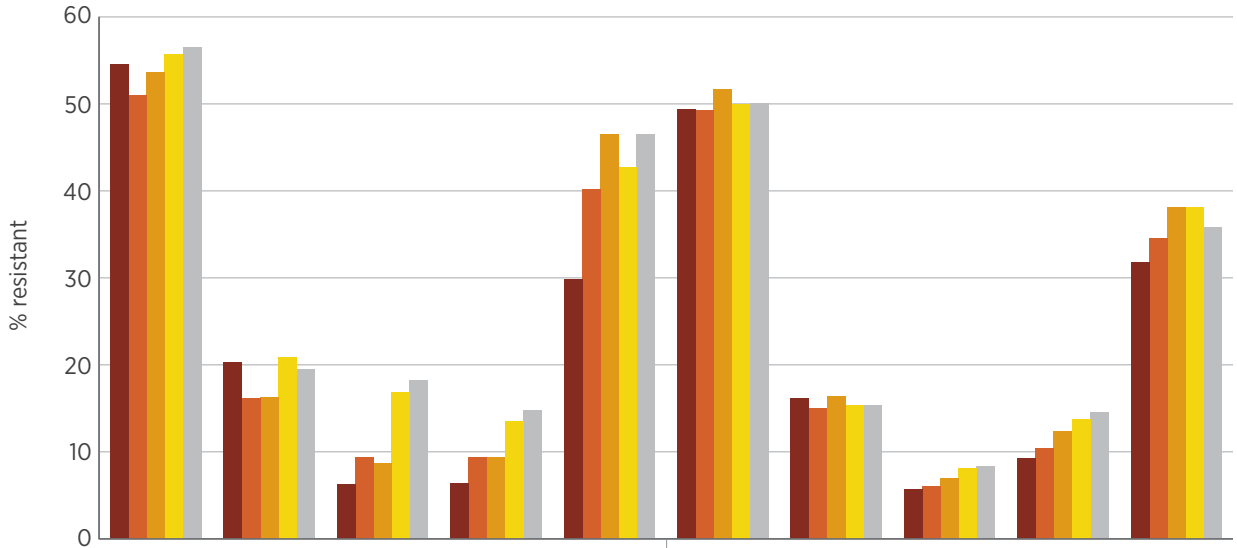
Figure 6.4: Methicillin-resistant *Staphylococcus aureus,* by region and setting, 2015–2019



	Far north Western Australia					Northern Territory					Far north Queensland				
	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019
Community, %R	43.9	49.4	48.7	51.7	51.1	na	na	na	na	na	32.1	38.8	34.1	31.6	26.9
Hospital, %R	37.8	42.8	45.0	37.4	40.5	36.3	37.2	35.0	33.4	35.0	29.8	30.6	31.7	29.8	29.9
Total, %R	41.3	47.0	47.2	45.6	46.9	34.2	36.1	34.1	32.5	34.6	30.1	31.7	32.0	30.0	29.6
Community, *n*	1,889	2,370	2,267	1,941	2,132	279	168	140	134	50	1,322	1,618	1,556	1,428	1,385
Hospital, *n*	1,448	1,377	1,552	1,437	1,401	3,032	3,403	3,433	3,118	3,186	9,365	10,490	10,895	10,540	10,971
Total, *n*	3,337	3,747	3,819	3,378	3,533	3,311	3,571	3,573	3,252	3,236	10,687	12,108	12,451	11,968	12,356

na = not available (incomplete data)
Note: Most of the data from the NT were from hospitals settings. Data from community settings was incomplete.
Source: HOTspots (NT, Qld, WA)

Figure 6.5: *Escherichia coli* resistance in northern Australia, by specimen source, 2015–2019



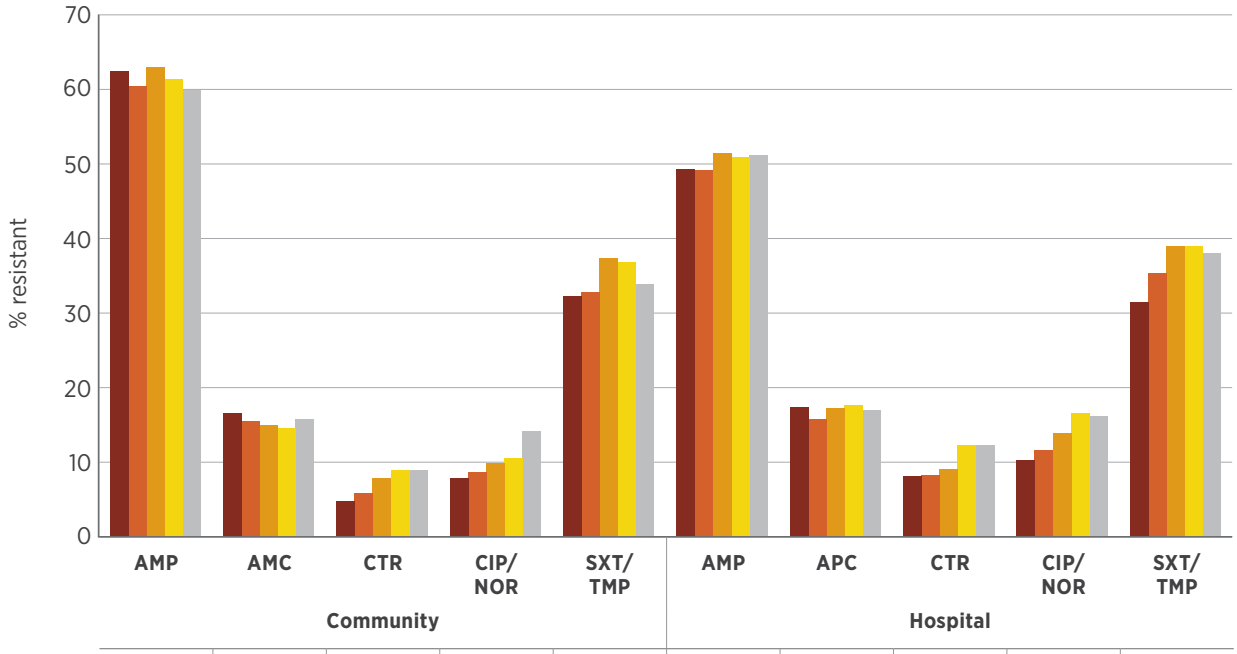
	AMP	AMC	CTR	CIP	SXT	AMP	APC	CTR	NOR	TMP
	Blood					Urine				
2015, %	54.6	20.3	6.3	6.4	29.8	49.4	16.2	5.7	9.2	31.8
2016, %	51.0	16.1	9.4	9.4	40.2	49.3	15.0	6.0	10.4	34.5
2017, %	53.6	16.3	8.7	9.4	46.5	51.7	16.4	7.0	12.4	38.1
2018, %	55.7	20.9	16.9	13.5	42.7	49.9	15.3	8.1	13.7	38.1
2019, %	56.5	19.5	18.2	14.8	46.5	50.1	15.4	8.3	14.6	35.8
2015, *n*	604	605	607	605	191	8,565	8,890	8,428	8,517	2,443
2016, *n*	626	632	630	630	209	8,848	9,178	8,692	8,791	2,571
2017, *n*	717	720	721	720	226	9,246	9,627	9,101	9,210	2,797
2018, *n*	598	723	717	721	225	7,833	9,677	9,222	9,307	2,714
2019, *n*	550	709	709	710	228	7,831	9,561	8,984	9,036	2,861

AMC = amoxicillin–clavulanic acid; AMP = ampicillin/amoxicillin; CIP = ciprofloxacin; CTR = ceftriaxone; NOR = norfloxacin; SXT = trimethoprim–sulfamethoxazole; TMP = trimethoprim

Note: Because of cascade reporting rules, ceftriaxone resistance from two pathology services in FN-WA is an adjusted estimate of the percentage resistant, based on the available data and the assumption that the primary susceptibility test (cefazolin) was susceptible.

Source: HOTspots (NT, Qld, WA)

Figure 6.6: *Escherichia coli* resistance in northern Australia, by setting, 2015–2019



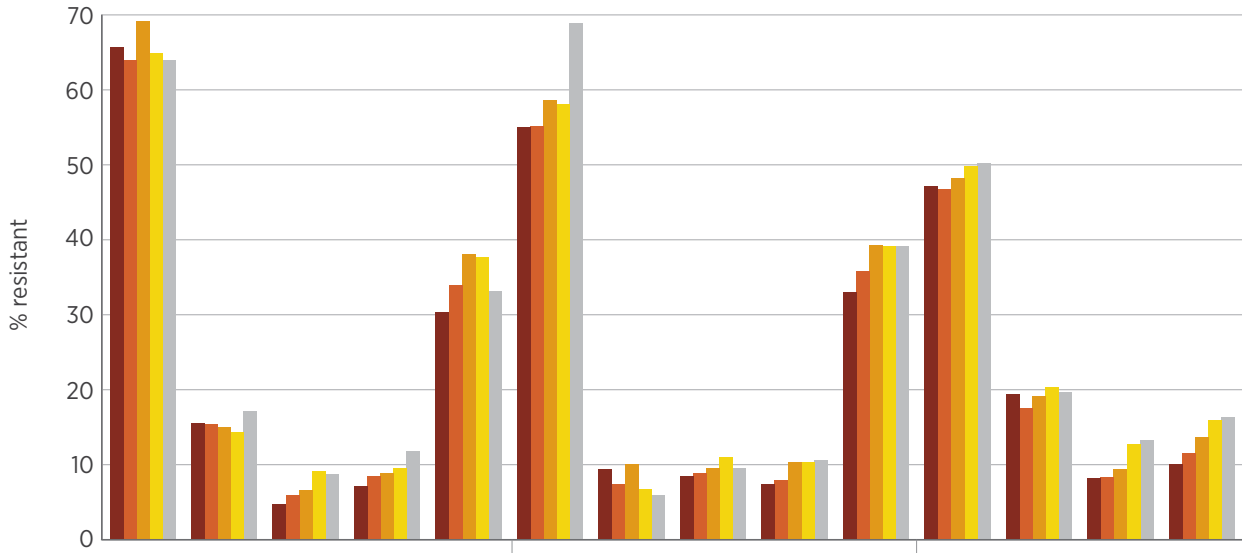
	Community					Hospital				
2015, %	62.4	16.5	4.7	7.9	32.3	49.3	17.4	8.1	10.2	31.5
2016, %	60.4	15.5	5.8	8.6	32.8	49.1	15.7	8.3	11.6	35.4
2017, %	63.0	15.0	7.8	9.8	37.4	51.4	17.3	9.1	13.9	39.0
2018, %	61.4	14.5	8.9	10.5	36.8	50.9	17.7	12.3	16.6	39.0
2019, %	59.9	15.8	8.9	14.1	33.9	51.2	17.0	12.3	16.2	38.0
2015, *n*	1,238	1,571	1,653	1,743	746	8,540	8,544	7,968	7,971	2,061
2016, *n*	1,234	1,583	1,677	1,761	800	8,808	8,805	8,212	8,226	2,159
2017, *n*	1,259	1,663	1,695	1,782	816	9,338	9,335	8,761	8,786	2,418
2018, *n*	1,192	1,653	1,745	1,805	807	7,891	9,606	9,042	9,063	2,383
2019, *n*	1,110	1,237	1,195	1,220	717	7,897	9,850	9,308	9,333	2,613

AMC = amoxicillin–clavulanic acid; AMP = ampicillin/amoxicillin; CIP/NOR = ciprofloxacin/norfloxacin; CTR = ceftriaxone; SXT/TMP = trimethoprim–sulfamethoxazole/trimethoprim

Note: Because of cascade reporting rules, ceftriaxone resistance from two pathology services in FN-WA is an adjusted estimate of the percentage resistant, based on the available data and the assumption that the primary susceptibility test (cefazolin) was susceptible.

Source: HOTspots (NT, Qld, WA)

Figure 6.7: *Escherichia coli* resistance in northern Australia, by region, 2015–2019



	Far north Western Australia					Northern Territory					Far north Queensland			
	AMP	AMC	CTR	CIP/NOR	SXT/TMP	AMP	AMC	CTR	CIP/NOR	SXT/TMP	AMP	AMC	CTR	CIP/NOR
2015, %	65.7	15.6	4.7	7.1	30.4	55.0	9.4	8.5	7.4	33.0	47.2	19.4	8.2	10.1
2016, %	63.9	15.4	6.0	8.5	33.9	55.2	7.4	8.9	8.0	35.8	46.7	17.6	8.3	11.5
2017, %	69.1	15.0	6.6	8.9	38.1	58.6	10.1	9.6	10.4	39.3	48.2	19.2	9.4	13.7
2018, %	64.9	14.3	9.2	9.5	37.7	58.1	6.8	11.0	10.3	39.1	49.8	20.4	12.7	15.9
2019, %	63.9	17.2	8.8	11.8	33.1	68.9	5.9	9.6	10.6	39.1	50.2	19.7	13.3	16.4
2015, *n*	1,337	1,701	1,939	1,938	1,320	1,559	1,527	1,493	1,413	1,314	6,882	6,887	6,181	5,771
2016, *n*	1,396	1,776	2,024	1,991	1,371	1,650	1,618	1,573	1,513	1,409	6,996	6,994	6,286	5,917
2017, *n*	1,384	1,813	2,012	1,979	1,352	1,939	1,911	1,861	1,779	1,671	7,274	7,274	6,569	6,172
2018, *n*	1,438	1,918	2,134	2,099	1,410	86	1,783	1,751	1,596	1,529	7,559	7,558	6,899	6,333
2019, *n*	1,340	1,454	1,540	1,507	1,302	45	2,009	1,991	1,818	1,787	7,622	7,624	6,961	6,421

AMC = amoxicillin–clavulanic acid; AMP = ampicillin/amoxicillin; CIP/NOR = ciprofloxacin/norfloxacin; CTR = ceftriaxone; SXT/TMP = trimethoprim–sulfamethoxazole/trimethoprim

Notes:

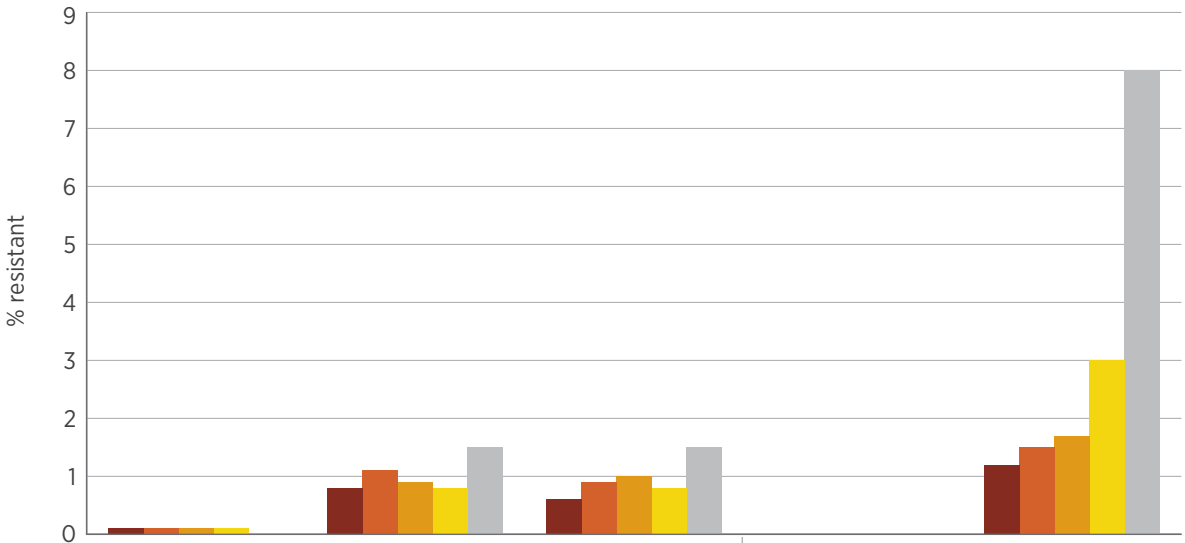
1. Ampicillin data from NT hospitals were not provided in 2018–19.
2. Because of cascade reporting rules, ceftriaxone resistance from two pathology services is an adjusted estimate of the percentage resistant, based on the available data and the assumption that the primary susceptibility test (cefazolin) was susceptible.
3. Trimethoprim–sulfamethoxazole data were not requested from Pathology Queensland.

Source: HOTspots (NT, Qld, WA)

Streptococcus pyogenes

There was a seven-fold increase in the rate of resistance to erythromycin in 2019 (8.0%) compared with 2015 (1.2%) (Figure 6.8). The FN-Q increase is across both the hospital and community settings. However, in 2019, there was a 10-fold increase in resistance in isolates from the community. In FN-WA, rates of resistance to erythromycin and clindamycin remain at less than 2%. There were insufficient data from the NT to include in this analysis.

Figure 6.8: *Streptococcus pyogenes* resistance in northern Australia, by region, 2015–2019



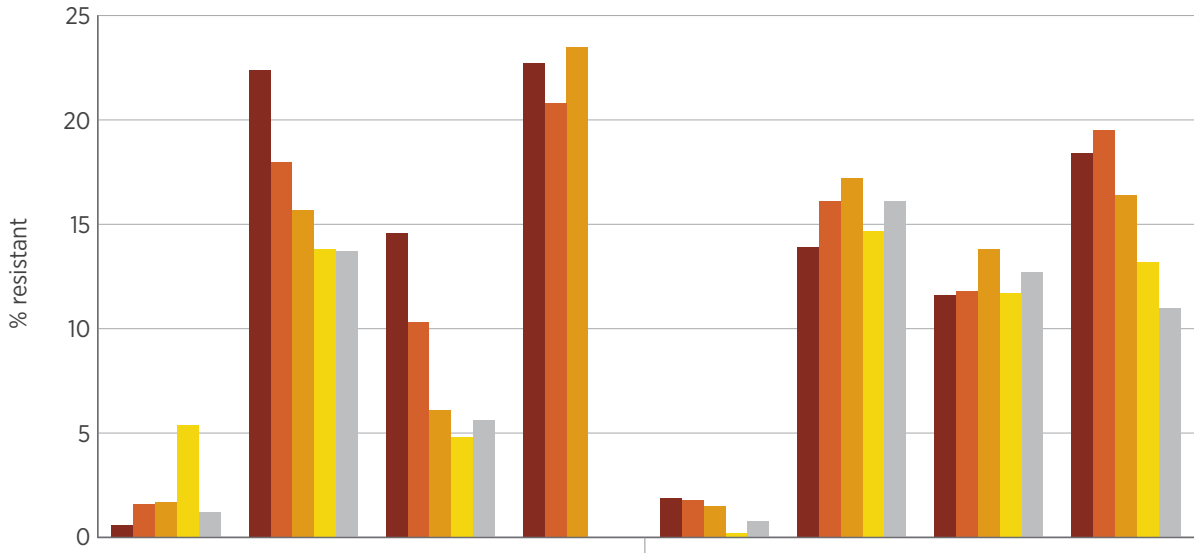
	PEN	ERY	CLN	PEN	ERY
	Far north Western Australia			Far north Queensland	
2015, %	0.1	0.8	0.6	0.0	1.2
2016, %	0.1	1.1	0.9	0.0	1.5
2017, %	0.1	0.9	1.0	0.0	1.7
2018, %	0.1	0.8	0.8	0.0	3.0
2019, %	0.0	1.5	1.5	0.0	8.0
2015, *n*	1,945	1,943	1,743	3,238	3,189
2016, *n*	2,199	2,198	2,184	3,697	3,652
2017, *n*	2,060	2,056	2,056	3,951	3,919
2018, *n*	1,809	1,262	1,813	4,024	3,996
2019, *n*	1,884	1,292	1,882	4,093	4,058

CLN = clindamycin; ERY = erythromycin; PEN = benzylpenicillin
Notes:
1. No data were available for the NT.
2. Clindamycin data were not available from FN-Q.
Source: HOTspots (NT, Qld, WA)

Streptococcus pneumoniae

The annual resistance to benzylpenicillin in *S. pneumoniae* was less than 2% between 2015 and 2019, except in 2018 when it was 5.4% in isolates from FN-WA (Figure 6.9). Resistance to both erythromycin and tetracyclines has declined in FN-WA. Whereas there was a decrease in trimethoprim–sulfamethoxazole resistance in FN-Q, there was little change in resistance to macrolides or tetracyclines. There were insufficient data from the NT to include in the analysis.

Figure 6.9: *Streptococcus pneumoniae* resistance in northern Australia, by region, 2015–2019



	Far north Western Australia				Far north Queensland			
2015, %	0.6	22.4	14.6	22.7	1.9	13.9	11.6	18.4
2016, %	1.6	18.0	10.3	20.8	1.8	16.1	11.8	19.5
2017, %	1.7	15.7	6.1	23.5	1.5	17.2	13.8	16.4
2018, %	5.4	13.8	4.8	nd	0.2	14.7	11.7	13.2
2019, %	1.2	13.7	5.6	nd	0.8	16.1	12.7	11.0
2015, *n*	174	210	158	211	432	432	397	272
2016, *n*	184	222	175	221	446	446	415	287
2017, *n*	180	204	132	183	478	476	450	317
2018, *n*	186	145	207	13	449	448	429	281
2019, *n*	172	95	180	nd	503	504	481	281

ERY = erythromycin; nd = no data (either not tested or tested against an inadequate number of isolates); PEN = benzylpenicillin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines

Notes:

1. Insufficient data were available for the NT.
2. Intermediate was reported as resistant for all antimicrobials except benzylpenicillin.

Source: HOTspots (NT, Qld, WA)

Commentary and comparison of northern Australian resistance data with national figures

Northern Australia has a higher proportion of Aboriginal and Torres Strait Islander peoples than the rest of Australia. An estimated 31% of NT residents are Aboriginal and Torres Strait Islander peoples; in 2020, an estimated 18% of Aboriginal and Torres Strait Islander peoples lived in remote and very remote areas, combined.[3] Nationally, 3.3% of Australians identify as Aboriginal or Torres Strait Islander peoples.[4] Prescribing guidelines appropriately recommend lower thresholds for antibiotic use in populations considered at higher risk of bacterial infections or their complications. Higher antimicrobial prescribing and poor housing conditions in northern Australia, especially in remote communities, are likely to be important determinants of AMR rates in this part of the country.

National resistance rates for major pathogens are detailed in Chapter 4. It should be noted that there is some overlap between HOTspots and the Australian Passive AMR Surveillance (APAS) program in Queensland and WA, because both programs collected data from Pathology Queensland and PathWest Laboratory Medicine WA. However, it was not possible to determine how much that overlap influenced the analyses in this section. The advantage of the inclusion of HOTspots data is that resistance information from the NT are included in AURA for the first time.

The data presented in this section focus on the four major bacterial pathogens seen in far north Australia, north of the Tropic of Capricorn.

MRSA is prevalent in northern Australia. In 2019, aggregate rates of MRSA for northern Australia were 27.7% for blood isolates, compared with 17.7% nationally. Aggregate rates were higher in skin and soft tissue isolates (34.7%) than in blood isolates; higher in community isolates (41.1%) than in hospital isolates (31.9%); and higher in FN-WA (46.9%) than in the NT (34.6%) and FN-Q (29.6%). A notable exception was the higher rate of resistance in hospital isolates (35.0%) than in community isolates (10.0%) in the NT. No major trends in resistance rates were seen between 2015 and 2019 in any of the three northern regions.

In 2019, rates of resistance to fluoroquinolones in *E. coli* were similar to national figures (HOTspots, 14.6–14.8%; national, 11.4–13.7%). In contrast, rates of resistance to third-generation cephalosporins (ceftriaxone or cefotaxime) were generally higher in northern Australia (8.3–18.2%) than nationally (8.0–11.9%). There have been upward trends in rates of both these resistances in *E. coli* since 2015, while rates of resistance to other agents have remained stable. Rates of resistance to both fluoroquinolones and third-generation cephalosporins were higher in hospitals than in the community, and fluoroquinolone resistance rates were higher in FN-Q than in the other two regions.

Erythromycin-resistant *S. pyogenes* has remained low (<2%) in FN-Q between 2015 and 2017, but has risen to 8.0% in 2019. Rates of resistance to erythromycin and tetracycline in *S. pneumoniae* have been falling in FN-WA but remained stable in FN-Q over the period 2015–2019. However, erythromycin resistance rates were still high in 2019: 11.0–16.1% across the three regions. The role of azithromycin (used for trachoma control) in driving this resistance is not clear, although the potential for this was described in the NT many years ago.[5]

Future developments

HOTspots is a longitudinal surveillance platform that has the capacity to perform a vital role in public health, informing decisions concerning region-specific and population-level infection prevention strategies and allocation of resources, and potentially providing the basis for evaluation of interventions. In addition to allowing detection of AMR hotspots, the interactive mapping platform permits epidemiological surveillance by capturing vital statistics (age and sex) and hosting increasing numbers of variables.[6] Planning has commenced to incorporate data on antibiotic use into HOTspots, and also measures of AMR-attributable morbidity, mortality and healthcare costs are being determined.[6]

As increasingly rich longitudinal data become available, HOTspots can increasingly be used to measure the impact of programs and interventions, and provide information to clinicians, program managers and policymakers on the evolving patterns of resistance and AU and their impacts (health and economic). The Australian Commission on Safety and Quality in Health Care (the Commission) and HOTspots will continue to work together to develop focused reports of resistance in northern Australia.

6.2 Impact of COVID-19 on antibiotic use in Australia during 2020

The World Health Organization declared COVID-19, caused by infection with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), a global pandemic on 11 March 2020.[7] Early reports of the COVID-19 pandemic suggested that it could result in increased morbidity and mortality, along with increased demand on health services. In response, all Australian governments initiated a series of structural and policy decisions, along with clinical practice changes, to minimise the impact of the pandemic.

Community lockdown restrictions, along with a greater emphasis on infection prevention and control actions such as physical distancing, hand hygiene, mask wearing and staying at home if unwell, came into effect from the week of 23 March 2020.[8] The recommendations and restrictions were emphasised for people at high risk of poor outcomes if they were to develop COVID-19.

The Australian Government expanded access to the Medical Benefits Schedule for telehealth consultations, and video and telehealth Medicare items were made available for people at risk of healthcare harms from COVID-19, and in quarantine from 13 March 2020.[9] Telehealth services were extended to enable vulnerable medical practitioners and health practitioners to provide telehealth for all their patients from 23 March 2020, and further expanded to all practitioners and all patients from 29 March 2020.[10]

The aims of these changes were to improve access to healthcare services and reduce opportunities for infectious illnesses to be transmitted. Improved emphasis on hand hygiene, working from home and physical distancing measures have the potential to reduce transmission of infectious conditions. The 2020 influenza season summary suggests that this was realised, with laboratory-confirmed cases of influenza in Australia for 2020 approximately eight times lower than the average for the previous five years.[11] In addition, for most of the pandemic to date, people with sore throats or cold and influenza-like symptoms were encouraged

to have a COVID-19 test and self-isolate until the results became available, which may have limited their attendance at general practices for upper respiratory tract infections. Sentinel surveillance reports found that presentations to general practitioners (GPs) for influenza-like symptoms in 2020 were four times lower in 2020 than the average in the previous five years.[11] Consistent with these events, early reports of changes in access to health care found falls in the use of antimicrobials in Australia in April 2020.[12]

This section examines the impact of the COVID-19 pandemic on community antibiotic use in Australia in 2020. In this section, the term prescriptions refers to dispensed prescriptions, and the data used are from 2020.

In April 2020, there were also Pharmaceutical Benefits Scheme (PBS) policy changes for Australia's five most commonly dispensed antibiotics: amoxicillin, amoxicillin with clavulanic acid, cefalexin, doxycycline and roxithromycin.[13] These changes reduced the number of repeat prescriptions permissible (typically from one to zero), with no change in the maximum quantity that could be dispensed for unrestricted antibiotics. Larger quantities were only available under authorisation policies. These changes were intended to reduce inappropriate prescribing by encouraging prescribers to prescribe antibiotic repeats only when clinically indicated.[13]

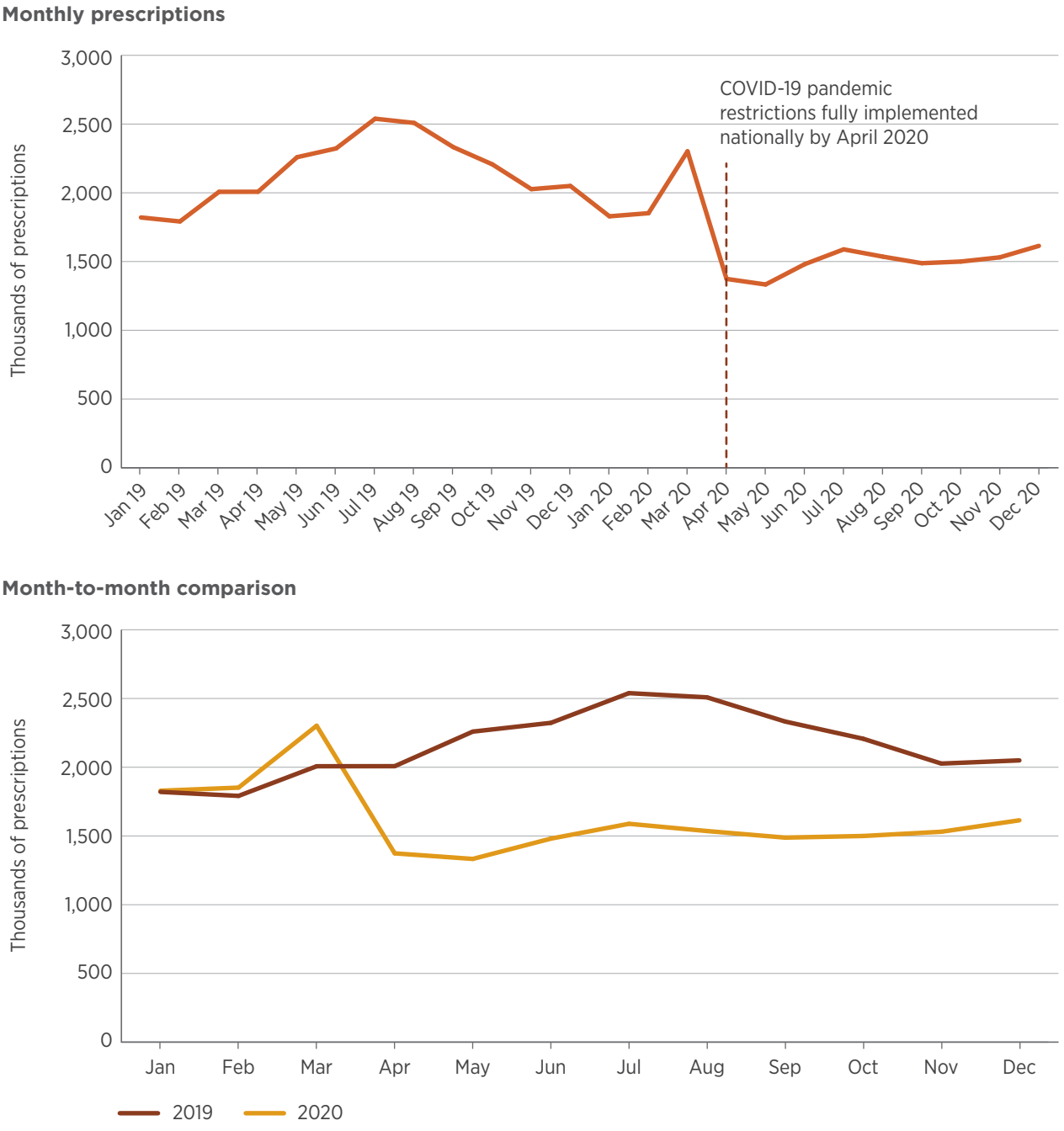
Monthly number of prescriptions for antibiotics for systemic use supplied in 2019 and 2020

Figure 6.10 shows the number of PBS prescriptions supplied for systemic antibiotics during 2019 and 2020. Increased supply of antibiotics can be observed in March 2020, which is consistent with observed stockpiling of medicines[14] and other goods, before the national physical distancing restrictions. Use of PBS-supplied antibiotics fell significantly in April 2020. The number of prescriptions supplied decreased from 2.3 million in March 2020 to 1.4 million in April 2020 – a fall of 40%.

Table 6.2 reports changes in systemic antibiotic use in each month of 2020 compared with the same month in 2019, expressed as percentage change in prescription numbers and percentage change in volume of antibiotics, measured as defined daily doses per 1,000 people per day (DDD/1,000/day). The average fall in number of prescriptions supplied between April and December 2020 compared with the same period in 2019 was 34%. The average fall in volume supplied between April and December 2020 compared with the same period in 2019 was 39%.

Use of the 10 most commonly dispensed antibiotics for the period July 2016 to October 2020 was analysed. In April 2020, there were significant reductions in use of seven of the 10 antibiotics: amoxicillin (49%), amoxicillin with clavulanic acid (40%), cefalexin (28%), clarithromycin (31%), doxycycline (27%), phenoxymethylpenicillin (22%) and roxithromycin (42%), all of which are frequently used for upper respiratory tract infections (Table 6.3). In contrast, use remained stable for flucloxacillin (0%), metronidazole (3%) and trimethoprim (3%), none of which are usually used for upper respiratory tract infections. By the end of October 2020, use of flucloxacillin, metronidazole and trimethoprim had remained stable. For the remaining seven antibiotics, use remained lower than pre-pandemic levels.

Figure 6.10: Number of prescriptions for systemic antibiotics (J01) supplied in 2019 and 2020



J01 = antibiotics from the Anatomical Therapeutic Chemical Classification System code group J01

Table 6.2: Difference in number of prescriptions and antibiotic volume between 2020 and 2019

Month	Prescription numbers, 2019	Prescription numbers, 2020	Change in prescription numbers, 2019 to 2020 (%)	Volume (DDD/1,000/day), 2019	Volume (DDD/1,000/day), 2020	Change in volume from 2019 to 2020
Jan	1,820,483	1,828,814	0.5	18.61	17.73	–4.7
Feb	1,791,389	1,851,621	3.4	20.1	19.7	–2.0
Mar	2,007,020	2,301,800	14.7	20.45	22.88	11.9
Apr	2,007,517	1,373,470	–31.6	21.39	13.88	–35.1
May	2,259,025	1,332,901	–41.0	23.54	12.96	–44.9
Jun	2,322,758	1,480,499	–36.3	24.81	14.75	–40.5
Jul	2,538,929	1,588,499	–37.4	26.39	15.43	–41.5
Aug	2,508,220	1,535,752	–38.8	23.15	14.82	–36.0
Sep	2,332,355	1,487,862	–36.2	25.17	14.77	–41.3
Oct	2,207,047	1,499,769	–32.0	23.33	14.31	–38.7
Nov	2,026,532	1,530,543	–24.5	22.18	14.95	–32.6
Dec	2,049,800	1,613,988	–21.3	22.21	15.55	–30.0

DDD/1,000/day = defined daily dose per 1,000 people per day
Note: A number of COVID-19 public health–related actions were in place by April 2020.

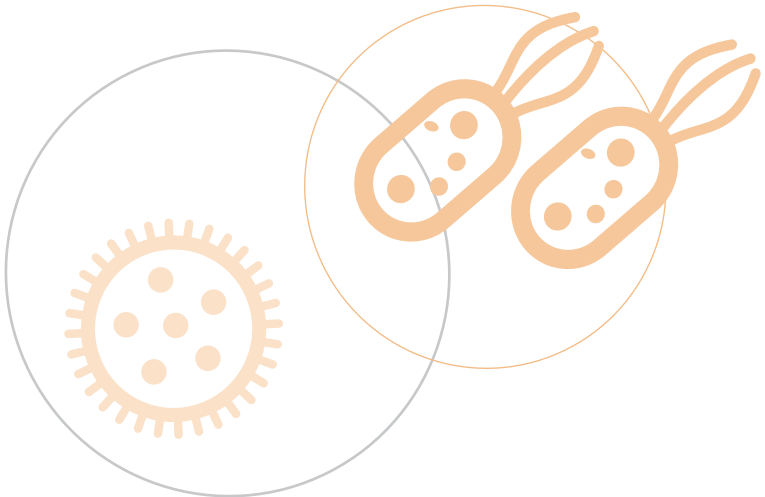
Table 6.3: Estimated number of antibiotic dispensings per 1,000 people in Australia, July 2016 to October 2020, by selected agent

Antibiotic	Monthly prescriptions at baseline*	Monthly trend in prescriptions, July 2016 to March 2020		Change in prescriptions, July 2016 to April 2020			Monthly trend in prescriptions, April 2020 to October 2020	
		Prescriptions	*P*	Prescriptions	*P*	%	Prescriptions	*P*
Amoxicillin	19.43	−0.02	0.262	−9.54	<0.001	−49	−0.07	0.838
Cefalexin	18.92	−0.01	0.308	−5.33	<0.001	−28	0.19	0.064
Amoxicillin with clavulanic acid	17.88	−0.05	0.007	−7.11	<0.001	−40	−0.16	0.524
Doxycycline	7.81	0.02	<0.001	−2.09	<0.001	−27	−0.12	0.199
Roxithromycin	5.65	−0.04	0.001	−2.39	0.002	−42	−0.10	0.447
Clarithromycin	3.19	−0.02	0.003	−1.01	0.003	−31	−0.05	0.484
Trimethoprim	3.16	−0.01	<0.001	−0.09	0.237	−3	0.02	0.170
Flucloxacillin	2.68	−0.01	0.440	0.01	0.973	0	0.02	0.704
Phenoxy-methylpenicillin	2.54	−0.01	<0.001	−0.57	<0.001	−22	−0.07	0.011
Metronidazole	2.51	−0.01	<0.001	−0.07	0.361	−3	0.02	0.258

P = the *P* value for the statistical significance of the change

* Baseline month is July 2016.

Source: Gadzhanova, Roughead[15]



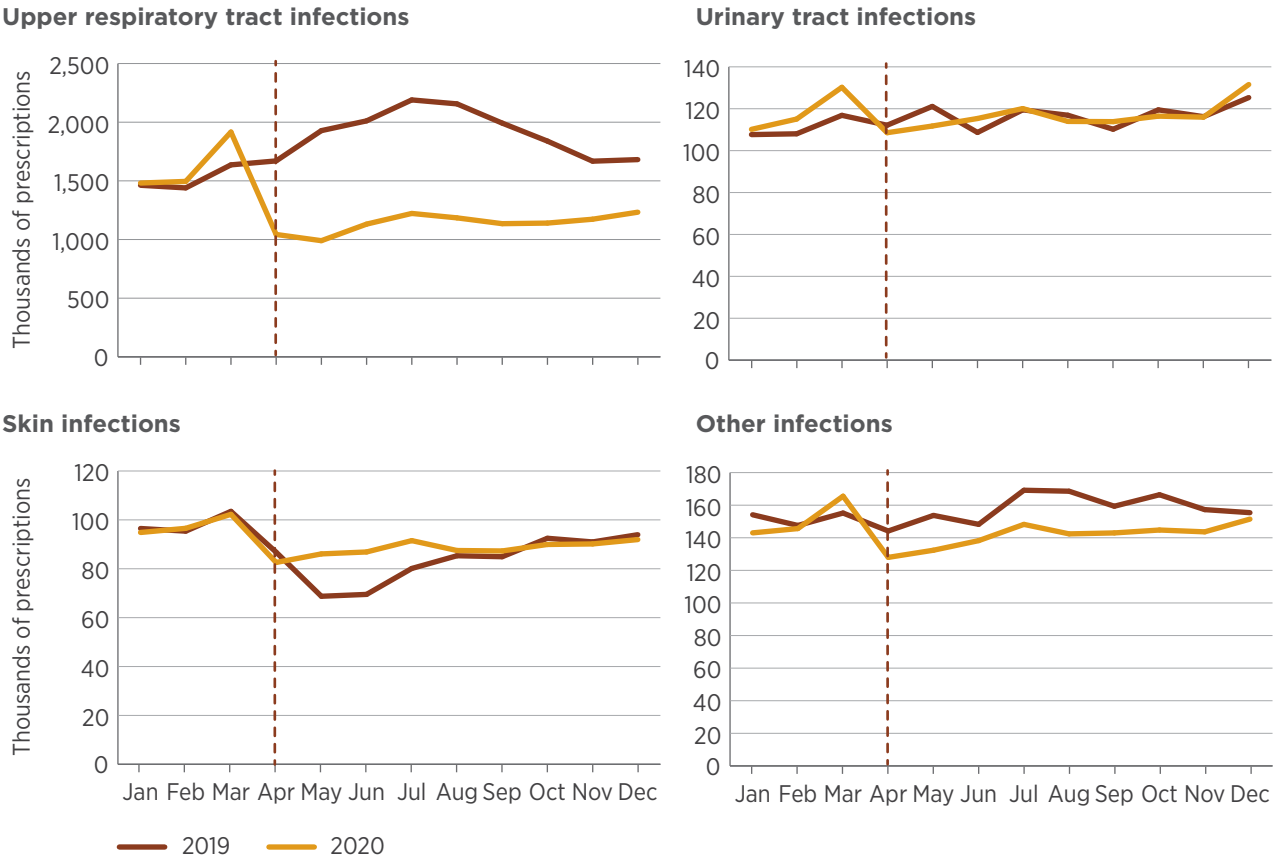
Number of prescriptions for systemic antibiotics by indication for use

To further determine the impact of the COVID-19 pandemic on the use of various types of antibiotics, oral systemic antibiotics were grouped by indication for use into:

- Oral systemic antibiotics, principally for upper respiratory tract infections – doxycycline, amoxicillin, amoxicillin and clavulanic acid, cefalexin, roxithromycin, erythromycin, azithromycin, cefaclor, clarithromycin, ciprofloxacin, phenoxymethylpenicillin
- Oral systemic antibiotics for urinary tract infections – trimethoprim, norfloxacin, nitrofurantoin, methenamine
- Oral systemic antibiotics for skin conditions – minocycline, flucloxacillin
- Oral systemic antibiotics for other conditions – the remaining J01 antibiotics (antibiotics from the Anatomical Therapeutic Chemical Classification System code group J01).

Figure 6.11 shows the number of prescriptions supplied in 2020 for these indications of use, and Figures 6.12–6.15 compare 2020 with 2019. Antibiotics for upper respiratory tract infections were the most commonly prescribed antibiotics in 2020 (Figure 6.11). The largest decrease in supply of antibiotics after the COVID-19 pandemic began was for antibiotics for upper respiratory tract infections (Figure 6.12).

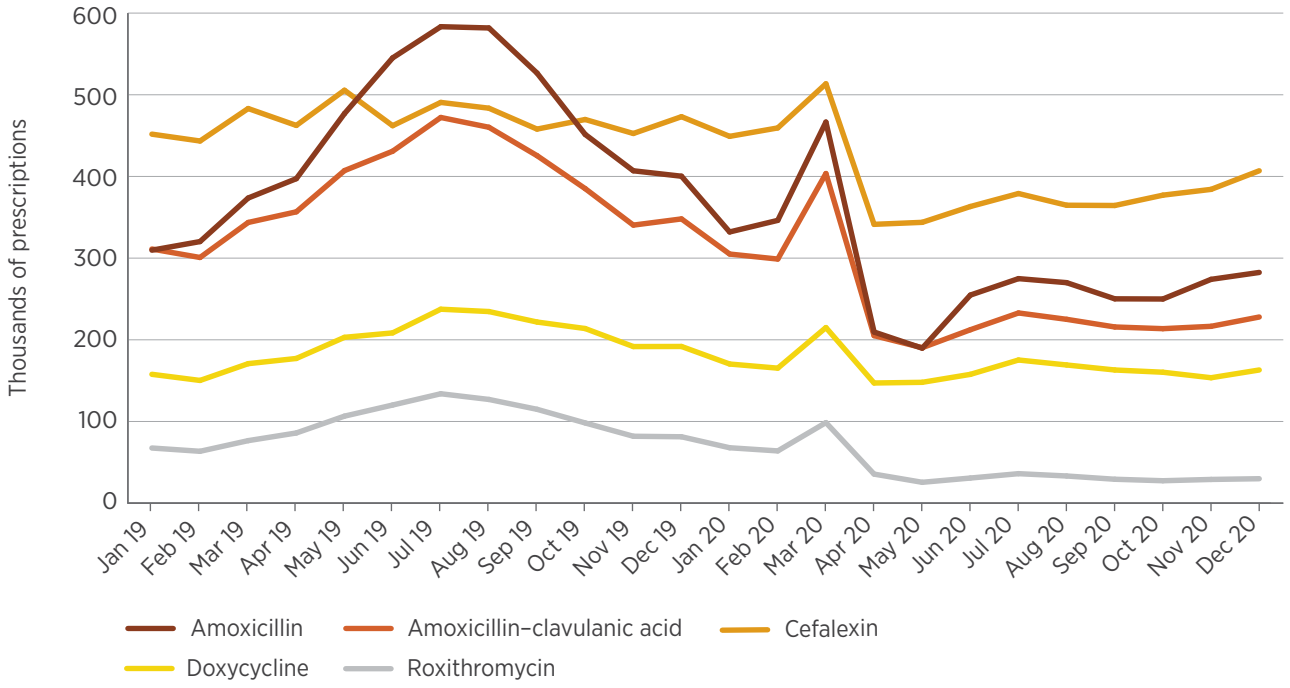
Figure 6.11: Number of prescriptions for oral systemic antibiotics typically used for upper respiratory tract infections, urinary tract infections, skin infections and other infections, 2019 and 2020



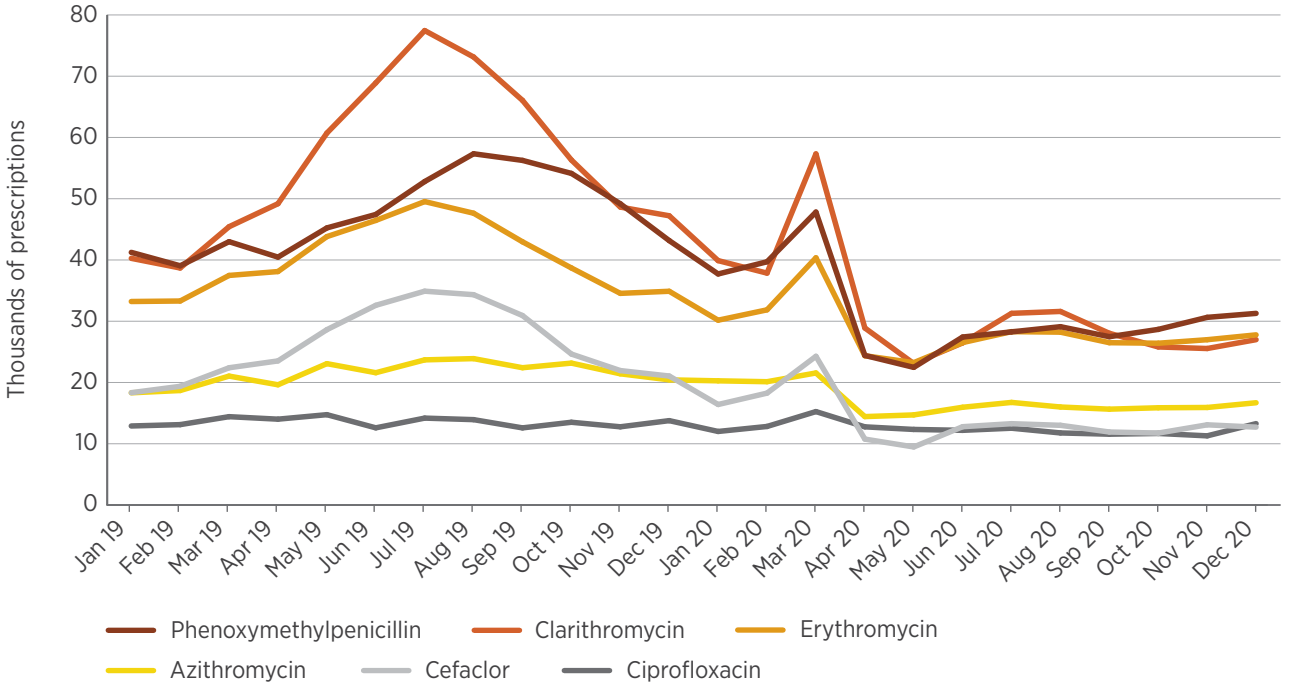
Note: Vertical dashed line indicates full implementation of COVID-19 pandemic restrictions by April 2020.

Figure 6.12: Number of prescriptions for antibiotics frequently used for upper respiratory tract infections, by type of antibiotic, 2019 and 2020

a. Antibiotics with PBS restriction changes



b. Antibiotics without PBS restriction changes



PBS = Pharmaceutical Benefits Scheme

Changes in use of antibiotics for upper respiratory tract infections due to COVID-19

Figure 6.12 presents the use of antibiotics for upper respiratory tract infections by type of antibiotic. Doxycycline, amoxicillin, amoxicillin with clavulanic acid, cefalexin and roxithromycin were the antibiotics with the largest reductions in use around April 2020. These were the same antibiotics subject to PBS restriction changes in April 2020 (Figure 6.12a). Restriction changes, however, do not account for all the reduction in use, because other antibiotics frequently used for upper respiratory tract infections also had sustained falls in use (Figure 6.12b).

Figure 6.13 shows the number of prescriptions for upper respiratory tract infections per 1,000 people at state and territory level, comparing 2020 with 2019. There was a decrease in all states in 2020 compared with 2019, with the largest decrease (35%) in Victoria and the smallest (21%) in the NT. Further analysis for Victoria showed that, in 2020, there were 530 prescriptions per 1,000 people for Greater Melbourne, compared with 576 prescriptions per 1,000 people for the rest of Victoria. Victoria had the longest lockdown period of all Australian states and territories.

Figure 6.13: Number of prescriptions per 1,000 people for antibiotics for upper respiratory tract infections, by state and territory, 2019 and 2020

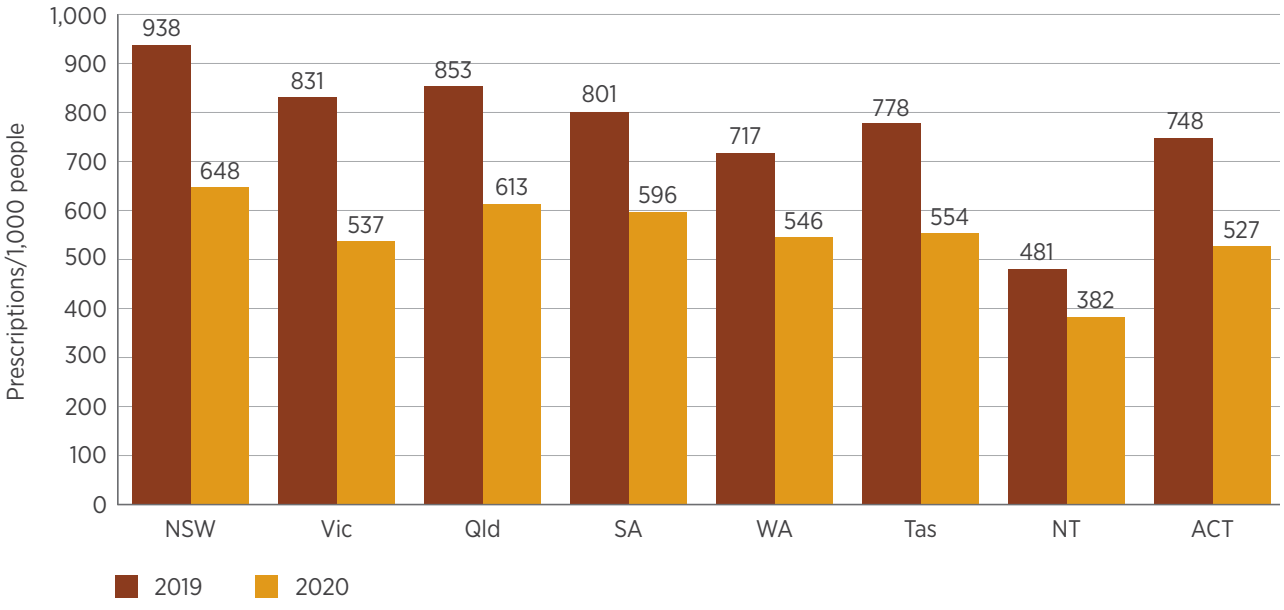


Figure 6.14 shows the number of prescriptions of antibiotics frequently used for upper respiratory tract infections per 1,000 people by age groups, comparing 2020 with 2019. There was a decrease in all age groups. The largest decrease was in children aged 0–4 years (41%) and 5–14 years (42%). The decrease in use was the smallest (25%) in people aged 75 years and over. The findings in children are consistent with falls in the numbers of standard GP consultations in these age groups around the commencement of the COVID-19 pandemic in Australia in March 2020 (Figure 6.15).

To ascertain if access to GP services contributed to some of the fall in antibiotic use, the Medicare claims data for standard consultation (item 23, and COVID telehealth items 91809 and 91800) were examined. The assumption was that a standard consultation was the most likely billing code for management of an upper respiratory tract infection. During the peak pandemic period, up to one-third of GP consultations were delivered by telehealth. However, the overall numbers of GP consultations were similar in 2019 and 2020 (Figure 6.15a). When analysed by age, a lower number of GP visits by children aged 0–4 years (Figure 6.15b) and 5–14 years (Figure 6.15c) was found in 2020, compared with 2019.

Figure 6.14: Number of prescriptions per 1,000 people for antibiotics for upper respiratory tract infections, by age group, 2019 and 2020

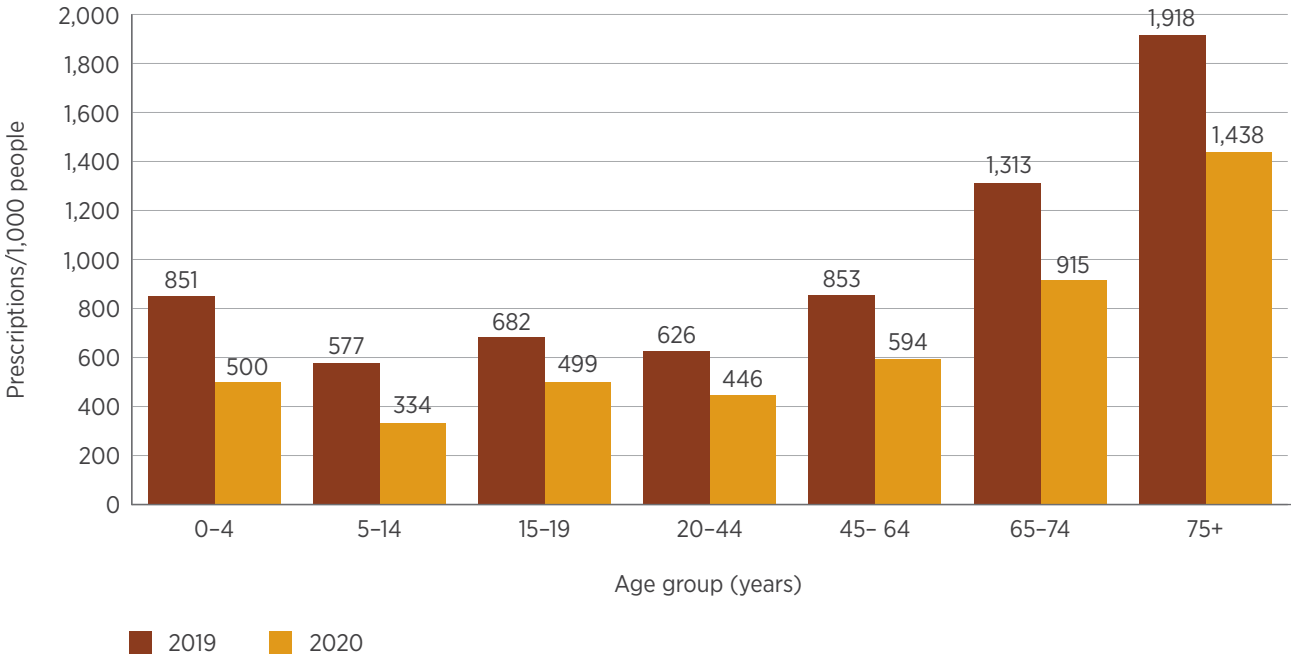
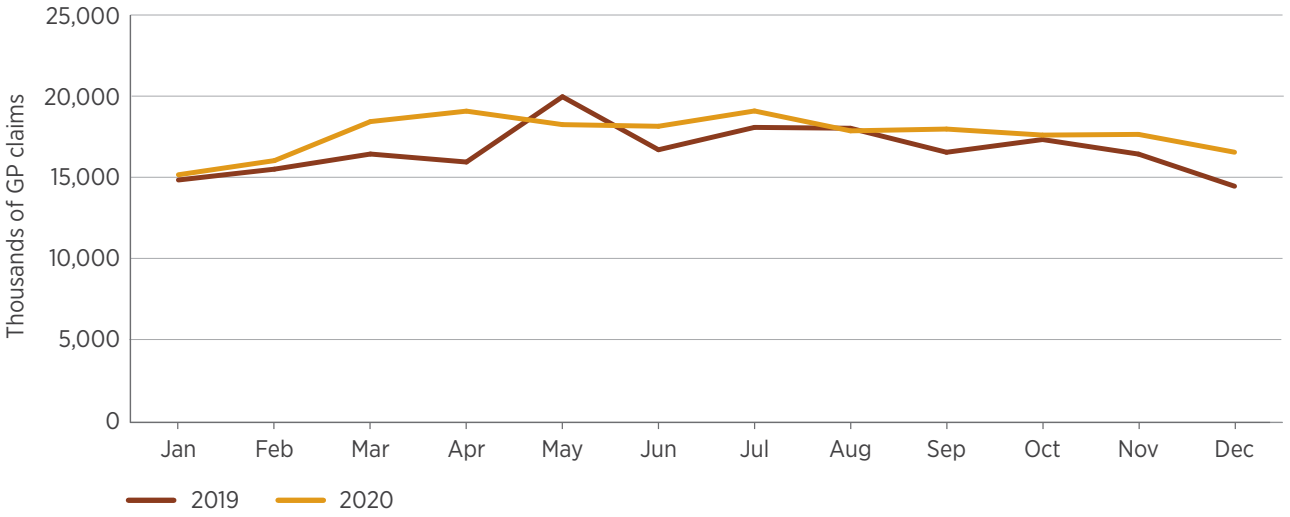
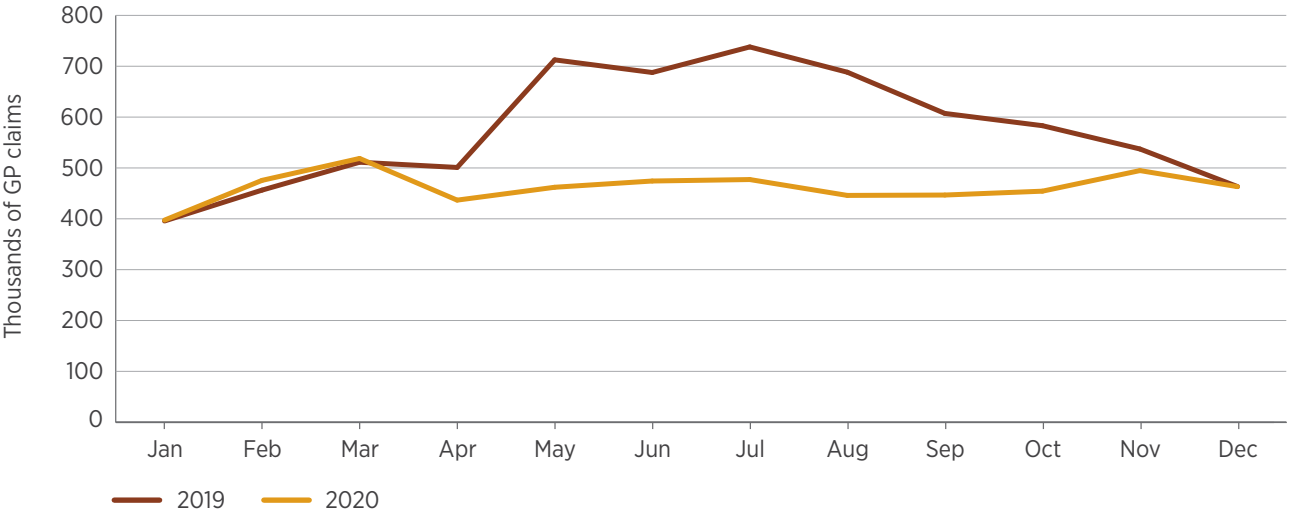


Figure 6.15: Number of GP standard consultations (standard and COVID telehealth items), 2019 and 2020

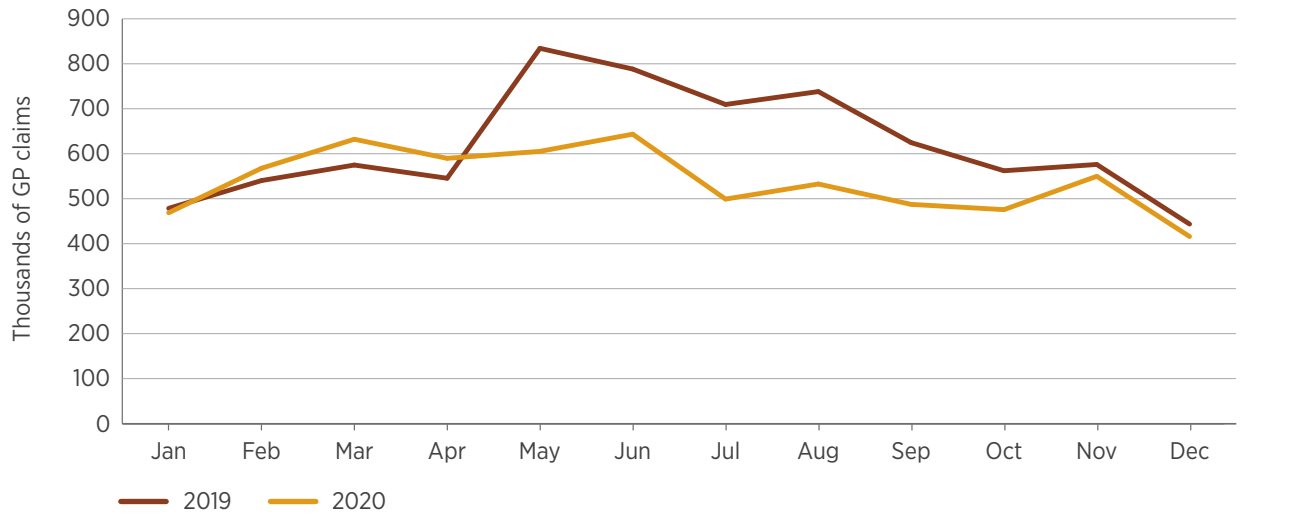
a. All ages



b. 0–4 years



c. 5–14 years



Discussion

There are several potential explanations discussed in relation to the decreases in AU observed during the COVID-19 pandemic.

Changes in the availability of PBS-subsidised repeat prescriptions for Australia's five most commonly dispensed antibiotics (amoxicillin, amoxicillin with clavulanic acid, cefalexin, doxycycline and roxithromycin) are likely to account for some of the reduction in AU. However, use of some antibiotics that were not subject to this policy change also fell (that is, clarithromycin and phenoxymethylpenicillin), suggesting that changes in circulating respiratory illnesses and changes in health-seeking behaviour account for some of the decrease.

Australia is not the only country to report falls in use of antibiotics during the COVID-19 pandemic, with falls also observed in the United States[16] and New Zealand.[17] The New Zealand analysis also found the fall was not associated with a significant increase in morbidity, as hospitalisations for infections preventable by community antimicrobial use did not increase.[17] These results suggest that lower levels of AU in Australia are achievable long term and that active efforts now to maintain lower levels of AU after the pandemic are essential.

Historically, Australia has had high and relatively stable levels of AU relative to most other countries in the Organisation for Economic Co-operation and Development[18] (see Section 6.5). This is despite significant national efforts for more than 20 years to reduce AU, including national campaigns, antimicrobial guidelines, the National Safety and Quality Health Service Standards, and audit and feedback targeting prescribers.[19] Many of these interventions have focused on improving prescribing practices. The change in AU as a result of COVID-19 suggests that infection control approaches are another important lever for reducing community AU, which should be given a greater profile in the community.

In addition to national campaigns for hand hygiene and physical distancing, Australian workplaces issued 'stay home if sick' orders, as did schools and childcare centres, and most workplaces enabled 'work from home' practices on a scale that had not previously been experienced. These actions meant that parents and carers could work from home with greater flexibility when children were sick. This has removed a potential pressure on antimicrobial prescribing and use – that is, antimicrobials may have previously been issued in response to perceptions that use of an antibiotic may enable continued attendance at work, school or child care. This information suggests that a systematic approach to support workplaces, schools and child care is necessary for ongoing improvements to antimicrobial stewardship in the community.

The Commission will therefore promote continuing infection prevention and control programs that emphasise the broader benefits of these initiatives for reducing infections and AU. The Commission will work with the states and territories to promote these strategies.

These results suggest that lower levels of AU in Australia are achievable long term and that active efforts now to maintain lower levels of AU after the pandemic are essential.

6.3 *Clostridioides difficile* infection

This section summarises key data from the first five years (2013–2018) of the *C. difficile* Antimicrobial Resistance Surveillance (CDARS) study, highlighting the importance of *Clostridioides difficile* infection (CDI) surveillance in Australia, and areas for action.

Clostridioides difficile infection in Australia

CDI causes life-threatening diarrhoea and is the leading healthcare-related gastrointestinal infection in the world.[20] While the circumstances for CDI in the United States are different from those in Australia, it is important to note that the Centers for Disease Control and Prevention lists the rates of *C. difficile* as an urgent AMR threat, costing the United States healthcare system around US$1 billion annually.[21]

Each year in Australia, there are around 6,000 cases of CDI[22,23], costing $76–114 million.[23] While there have been additional infection control practices implemented in Australia, in recent years there has been increased presentation of community-associated CDI identified in Australian public hospitals.[22,24] In WA, for example, CDI incidence increased from 3.25 to 5.5 cases per 10,000 patient days between 2011 and 2020.[25,26] Increased rates of CDI may be a result of more testing or implementation of more sensitive diagnostic algorithms, but enhanced surveillance suggested that at least one-quarter of the increase was attributable to community-associated CDI.[22,24,27]

The *Clostridioides difficile* Antimicrobial Resistance Surveillance study

CDI is not a notifiable disease in Australia. Monitoring of CDI rates in hospitals has been supported by the Commission.[22] Despite increases in the incidence of CDI in Australia and the emergence of new virulent ribotypes (RTs)[25,28], most clinical microbiology laboratories in Australia do not culture or further characterise disease-causing strains of *C. difficile*. The CDARS study was initiated in 2013 to address this issue and carry out nationwide longitudinal surveillance for CDI in Australia.

Since 2013, 10 diagnostic microbiology laboratories from five states (New South Wales, Victoria, Queensland, South Australia and WA) have participated in the CDARS study. From each state, one private and one public laboratory submits isolates of *C. difficile* or PCR-positive stool samples during two collection periods per year from February to March (summer/autumn) and August to September (winter/spring). Specimens from private laboratories represent community-associated CDI because these laboratories test patients from GPs, aged care facilities and some private (community) hospitals. Conversely, specimens from public laboratories serving large tertiary care hospitals represent hospital-identified CDI. *C. difficile* is characterised by PCR ribotyping, toxin gene profiling and antimicrobial susceptibility testing using a panel of nine agents following agar incorporation methodology and CLSI/EUCAST breakpoints.

Clostridioides difficile infection molecular epidemiology, 2013–2018

CDI molecular epidemiology data for the first five years of CDARS were published in 2020.[29] A total of 1,523 *C. difficile* isolates were recovered during 10 collection phases (two phases per year). PCR ribotyping yielded 203 unique RTs. The 20 most prevalent RTs of *C. difficile*, which comprised 76.1% of all isolates (n = 1,159), and their distribution between states and laboratory types are shown in Table 6.4.

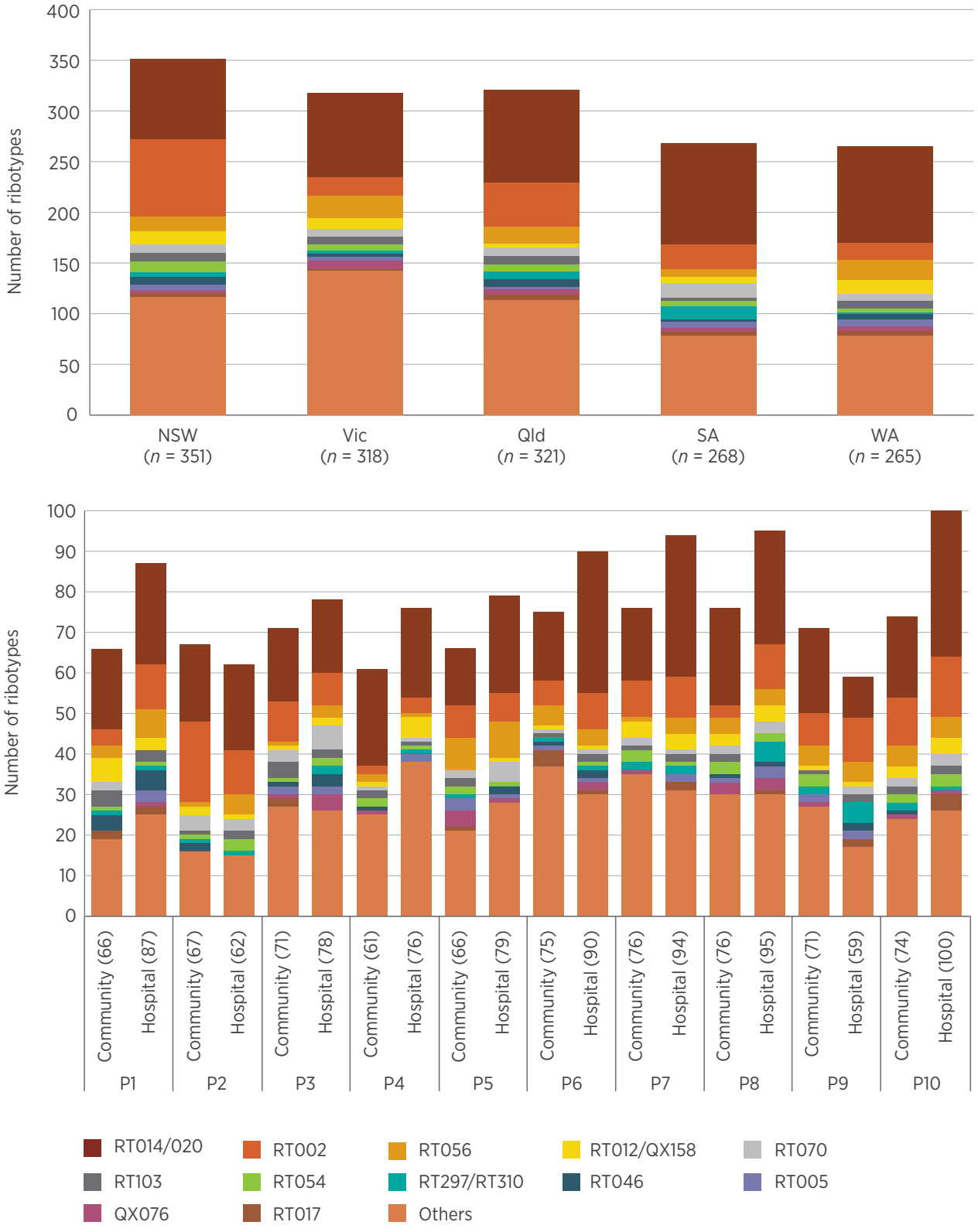
Table 6.4: Summary of the 20 most prevalent *Clostridioides difficile* ribotypes, and their toxin gene profiles and distribution

				RT distribution								
	Toxin gene profile			Site type		State						
Ribotype	*tcdA*	*tcdB*	*cdtA/ cdtB*	Private	Public	NSW	Vic	Qld	SA	WA	*N*	%
RT014/020	+	+	–	195	254*	79	83	92	100	95	449	29.5
RT002	+	+	–	82	97	76*	19	43	24	17	179	11.8
RT056	+	+	–	35	47	15	22	17	8	20	82	5.4
RT012	+	+	–	22	26	13	11	4	6	14	48	3.2
RT070	+	+	–	19	25	8	7	8	14*	7	44	2.9
RT103	+	+	–	20	16	9	8	9	3	7	36	2.4
RT054	+	+	–	18	15	10	6	7	6	4	33	2.2
RT297/RT310	+	+	–	10	19	5	3	7	13	1	29	1.9
RT046	+	+	–	11	15	7	3	8	2	6	26	1.7
RT005	+	+	–	9	16	6	4	2	6	7	25	1.6
QX076	+	+	–	12	12	3	8	5	4	4	24	1.6
RT106	+	+	–	12	9	6	4	7	1	3	21	1.4
RT017	–	+	–	9	12	4	2	6	4	5	21	1.4
RT043	+	+	–	7	11	4	7	2	4	1	18	1.2
RT137	+	+	–	10	7	3	4	0	5	5	17	1.1
RT126/QX360	+	+	+	6	10	1	11	1	4	0	17	1.1
RT018	+	+	–	8	7	2	2	4	5	2	15	1.0
RT010	–	–	–	12	3	4	5	0	2	4	15	1.0
QX013	+	+	–	5	7	3	3	5	1	0	12	0.8
RT039	–	–	–	10	1	0	11	0	0	0	11	0.7

* $P < 0.05$; proportion of ribotype by site type, or state was compared by chi-squared tests.

Overall, *C. difficile* RT014/020 (*n* = 449; 29.5%) was the most prevalent strain, followed by RT002 (*n* = 179; 11.8%) and RT056 (*n* = 82; 5.4%). *C. difficile* RT014 predominates in pig herds in Australia, and genomic studies have shown that *C. difficile* RT014 from piglets and humans in Australia share recent ancestry, with evidence of long-range interspecies clonal transmission.[29,30] The distribution of the 12 most common RTs was stable throughout the five years (Figure 6.16). Almost half the RT002 strains reported were isolated in New South Wales (*n* = 76), the majority (63.2%) from laboratories servicing tertiary hospitals in the public sector. However, there was no temporal clustering over the five-year period.[31] The epidemic *C. difficile* RTs 027 (*n* = 2) and 078 (*n* = 6), and virulent RTs 251 (*n* = 10) and 244 (*n* = 6) were found in low numbers. Most *C. difficile* strains (*n* = 1,423; 93.4%) were positive for the major toxin genes *tcdA/B* (A^+B^+), and 4.1% (*n* = 63) also contained

Figure 6.16: Distribution of *Clostridioides difficile* ribotypes, by (a) state and (b) private or public collection site, over 10 collection phases, 2013–2018



Note: Numbers of ribotypes are in brackets

cdtA/B (CDT^+) genes. Twenty-two strains had a variant toxin profile $A^-B^+CDT^-$ (RT017, *n* = 21; QX134, *n* = 1), while five were positive for *tcdB* and *cdtA/B*, resulting in the rare toxin profile of $A^-B^+CDT^+$. The overall prevalence of CDT^+ *C. difficile* strains was 4.5% (*n* = 69). Two non-toxigenic strains, RTs 010 and 039 (*n* = 15 and *n* = 11, respectively), ranked in the top 20 most prevalent *C. difficile* strains.

Clostridioides difficile antimicrobial resistance surveillance, 2013–2018

2013–2014 snapshot (*n* = 474 isolates)

C. difficile AMR surveillance data for the first two years of CDARS were published in 2014.[32] Fidaxomicin showed potent in vitro activity (MIC range ≤0.008–0.5 mg/L), inhibiting 99.8% (439/440) of isolates at 0.25 mg/L and all isolates at 0.5 mg/L. The in vitro activity of fidaxomicin (MIC_{50}/MIC_{90} 0.03/0.12 mg/L) was superior to that of metronidazole (MIC_{50}/MIC_{90} 0.25/0.5 mg/L) and vancomycin (MIC_{50}/MIC_{90} ½ mg/L) but was slightly lower than that of rifaximin (MIC_{50}/MIC_{90} 0.008/0.015 mg/L). Resistance to vancomycin (MIC >2 mg/L) and metronidazole (MIC >16 mg/L) was not detected (these are the first- and second-line treatments for CDI recommended by national guidelines). Non-susceptibility to ceftriaxone was 86.1% and to clindamycin 95.0%. All isolates were susceptible to amoxicillin–clavulanic acid and rifaximin, and non-susceptibility to meropenem was very low (0.5%; 2/440). Moreover, the percentage of isolates resistant to moxifloxacin (MIC >4 mg/L) was low (3.4%; 15/440).

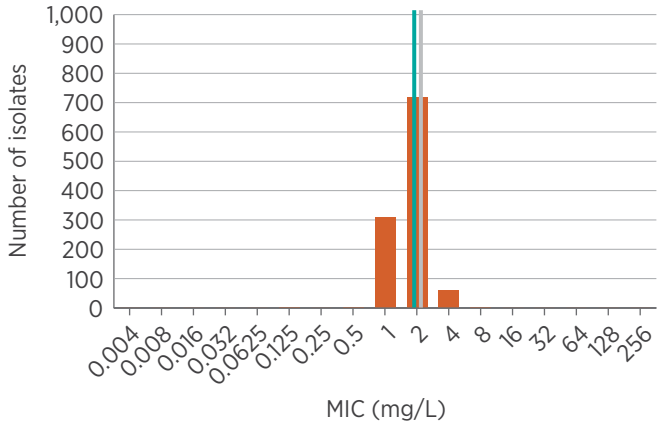
2015–2018 snapshot (*n* = 1,091 isolates)

C. difficile AMR surveillance data for years 3–5 of CDARS were published in 2021.[33] All isolates were susceptible to metronidazole, fidaxomicin, rifaximin and amoxicillin–clavulanic acid. Low numbers of resistant strains were observed for meropenem (0.1%; 1/1091), moxifloxacin (3.5%; 38/1091) and vancomycin (5.7%; 62/1091) (Figure 6.17). Resistance to clindamycin was common (85.2%; 929/1,091), followed by resistance to ceftriaxone (18.8%; 205/1091). The in vitro activity of fidaxomicin (geometric mean MIC 0.101 mg/L) was superior to that of vancomycin (1.700 mg/L) and metronidazole (0.229 mg/L). The prevalence of multidrug-resistant (MDR) *C. difficile*, as defined by resistance to three or more antimicrobial classes, was low (1.7%; 19/1091). The most common MDR profiles were resistance to clindamycin, ceftriaxone and moxifloxacin (57.9%; *n* = 11/19), shared by RT017 (*n* = 4), RT002 (*n* = 3), RT039 (*n* = 2), RT014/020 (*n* = 1) and RT046 (*n* = 1); and resistance to vancomycin, clindamycin and ceftriaxone (26.3%; 5/19), shared by RT002 (*n* = 2), RT014/020 (*n* = 2) and RT053 (*n* = 1). Resistance to four classes of antimicrobials was observed in one strain each of RT017 (clindamycin, ceftriaxone, meropenem and moxifloxacin) and RT027 (vancomycin, clindamycin, ceftriaxone and moxifloxacin).

Overall, at this time, acquired resistance in this species is not common in Australia.

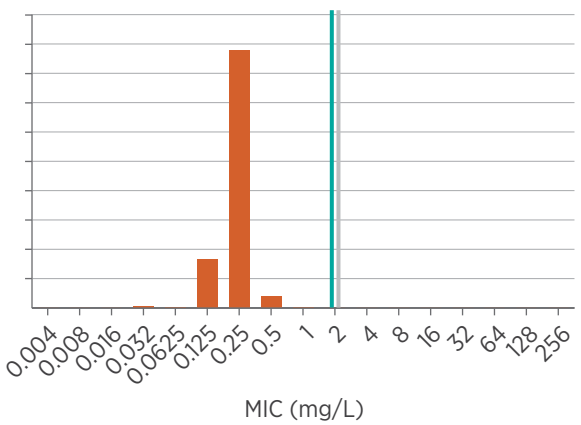
Figure 6.17: Minimum inhibitory concentration distributions for nine antimicrobials against 1,091 *Clostridioides difficile* isolates

VAN



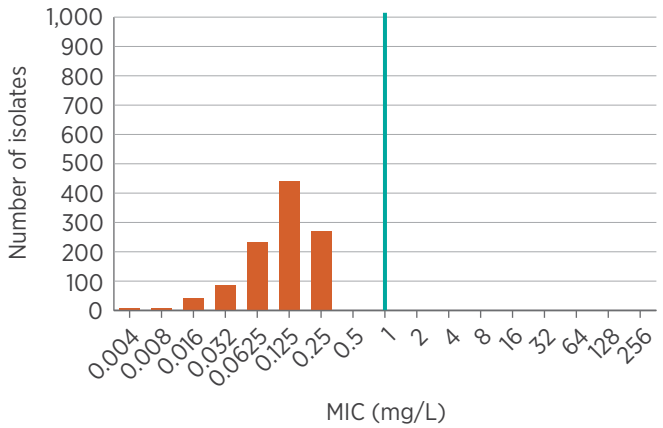
MIC50	MIC90	GM	%R
2	2	1.700	5.7

MTZ



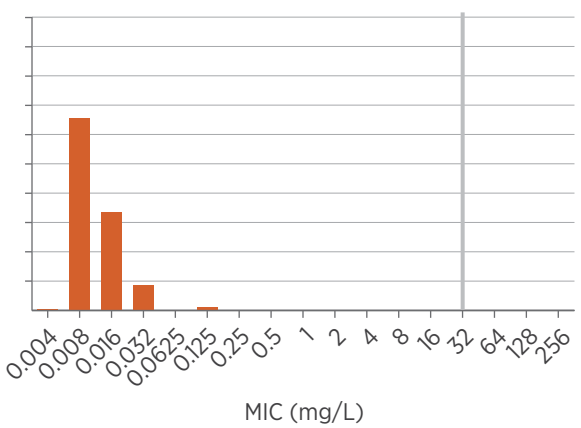
MIC50	MIC90	GM	%R
0.25	0.25	0.229	0.0

FDX



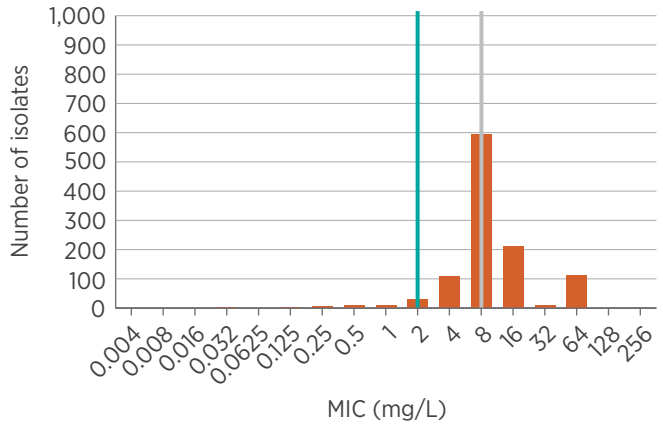
MIC50	MIC90	GM	%R
0.125	0.25	0.101	0.0

RFX



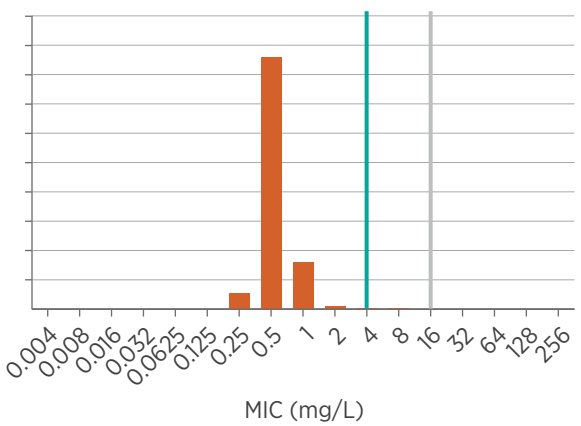
MIC50	MIC90	GM	%R
0.008	0.015	0.011	0.0

CLI



MIC50	MIC90	GM	%R
8	>32	8.951	85.2

AMC

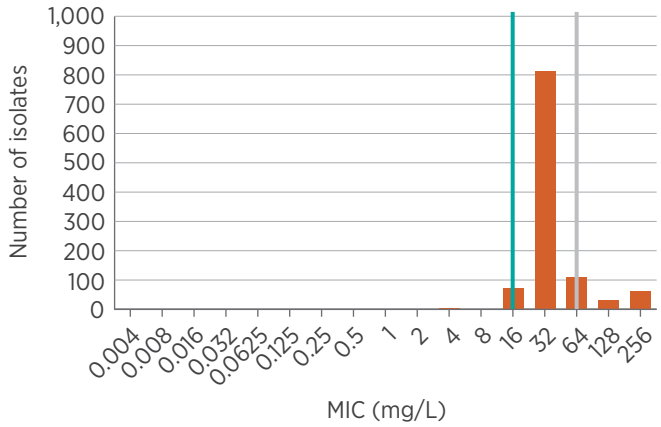


MIC50	MIC90	GM	%R
0.5	1	0.548	0.0

continues

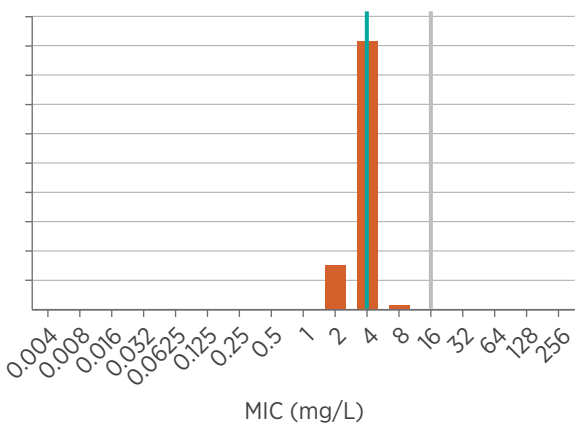
Figure 6.17: *continued*

CTX



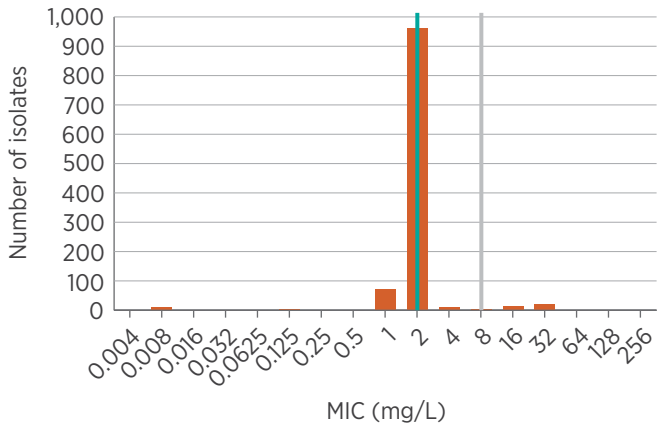
MIC50	MIC90	GM	%R
32	64	36.707	18.8

MEM



MIC50	MIC90	GM	%R
4	4	3.646	0.1

MXF



MIC50	MIC90	GM	%R
2	2	1.971	3.5

AMC = amoxicillin–clavulanic acid; CLI = clindamycin; CTX = ceftriaxone; FDX = fidaxomicin; GM = geometric mean MIC; MEM = meropenem; MTZ = metronidazole; MXF = moxifloxacin; RFX = rifaximin; VAN = vancomycin
Note: Where available, established susceptible and resistant breakpoints are indicated by vertical blue and grey lines, respectively.

Future directions

The Commission will work with the states and territories, private laboratories, and the Royal College of Pathologists of Australasia to promote harmonisation of processes to enable a more consistent case definition for CDI. The Commission will also work with states and territories, and the private sector to continue to promote both the importance of CDI in antimicrobial stewardship and infection prevention and control activities for CDI.

Clostridioides difficile is indicated for monitoring, through passive surveillance, as an AURA priority organism, and will be prioritised if a signal emerges.

The Commission will continue to work with experts and stakeholders to ensure effective monitoring and response, as required.

C. difficile is an important One Health issue, and the Commission will support any national work, as required.

6.4 International comparisons of antimicrobial resistance

Australia's AMR rates can be compared with those of European countries for selected pathogens, because Europe is the only region that regularly releases comparable data. Data from the Australian Group on Antimicrobial Resistance (AGAR) can be directly compared with data from the European Antimicrobial Resistance Surveillance Network (EARS-Net) program[34-36], because both surveillance systems review resistance in bacterial pathogens found in blood cultures.

Rates of resistance to fluoroquinolones in *E. coli* and *Klebsiella pneumoniae* (represented by resistance to ciprofloxacin) remain low in Australia compared with most European countries (Figures 6.18 and 6.19). Fluoroquinolone resistance in Australia has increased substantially from 2015 to 2019, for both *E. coli* and *K. pneumoniae*. In contrast, there were decreases in the European Union and European Economic Area (EU/EEA) averages for both species.

Australia now ranks towards the middle in rates of resistance to third-generation cephalosporins in *E. coli*, and is now just below the EU/EEA average. It has slowly risen in rank over the previous decade. Third-generation cephalosporin resistance in *K. pneumoniae* is low by comparison (Figures 6.20 and 6.21). In Australia, there was an increasing trend in third-generation cephalosporin resistance from 2015 to 2019. Almost three-quarters of European countries had either decreasing trends or no change.

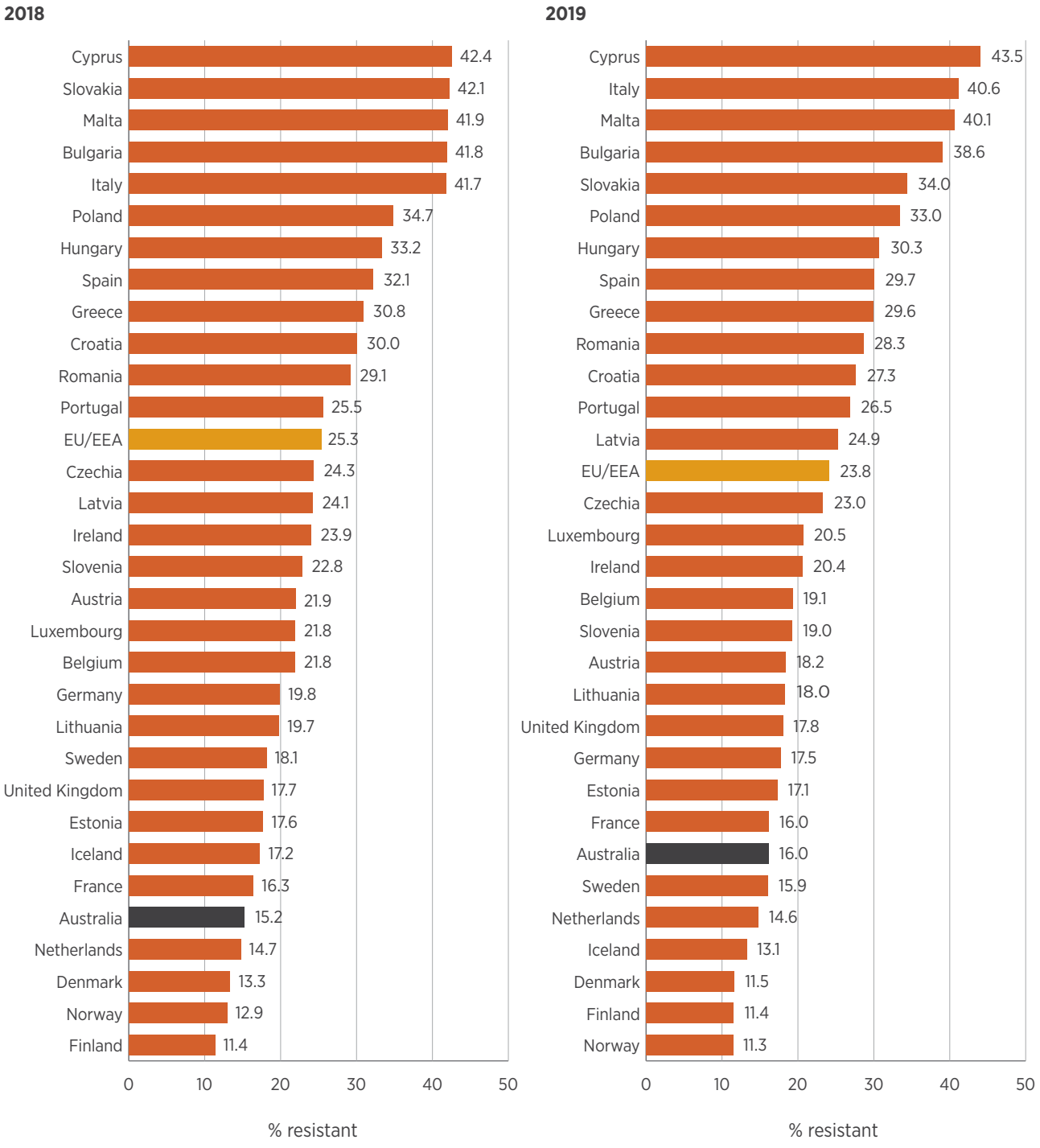
Resistance to piperacillin–tazobactam in *Pseudomonas aeruginosa* was moderate, but lower than the EU/EEA average (Figure 6.22). There was little change in the resistance rate from 2015 to 2019.

Australia ranks towards the middle in rates of resistance to methicillin in *S. aureus*, with rates similar to the EU/EEA (Figure 6.23). The methicillin resistance rate has remained steady in Australia from 2015 to 2019, while a little over one-third of European countries had decreasing trends.

Rates of resistance to vancomycin in *Enterococcus faecium* were higher in Australia than in all European countries except Cyprus, Greece and Poland in 2019 (Figure 6.24). Resistance rates in Australia have declined from 2015 to 2019. In contrast, just under one-half of European countries had increasing trends.

For fluoroquinolone-resistant Escherichia coli*, Australia ranked third lowest compared with European countries in 2015, but rose to sixth lowest by 2019, despite increases in resistance rates in most European countries.*

Figure 6.18: *Escherichia coli* rates of resistance to fluoroquinolones* in Australia and European countries, 2018 and 2019

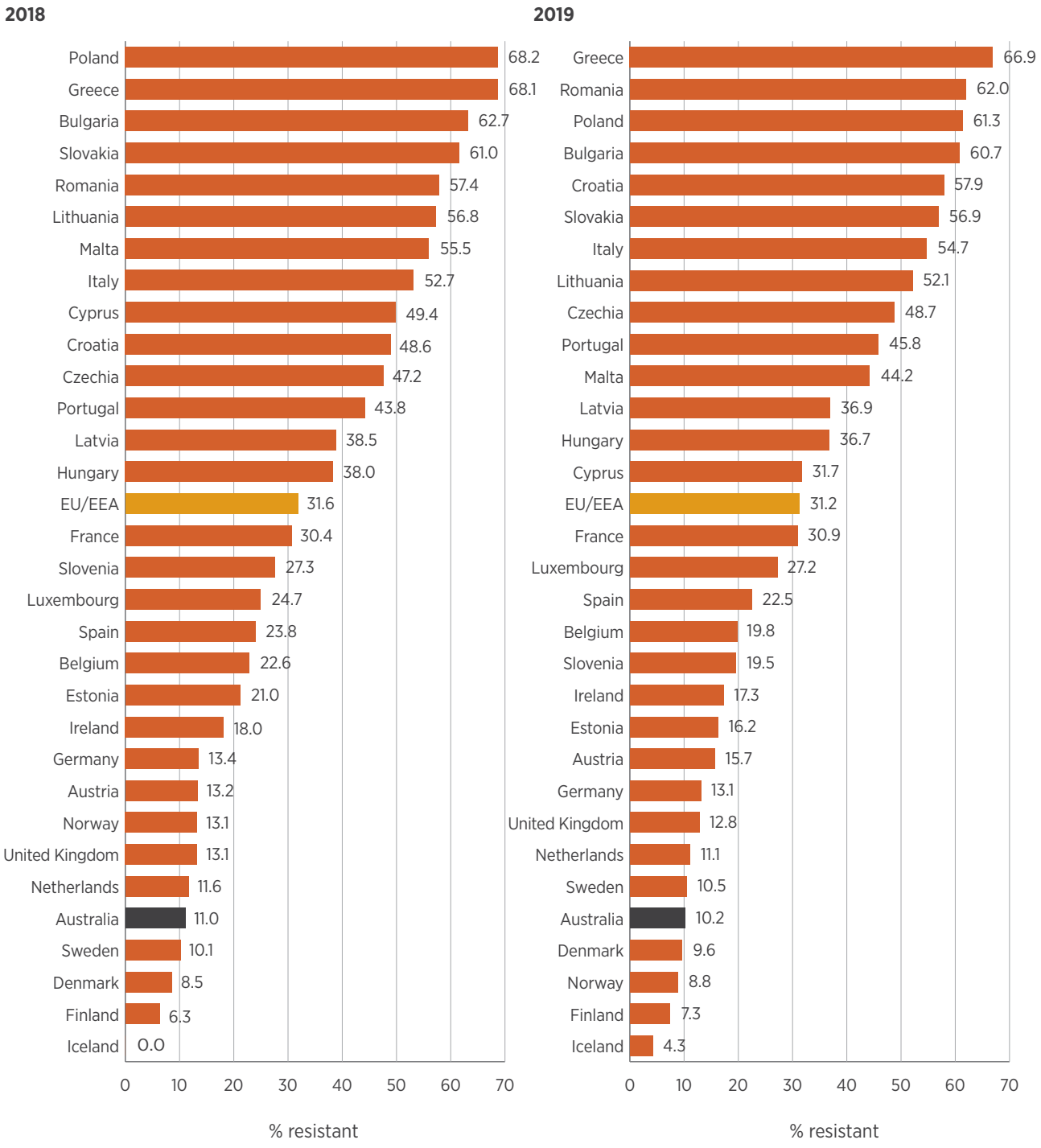


EU/EEA = European Union (EU) and European Economic Area (EEA) countries' population-weighted mean percentages

* Represented by resistance to ciprofloxacin

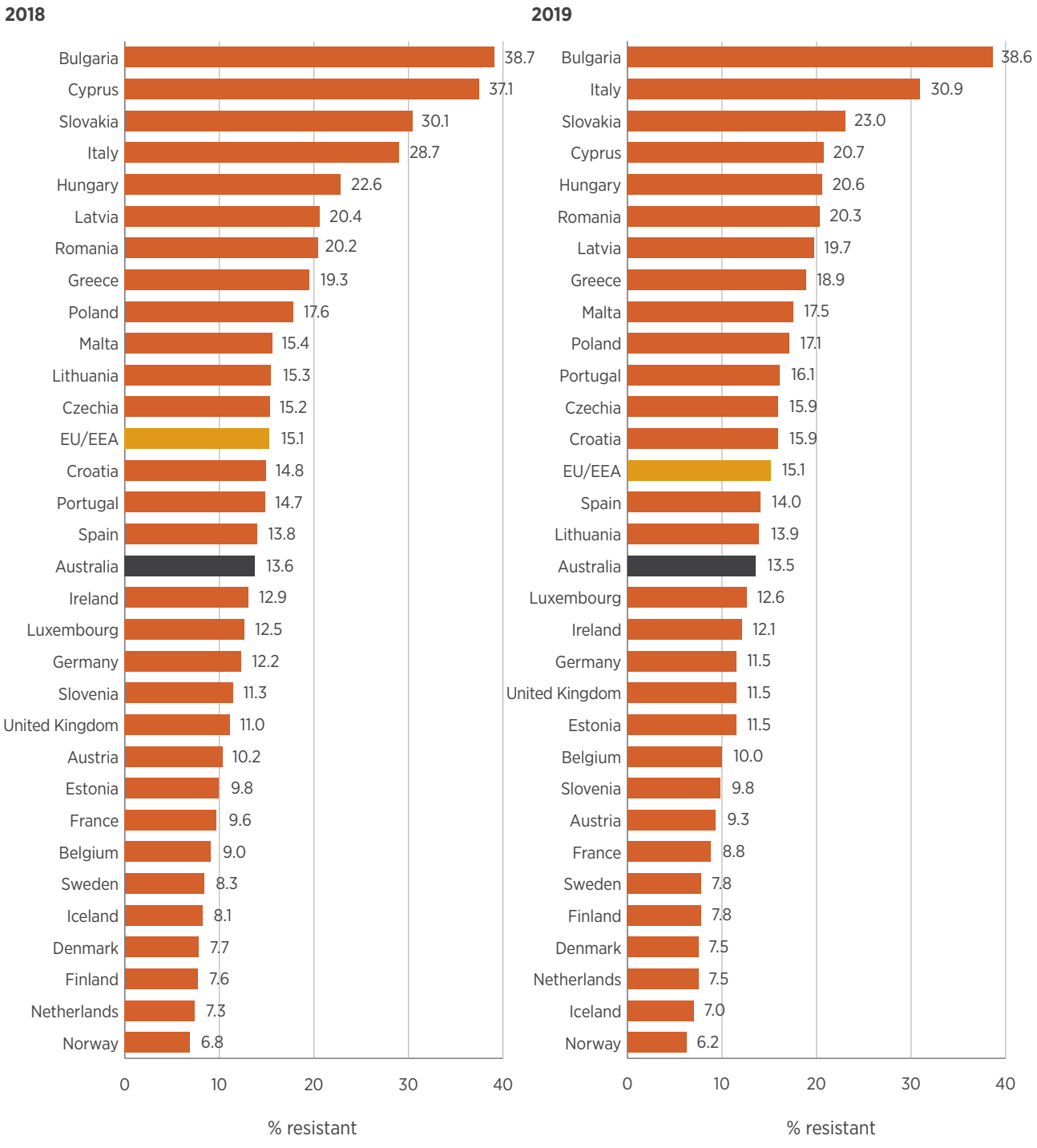
Sources: AGAR (Australia); EARS-Net (Europe)

Figure 6.19: *Klebsiella pneumoniae* rates of resistance to fluoroquinolones* in Australia and European countries, 2018 and 2019



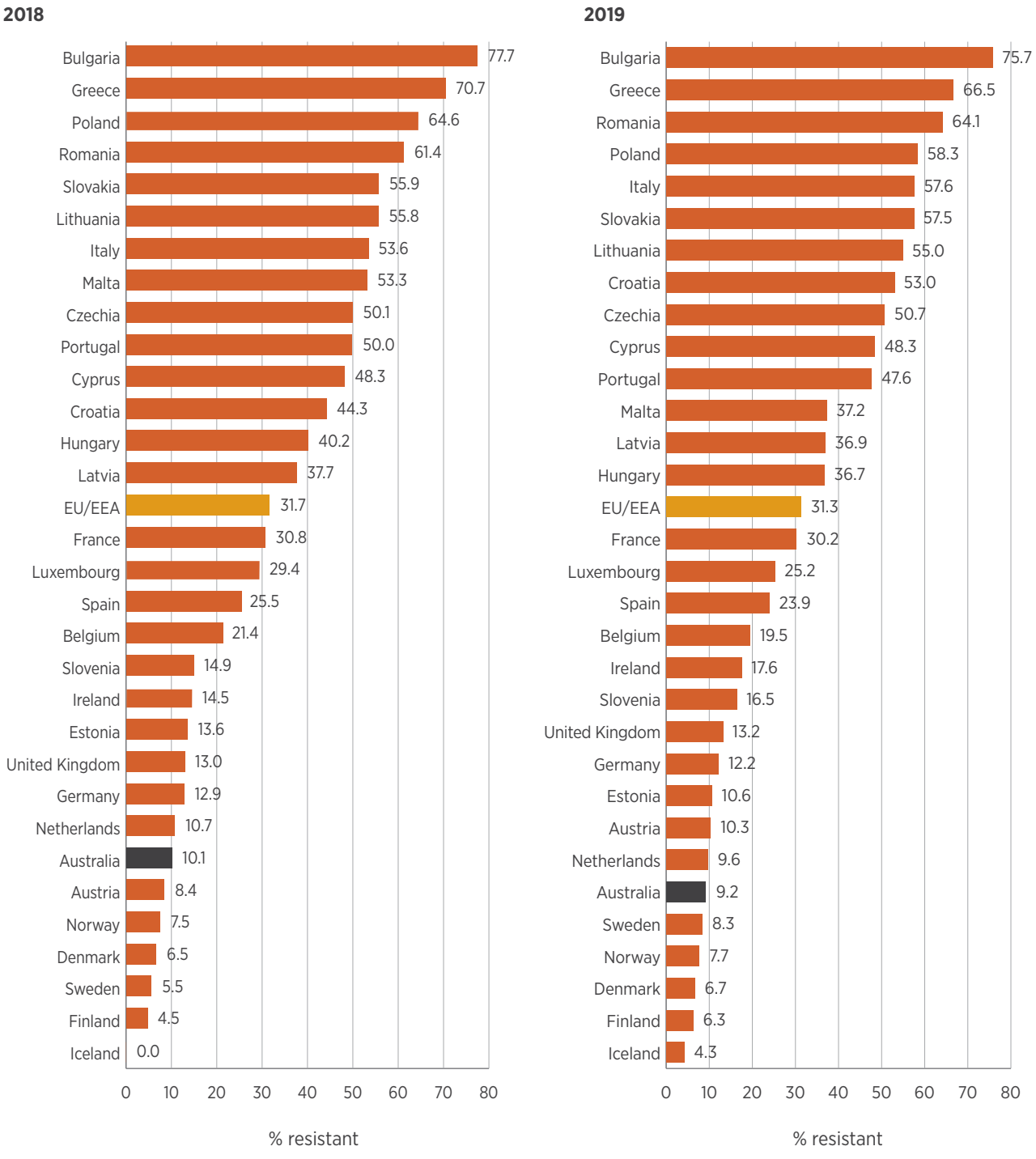
EU/EEA = European Union (EU) and European Economic Area (EEA) countries' population-weighted mean percentages
* Represented by resistance to ciprofloxacin
Sources: AGAR (Australia); EARS-Net (Europe)

Figure 6.20: *Escherichia coli* rates of resistance to third-generation cephalosporins in Australia and European countries, 2018 and 2019



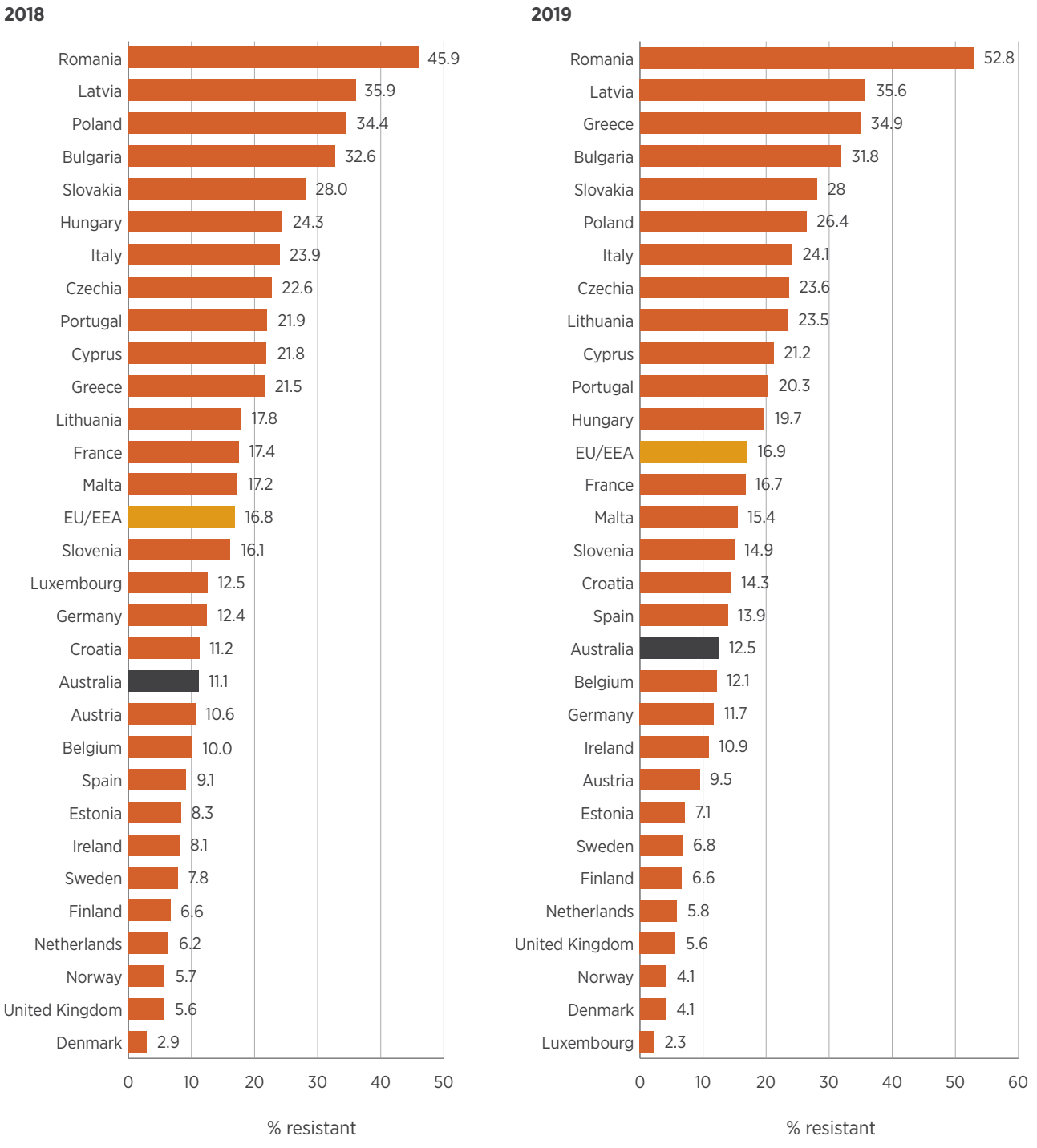
EU/EEA = European Union (EU) and European Economic Area (EEA) countries' population-weighted mean percentages
Sources: AGAR (Australia); EARS-Net (Europe)

Figure 6.21: *Klebsiella pneumoniae* rates of resistance to third-generation cephalosporins in Australia and European countries, 2018 and 2019



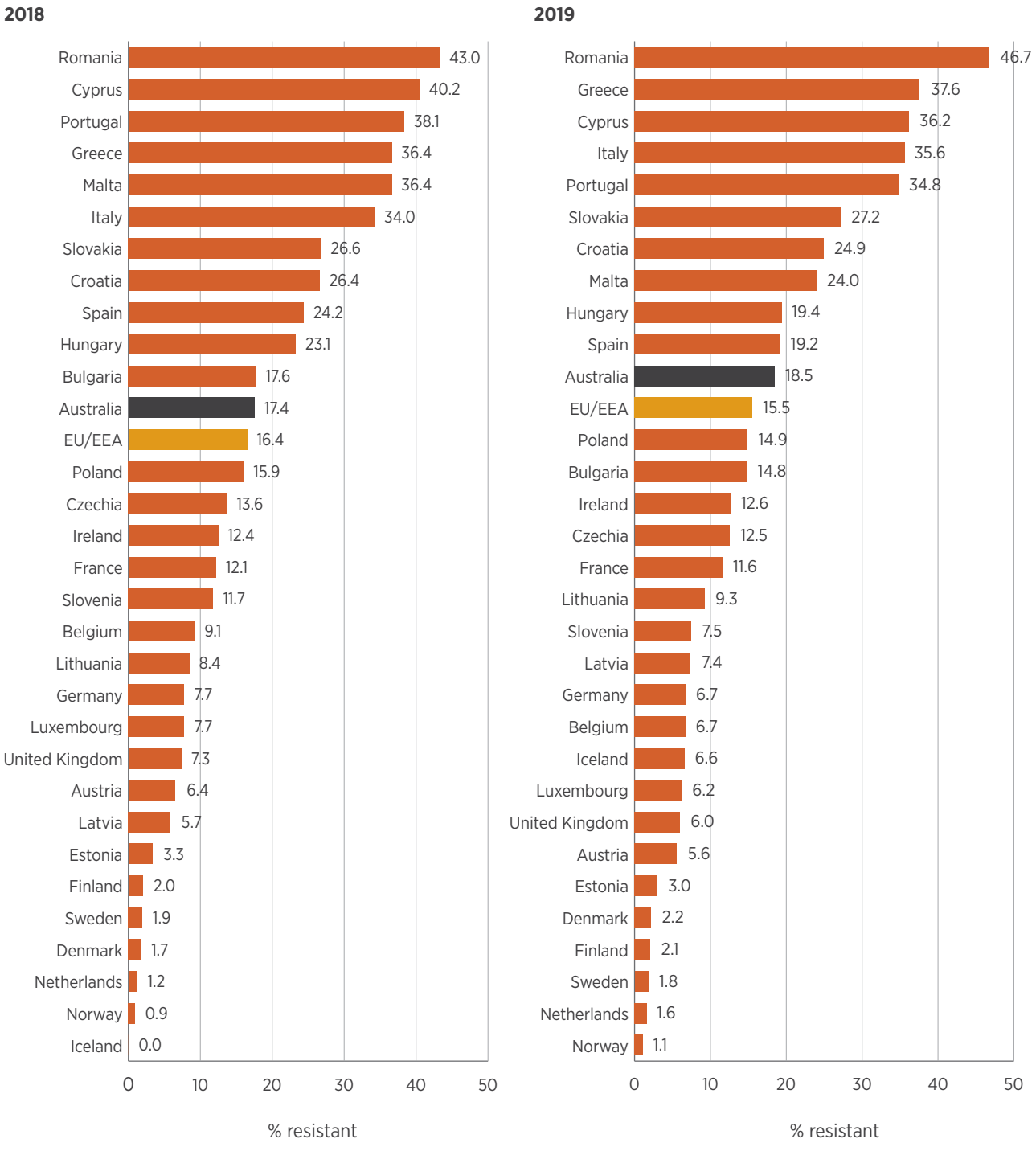
EU/EEA = European Union (EU) and European Economic Area (EEA) countries' population-weighted mean percentages
Sources: AGAR (Australia); EARS-Net (Europe)

Figure 6.22: *Pseudomonas aeruginosa* rates of resistance to piperacillin–tazobactam in Australia and European countries, 2018 and 2019



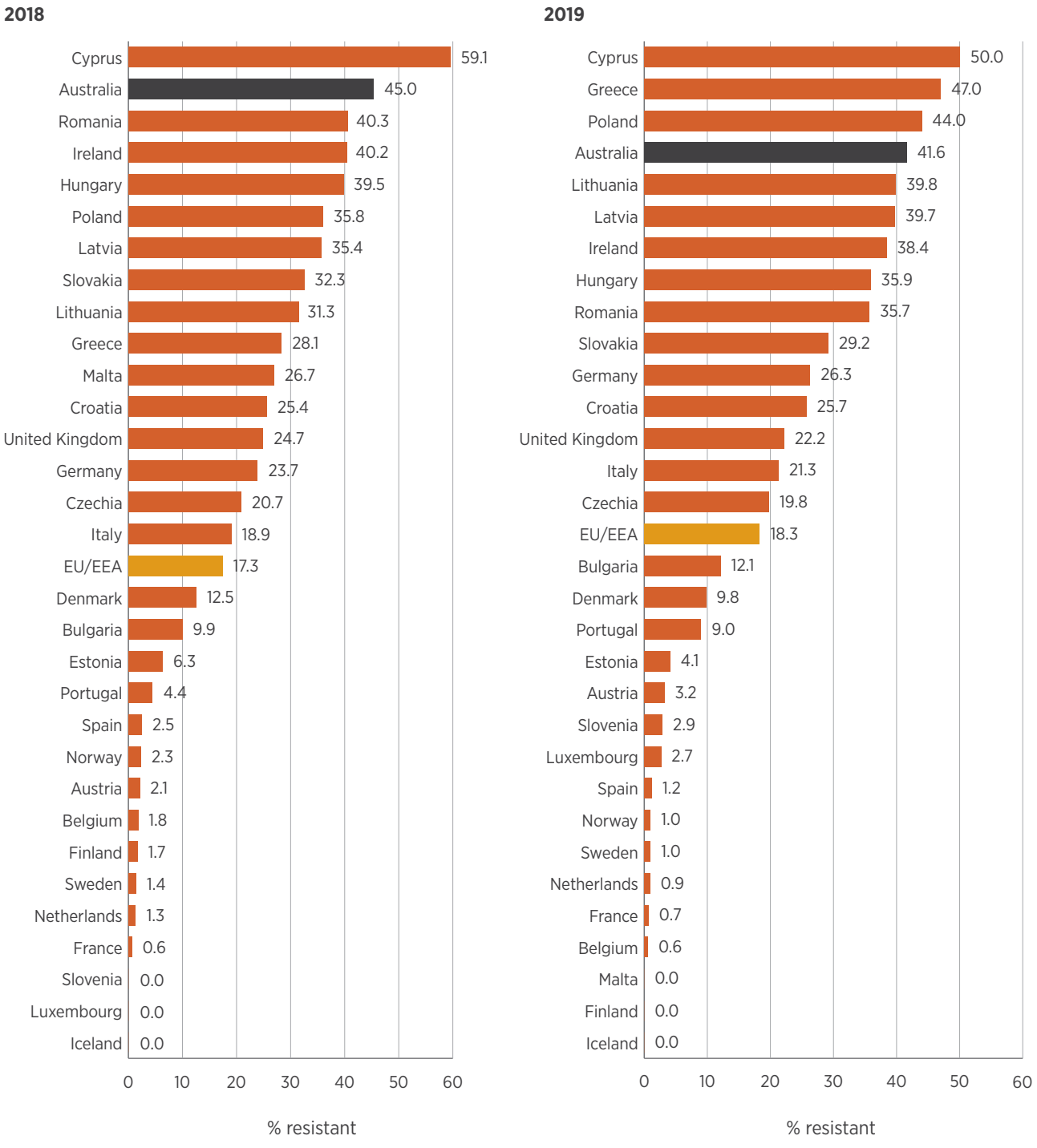
EU/EEA = European Union (EU) and European Economic Area (EEA) countries' population-weighted mean percentages
Sources: AGAR (Australia); EARS-Net (Europe)

Figure 6.23: *Staphylococcus aureus* rates of resistance to methicillin in Australia and European countries, 2018 and 2019



EU/EEA = European Union (EU) and European Economic Area (EEA) countries' population-weighted mean percentages
Sources: AGAR (Australia); EARS-Net (Europe)

Figure 6.24: *Enterococcus faecium* rates of resistance to vancomycin in Australia and European countries, 2018 and 2019



EU/EEA = European Union (EU) and European Economic Area (EEA) countries' population-weighted mean percentages
Sources: AGAR (Australia); EARS-Net (Europe)

Enterobacterales: fluoroquinolones and third-generation cephalosporins

Although Australia's rates of fluoroquinolone resistance in *E. coli* and *K. pneumoniae* remain very low compared with most European countries, Figures 6.18 and 6.19 show that resistance has increased when compared with some countries. Resistance rates to third-generation cephalosporins in these two species are lower than the European average (Figures 6.20 and 6.21).

Restricting access to fluoroquinolones in both the community and hospitals is thought to have kept rates of resistance to these antimicrobials low in Australia, ensuring their ongoing value for treating infections caused by strains that are resistant to other antimicrobial classes. However, this picture is now changing. For fluoroquinolone-resistant *E. coli*, Australia ranked third lowest compared with European countries in 2015 (AURA 2017 report), but rose to sixth lowest in 2019, despite increases in resistance rates in most European countries. This has occurred in the context of no major changes in Australian restrictions. The reasons for the increase in resistance rates are unclear. Possible contributing factors include (see Chapters 3 and 4):

- Spread of specific fluoroquinolone-resistant clones
- Co-selection of resistance as a result of high use of amoxicillin, amoxicillin–clavulanic acid and cefalexin in the community.

Rates of resistance to third-generation cephalosporins remained fairly low in Australia for some time, but have been increasing slowly (see Chapter 4). This antimicrobial class is restricted in the community, but is still widely used in hospitals – often unnecessarily, as the National Antimicrobial Prescribing Survey has shown (see Chapter 3). Also, similar to fluoroquinolone resistance, resistance co-selection may be playing a role.

Rates of resistance to third-generation cephalosporins remained fairly low in Australia for some time, but have been increasing slowly.

Pseudomonas aeruginosa: piperacillin–tazobactam

As for other gram-negative pathogens, Australian resistance rates to piperacillin-tazobactam in *P. aeruginosa* are lower than the European average (Figure 6.22). Because *P. aeruginosa* is a species with a largely environmental, rather than human, reservoir, differences between countries reflect environmental factors, and infection control standards and practices.

Staphylococcus aureus: methicillin; *Enterococcus faecium:* vancomycin

In contrast to the resistance rates for *E. coli* and *K. pneumoniae*, rates for *S. aureus* and *E. faecium* are not as favourable. Australia ranks in the top half of countries for MRSA rates (Figure 6.23), and had higher rates of resistance to vancomycin in *E. faecium* than more than 30 European countries in 2018 and more than 28 European countries in 2019 (Figure 6.24), even though rates in Australia have levelled off in recent years, as described in Chapter 4.

Australia ranks in the top half of countries for MRSA rates, and had higher rates of resistance to vancomycin in Enterococcus faecium *than most European countries in 2018 and 2019, even though rates in Australia have levelled off in recent years.*

For MRSA, overall resistance rates have changed very little in Australia in 2018 and 2019. However, there has been a:

- Continuing decline in the prevalence of the MDR healthcare-associated clone ST239
- Sustained presence of the United Kingdom–originating EMRSA-15 healthcare-associated clone
- Continuing rise in the prevalence of community-associated clones.[37,38]

European surveillance data do not include clonal analyses of MRSA, so the proportions of community-associated MRSA (CA-MRSA) and healthcare-associated MRSA (HA-MRSA) in a particular country are not known. In Europe, the proportion of community-onset infections caused by MRSA clones that are usually associated with HA-MRSA has increased, indicating transfer of HA-MRSA clones into the community.[39] In Australia, CA-MRSA has a similar prevalence to HA-MRSA.

6.5 International comparisons of antimicrobial use

Hospital use

In 2019, systemic AU (on a DDD/1,000 people basis) appeared to be higher in Australian hospitals than in any European country (Figure 6.25). However, it should be noted that the Australian value is based on extrapolation of data collected in the National Antimicrobial Utilisation Surveillance Program (NAUSP), which is biased towards larger hospitals. AU may be higher in larger hospitals because of greater patient complexity than the national average. It is estimated that NAUSP participation captured data from around 30% of national occupied bed days in 2019. Nevertheless, Australian AU is nearly four times that of the European country with the lowest AU – the Netherlands – and considerably higher than the AU in Canada, suggesting that use was comparatively high despite the caveat noted above.

Community use

Community use of antimicrobials in Australia in 2019 remained high compared with most European countries and Canada (Figure 6.26). Of the 31 comparator countries, AU (on a DDD/1,000 people basis) was higher in only five countries. Although the trend in Australia has been downward since 2015, the pace of reduction has been slow. This is similar to patterns in Europe.

The COVID-19 pandemic in 2020 has had a dramatic impact on community AU, as described in more detail in Section 6.2.

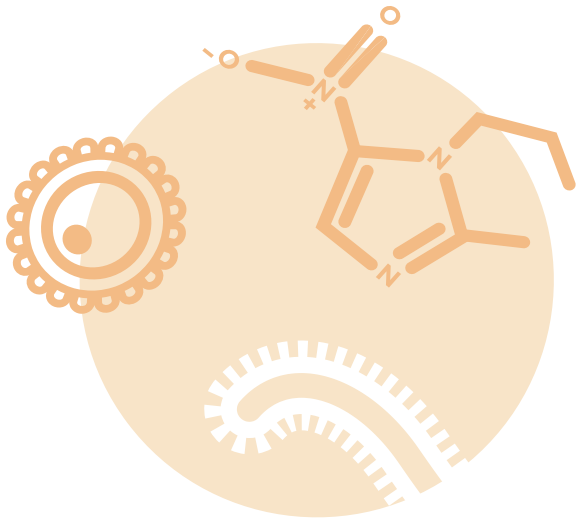
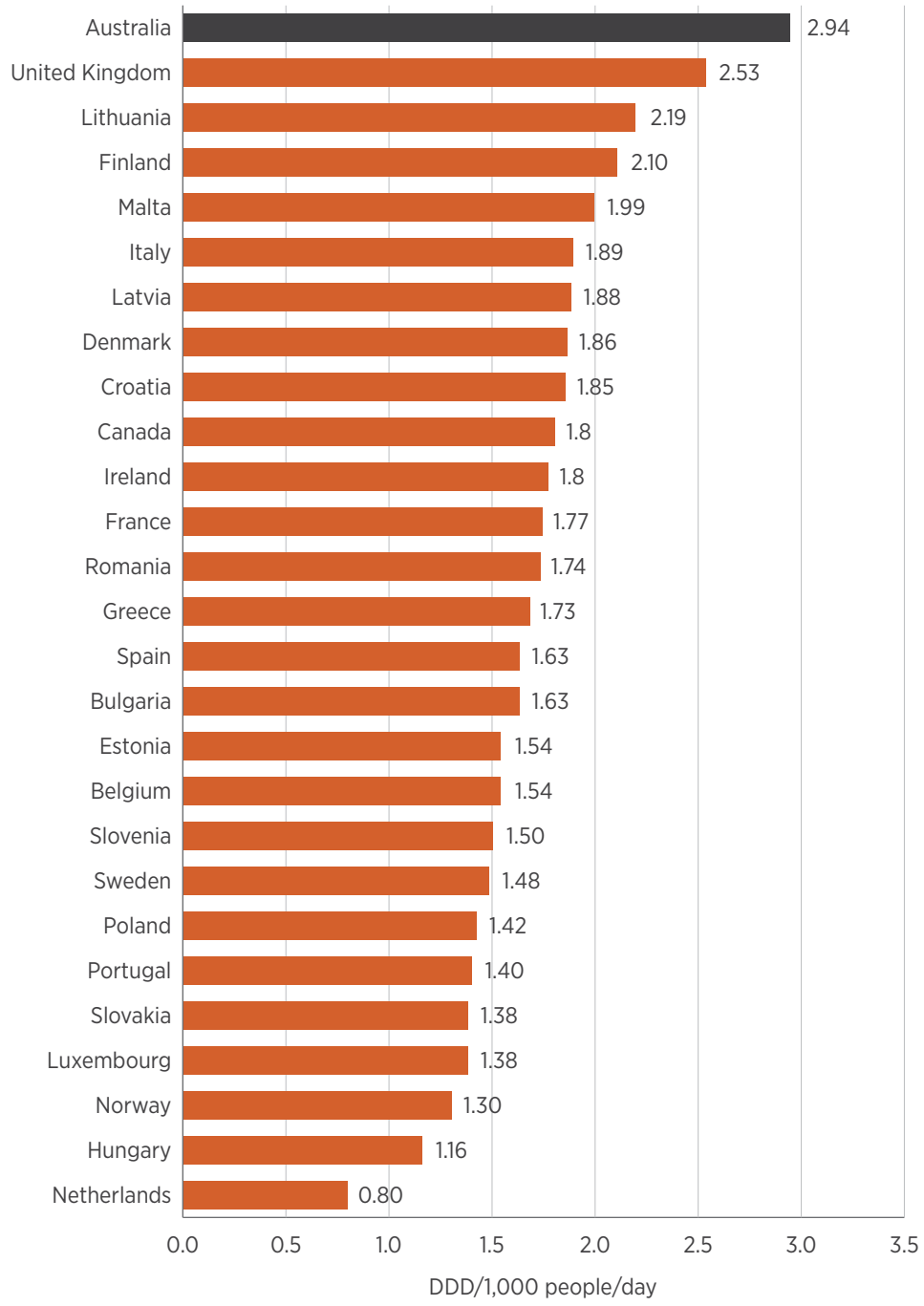
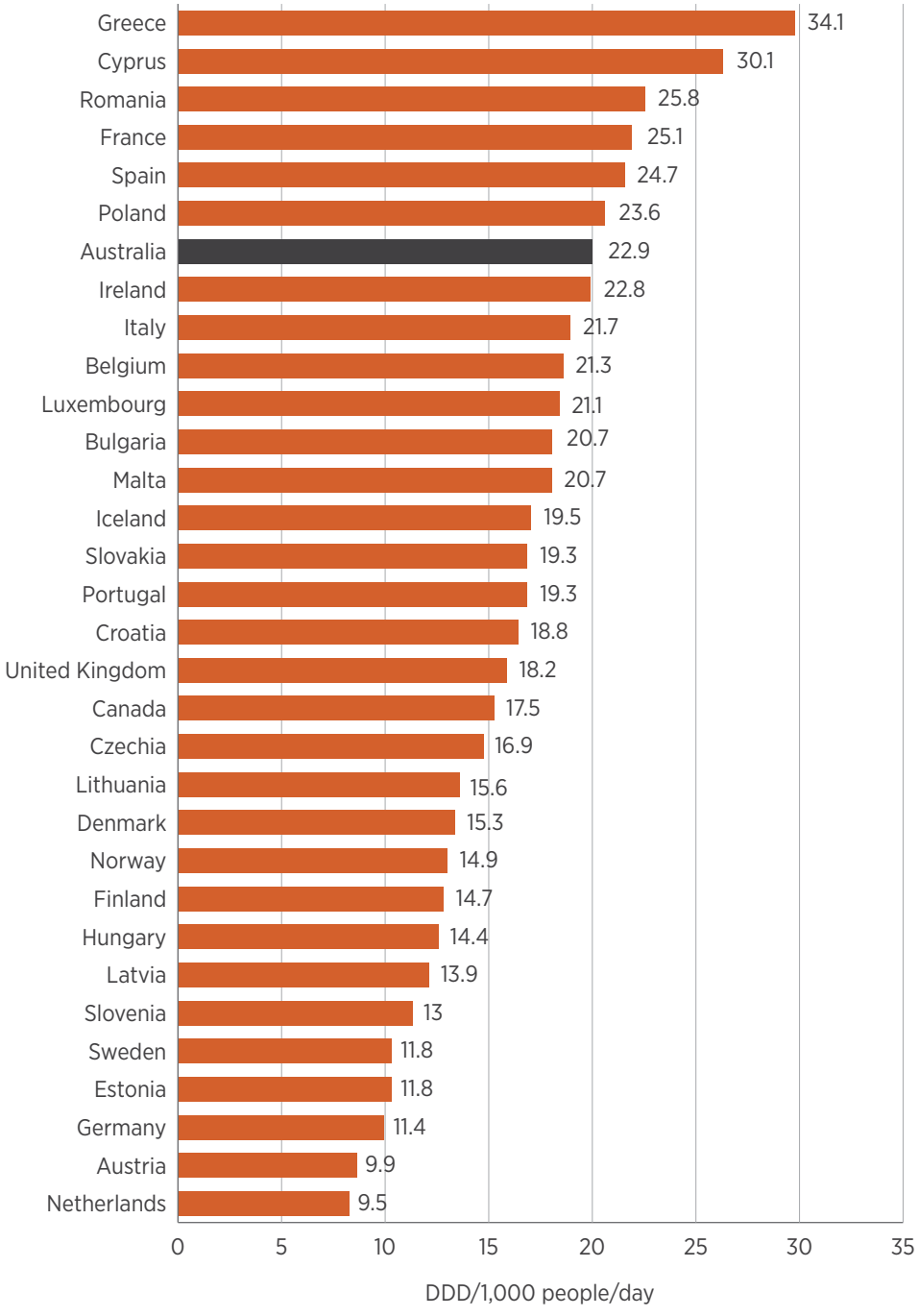


Figure 6.25: Hospital antimicrobial use in Australia, European countries and Canada, 2019



Sources: NAUSP (Australia); EARS-Net (Europe); CARSS 2020 (Canada)

Figure 6.26: Community antimicrobial use in Australia, European countries (2019) and Canada (2018)



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7

Chapter 7
Conclusions and future developments

Key messages

- Since 2013, when the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System was established, antimicrobial resistance (AMR) has continued to increase. AMR remains a risk to patient safety because it reduces the number and effectiveness of antimicrobials available to treat infections, increases morbidity and mortality associated with infections caused by multidrug-resistant organisms, and may limit future capacity to perform medical procedures such as organ transplantation, cancer chemotherapy, diabetes management and major surgery.
- The AURA Surveillance System has provided data that have improved understanding of local and national patterns and trends in antimicrobial use (AU) and AMR across Australia. It has provided clinicians, policymakers and health system managers with data on AMR and AU to inform clinical practice and policy development. AURA is now a world-class surveillance program, and in one important respect is more comprehensive than other national programs as it is able to monitor, and report on, appropriateness of use in both hospitals and the community.
- AURA 2021 complements the findings of previous national AURA reports and other focused reports on AMR and AU from the Australian Commission on Safety and Quality in Health Care (the Commission). Each report provides additional information, provided by all states and territories and the private sector, to support development of more targeted and effective strategies for appropriate antimicrobial prescribing, and to prevent and control AMR nationally.
- Resistance rates for many priority organisms have not changed substantially since AURA 2019. However, several changes in resistance have been highlighted, and are important to consider at the local, state and territory, and national levels.

continues

- In gram-negative pathogens, it is of serious concern that resistances to common agents used for treatment continue to increase in *Escherichia coli.* Carbapenem resistance in *Enterobacterales* remains uncommon. Rates of resistance in *Enterobacterales* to most agents were lower in the community than in hospitals. However, rates in aged care homes were often as high as, or higher than, rates in hospitals.
- In *Staphylococcus aureus*, the epidemiology of methicillin resistance continues to evolve. Previously dominant clones are being replaced by other clones, and community-associated methicillin-resistant *S. aureus* has become prominent, especially in rural and remote regions. This demonstrates the need for a renewed focus on infection prevention and control in both community and hospital settings.
- Overall rates of vancomycin resistance in *Enterococcus faecium* are declining nationally, but are still greater than 40%, which highlights the ongoing need for focused response strategies.
- Generally, reports of critical antimicrobial resistances (CARs) to the National Alert System for Critical Antimicrobial Resistances (CARAlert) remain at very low levels. However, there have been fluctuations since 2016 in reports of community-associated CARs such as multidrug-resistant *Shigella* species and ceftriaxone-nonsusceptible or azithromycin-nonsusceptible *Neisseria gonorrhoeae.* Ongoing monitoring and prevention and control strategies are essential to ensure that levels of CARs continue to remain low in Australia.
- The gradual decrease in the volume of AU in the community continued in 2019. There was a 40% drop in Pharmaceutical Benefits Scheme dispensing in 2020 during the response to the COVID-19 pandemic, which suggests that there are opportunities to intervene to sustain these lower levels of AU.
- The gradual increase of AU in hospitals continued in 2019, although the direct cause of this shift in volume remains unclear. While there have been changes in its coordination role in relation to AU, the Australian Commission on Safety and Quality in Health Care (the Commission) will continue to work with relevant stakeholders to monitor changes and develop appropriate response strategies.
- The overall appropriateness of antimicrobial prescribing in hospitals and residential aged care services that participated in the National Antimicrobial Prescribing Survey was static. However, in hospitals, appropriateness of prescribing varies widely between peer groups: smaller hospitals have higher rates of inappropriate prescribing, and appropriateness of prescribing appears to have deteriorated in private hospitals.
- Key areas of focus for the Commission in 2022 will be to support the relevant lead organisations in the aged care and primary care sectors, and clinicians and carers, to understand the reasons for inappropriate prescribing and improve prescribing practice.
- AURA 2021 data provide increased capacity to identify patterns and trends in resistance in the priority organisms for Australia in acute care, residential aged care services and the community.

continues

These data inform targeted responses to specific resistances in specific settings. The Commission will consult further with clinical and technical experts to provide this information in the most accessible form.

- AURA 2021 includes, for the first time, data from the HOTspots surveillance program, which monitors AMR in far north Australia, and also the inclusion of data on *Clostridioides difficile.* The Commission's AURA team will continue to integrate resistance data such as these to inform implementation of Australia's National AMR Strategy: 2020 and Beyond, and state, territory and private sector AMR response strategies.

This chapter provides an overview of the key issues identified from analyses of data for the Antimicrobial Use and Resistance in Australia (AURA) 2021 report, and suggestions for next phases of work and ongoing development of the AURA Surveillance System, in regard to One Health surveillance. The work of the Australian Commission on Safety and Quality in Health Care (the Commission) in supporting AURA, and antimicrobial resistance (AMR) prevention and control strategies, is also discussed.

7.1 Conclusions from AURA 2021

As a result of the expansion in the breadth and depth of AMR and antimicrobial use (AU) surveillance in Australia since 2013, there is a more comprehensive understanding of resistance, with examples of both improvements and worsening for specific organisms.

It remains clear that AMR is a substantial risk to patient safety because it reduces the number, and effectiveness, of antimicrobials available to treat infections, increases morbidity and mortality associated with infections caused by multidrug-resistant organisms, and may limit future capacity to perform medical procedures such as organ transplantation, cancer chemotherapy, diabetes management and major surgery.

Resistance rates for many priority organisms have not changed substantially since AURA 2019. However, several changes in resistance have been highlighted in this report, and are important to consider at the local, state and territory, and national levels.

In gram-negative pathogens, it is of serious concern that resistances to common agents used for treatment continue to increase in *Escherichia coli,* which is the most common cause of urinary tract infections and septicaemia. Resistance to fluoroquinolones is a marker of multi-drug resistance in this species, and there are very few options for treatment of these strains with oral antimicrobial agents. Although detailed reasons for the increase in resistance are not known, it is certain that high community use of other oral antimicrobials, to which fluoroquinolone-resistant strains are also resistant, is contributing.

Data from the Australian Group on Antimicrobial Resistance (AGAR) show that *E. coli* sepsis is mostly community associated. Resistance to ciprofloxacin and other fluoroquinolones has continued to rise in *E. coli* isolates from community-onset infections, despite restriction of access to these agents on the Pharmaceutical Benefits Scheme (PBS). These changes in resistance may result in increasing treatment failures and greater reliance on last-line treatments such as carbapenems.

Carbapenem resistance in *Enterobacterales* remains uncommon, and overall rates of resistance in *Enterobacterales* for most agents were somewhat lower in the community than in hospitals. However, rates in aged care homes were often as high as, or higher than, rates in hospitals. As residents regularly move between residential aged care services and the acute care sector, greater vigilance is required in their care and the care of other inpatients with whom they come into contact to minimise the risk of transmission of resistant organisms.

Resistance rates in some major gram-positive pathogens are steadily increasing; in others, they remain stable but high. In *Staphylococcus aureus*, the epidemiology of methicillin resistance continues to evolve. Community-associated clones of methicillin-resistant *S. aureus* (MRSA) continued to become more widespread nationally in 2019, especially ST93, which became the most common clone found in sepsis. This clone accounted for almost 1 in 4 MRSA isolates in 2019. However, there was a great diversity of clones across the states and territories. Community-associated MRSA was especially prominent in remote and very remote regions. This demonstrates a need for a renewed focus on infection prevention and control in both community and acute settings.

The rate of vancomycin resistance in *Enterococcus faecium* is declining nationally. However, rates still exceed 40%, and remain higher in Australia than in more than 30 European countries. Whereas the main type of vancomycin-resistant *E. faecium* circulating in Australia before 2017 was the *vanB* type, by 2018, the *vanA* type predominated. In 2019, nationally, *vanA* and *vanB* were circulating equally. These strains are resistant to teicoplanin, an agent used widely to manage infections with *vanB*-harbouring strains that have been dominant in Australia until recently. The situation in relation to *vanA*-harbouring strains is concerning because very few antimicrobials remain for the treatment of infections with these strains, and the efficacy of some of these agents is uncertain.

The rate of vancomycin resistance in Enterococcus faecium *is declining nationally. However, rates still exceed 40%, and remain higher in Australia than in more than 30 European countries.*

A small proportion of *E. faecium* strains that have a *vanA* or *vanB* gene are susceptible to vancomycin. These strains may act as a hidden reservoir of resistant gene complexes. Different sequence types of *E. faecium* have become established in different states and territories, consistent with rapid local or regional spread. This emphasises the importance of local infection prevention and control practices to contain the spread of vancomycin-resistant strains.

Trends in resistance for a number of organisms have implications for treatment choices. In *Salmonella*, ciprofloxacin resistance in typhoidal species (*Salmonella* Typhi and *Salmonella* Paratyphi) exceeded 78% in 2019, confirming that ciprofloxacin should no longer be relied on for empirical treatment. Rates of *Shigella sonnei* resistance to ceftriaxone, ciprofloxacin and ampicillin were considerably larger than the 2017 rates noted in AURA 2019. In *Streptococcus agalactiae*, resistance to erythromycin and clindamycin has steadily increased to approximately 33% in 2019. Macrolide resistance in *S. pyogenes* has doubled since 2017 to 9% in 2019, reducing the utility of these second-line agents.

Patterns of AU in Australian hospitals remain stable. The gradual increase in volume of AU in hospitals that commenced in 2017, as shown in

data from the National Antimicrobial Utilisation Surveillance Program (NAUSP), continued in 2019. The reasons for this increase are not clear, but will continue to be monitored.

Analyses of NAUSP data, undertaken using the Priority Antibacterial List[1], demonstrate the practical benefits of stratification of antibiotics to contain AMR in human health, and also enable Australian hospitals to benchmark their AU against other similar hospitals, and monitor their AU over time. The analyses showed variations between states and territories in use of the various categories of antibiotics, and highlighted opportunities for states and territories and the private sector to develop local strategies to maximise use of antibiotics in the Access category. This category includes antibiotics recommended as first-line treatment for common infections, and which have a low potential for promoting AMR.

It is concerning that overall appropriateness of prescribing in Australian hospitals has not improved among contributors to the National Antimicrobial Prescribing Survey (NAPS), noting that there is variability between hospital peer groups. Rates of appropriateness are lower in smaller public hospitals, and appear to have deteriorated in participating private hospitals. The amount, nature and range of resources available to be designated to support antimicrobial stewardship (AMS) programs may be factors in the differences between large hospitals, small hospitals and the private sector. The rate of overall appropriateness may also be influenced by increased participation in the Hospital NAPS by smaller public and private hospitals.

Areas for action

Review prescribing practices in light of current and emerging resistances and inform guideline development

Resistance rates in some common pathogens are at levels at which prescribing practices should be reviewed.

Resistance to trimethoprim in *E. coli* is currently at around 25% nationally. This has a potential impact on the treatment of lower urinary tract infections.

High rates of resistance (>75%) to ciprofloxacin in the *Salmonella* species causing enteric fever (*Salmonella* Typhi, *Salmonella* Paratyphi) imply that these agents should no longer be used as initial empirical therapy.

Rates of resistance to clindamycin in *Streptococcus agalactiae* (group B *Streptococcus*) mean that this agent should only be used at delivery for preventing neonatal sepsis if the organism is known to be susceptible after laboratory testing.

The Commission's AURA team will continue to work with Therapeutic Guidelines Limited to inform the guidelines, and promote these findings through clear communications with prescribers.

The Commission's AURA team will continue to:

- Work with Therapeutic Guidelines Limited to inform the guidelines, and promote these findings through clear communications with prescribers
- Promote use of the Priority Antibacterial List in public and private hospitals, along with other AMS surveillance tools to support improvement in AU and patient safety.

From 2015 to 2019, there were improvements in three key indicators of appropriateness of antimicrobial prescribing: documentation of indication, documentation of review or stop date, and the proportion of surgical prophylaxis given for greater than 24 hours. Nevertheless, further improvement is needed because, along with compliance with national guidelines, these aspects of prescribing are requirements of the AMS Clinical Care Standard[2], and remain challenges for AMS programs. New and enhanced AMS actions included in the 2021 Preventing and Controlling Infections Standard build on the Commission's previous work to address these issues, by requiring health service organisations to:

- Have an antimicrobial formulary that is informed by current evidence-based Australian therapeutic guidelines or resources, in addition to the previous requirement for restriction rules and approval processes
- Demonstrate action on the results of audits of AU and appropriateness of prescribing to promote continuous quality improvement
- Report to clinicians and the governing body about areas of action for AMR and areas of action to improve appropriateness of prescribing
- Demonstrate compliance with current evidence-based Australian therapeutic guidelines or resources on antimicrobial prescribing, and demonstrate the health service organisation's performance in the use and appropriate use of antimicrobials.

Reports of inappropriate prescribing of a number of broad-spectrum antimicrobials continue. The indications with the most inappropriate prescribing – chronic obstructive pulmonary disease (COPD), surgical prophylaxis and non-surgical wounds – showed no changes from 2018 to 2019. Along with trends in poor guideline compliance for community-acquired pneumonia, these areas require continuing focus and urgent intervention.

Area for action

Improve appropriateness of prescribing for COPD

Inappropriate prescribing of antimicrobials for the treatment of COPD continues.

To build on previous efforts to highlight this issue, and emphasise the need for improvement action, the Commission's AURA team will collaborate with Lung Foundation Australia and the Thoracic Society of Australia and New Zealand to promote appropriate prescribing and adherence to national guidelines. These guidelines include *Therapeutic Guidelines: Antibiotic*[3] and the *COPD-X Plan: Australian and New Zealand guidelines for the management of chronic obstructive pulmonary disease*.[4]

The Surgical NAPS identified specific patterns of inappropriate prescribing, such as prolonged duration of AU post-procedure and inappropriate choice of antimicrobials for some surgical specialties. There are opportunities for the Commission to continue its collaborative work with the Royal Australasian College of Surgeons and the relevant specialty societies to provide tailored and appropriate information for different procedural groups to improve prescribing.

The declining volume of prescriptions in primary care since 2015 is encouraging, especially when coupled with the very large drop in PBS prescriptions during the response to the COVID-19 pandemic in 2020. This is testament to efforts by general practitioners,

Area for action

Improve appropriateness of prescribing in primary care

There are opportunities to build on the encouraging decrease in the volume of antimicrobial prescribing in primary care by focusing on strategies to improve the appropriateness of prescribing, and enhance data on prescribing.

The Commission will continue to work with clinicians, state and territory governments, and the Australian Government to develop targeted strategies to improve appropriateness of prescribing, especially for upper respiratory tract infections.

The Commission will also explore opportunities, in liaison with NPS MedicineWise and the Australian Government Department of Health, to further analyse and enhance the availability of data on private prescriptions for antibiotics to provide a more complete picture of AU.

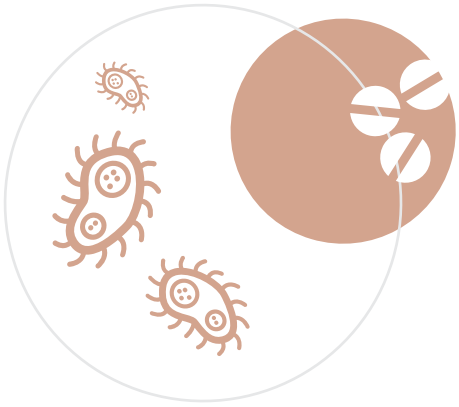
NPS MedicineWise and the Australian Government Department of Health to reduce unnecessary prescribing in the community. It suggests that there is further opportunity to sustain low levels of prescribing and reinforce messaging that antibiotics are not required for treatment of viral respiratory infections.

Results from NPS MedicineWise MedicineInsight data relating to private prescriptions highlight the important issue that data on these prescriptions are not available through the PBS. More in-depth analysis is required to understand the volume of community AU associated with these prescriptions, mechanisms that might be employed to capture data on them routinely, and opportunities to intervene to promote appropriate prescribing of antibiotics.

Findings from the 2019 Aged Care NAPS reinforce the results of all previous surveys in relation to high levels of PRN ('as needed') prescriptions, especially for topical antimicrobials, as well as prescribing of antimicrobials for prophylaxis and for conditions that can be prevented by managing hydration and providing good basic hygiene.

In collaboration with clinicians, aged care providers, state and territory governments, and the Australian Government, the Commission will continue to support further reductions in prescribing volume, and focus on strategies to improve appropriateness of prescribing.

Prescribing in the primary care sector in Australia is still substantially higher than in most European countries, and more than double that of benchmark countries such as the Netherlands. These comparisons should act as incentives to improve practice and to consider setting targets as part of future AMR strategies.



Area for action

Improve appropriateness of prescribing in residential aged care

In addition to the data on the prevalence of some multidrug-resistant pathogens in aged care homes, the 2019 Aged Care NAPS demonstrated ongoing very high levels of unnecessary antimicrobial prescribing.

The Commission's AURA team will continue to liaise with the Aged Care Quality and Safety Commission, aged care providers and general practitioners to promote appropriate prescribing and personal and clinical care for residents of aged care services, consistent with the Aged Care Quality Standards.

In addition, the Commission has published a chapter on aged care in *Antimicrobial Stewardship in Australian Health Care*.

7.2 Future developments for the AURA Surveillance System and AURA reports

The Commission's AURA team has sought opportunities to build on its established model of partnering with a broad range of clinicians, health service organisations, laboratories, health departments and the private sector to increase the volume and representativeness of surveillance data on AU and AMR. As a result, there have been considerable enhancements to AURA since 2013, and a greater breadth and depth of surveillance data to inform AMR prevention and control strategies.

From 2016 to 2019, numbers of contributors to surveillance of AU and appropriateness of prescribing increased substantially. The number of participants in NAUSP and the Hospital NAPS almost doubled during this period, and participation in the Aged Care NAPS increased by almost 250%. This has increased the value of analysis and reporting. The Commission's AURA team has also continued to collaborate with NPS MedicineWise to obtain community-prescribing data through the MedicineInsight program, and to incorporate data from the PBS and the Repatriation PBS for analysis of prescribing in primary care.

All states and the Australian Capital Territory contribute data on AMR through the Australian Passive AMR Surveillance (APAS) system; selected hospitals from all states and territories provide resistance data through AGAR; and laboratories from all states and territories provide reports to the National Alert System for Critical Antimicrobial Resistances (CARAlert).

The Northern Territory, Victoria and the private sector are ongoing areas of focus for the AURA team to improve geographic coverage for APAS. To enhance surveillance of AU and appropriateness of prescribing, the AURA team will continue to promote participation by smaller health services, especially in rural and remote areas, and by residential aged care services nationally.

The AURA Surveillance System is the result of collaboration by the Commission with many organisations that supported the provision of their AMR and AU data on a voluntary basis, along with the program partners that

collected, analysed and reported on these data.

The voluntary contribution of data on AMR has worked well during the establishment of the AURA Surveillance System, and created a large national dataset that includes all states and territories, the public and private sectors, and hospital and community settings. However, it does not yet provide a complete picture of AMR in Australia.

Opportunities to increase the surveillance data available to AURA should continue to be explored, such as through processes similar to those used in the states and territories for mandatory reporting of designated communicable diseases.

National processes, such as the National Health Security Agreement, could also be considered to establish nationally consistent resistance surveillance definitions and response protocols, to require key priority organisms to be notifiable.

Area for action

CDI surveillance

Enhance surveillance of CDI by promoting:

- National harmonisation of CDI diagnostic methods
- CDI surveillance by all states and territories
- National reporting on CDI surveillance to highlight important emerging strains of *C. difficile* and the value of public health genomics
- Incorporation of responses to CDI in AMS programs
- Opportunities to capture molecular data.

A further measure for consideration might be a requirement for all laboratories receiving payments through the Medical Benefits Schedule, for susceptibility testing, to provide resistance data to APAS.

The collaboration with HOTspots and the *Clostridioides difficile* Antimicrobial Resistance Surveillance (CDARS) study, and their inclusion in AURA 2021, has expanded the geographic scope of AURA to far northern Australia, and expands the monitoring of organisms to include *C. difficile* infection (CDI), which is an important AMR threat internationally. CDI is also important in the context of a One Health approach to AMR, due to inter-species considerations. The Commission intends to work with both HOTspots and CDARS to continue to include these aspects in surveillance of resistance.

Public and private laboratories play key roles in contributing to AMR surveillance. The Commission will continue to work with laboratories to promote improved harmonisation of susceptibility testing methods, CDI diagnostic methods, and surveillance of CDI by all states and territories. These efforts will contribute to reducing the impact that different testing methods have on reporting of resistance, and improve the national surveillance effort.

AURA 2021 further promotes the value of data from CARAlert for infection prevention and control programs implemented by health service organisations to meet the requirements of the 2021 Preventing and Controlling Infections Standard of the National Safety and Quality Health Service Standards.[5] Regular reports will continue to be refined to meet user requirements.

As carbapenemase-producing *Enterobacterales* (CPE) remain the critical AMR most frequently reported to CARAlert, the Commission's AURA team will continue

to work with the states and territories to promote consistency of screening, infection prevention and control practices, and outbreak responses to improve CPE containment. A priority focus of this work will be support for implementation of the 2021 *Recommendations for the control of carbapenemase-producing* Enterobacterales *(CPE): A guide for acute care health facilities*.[6]

The AURA Surveillance System is focused on human health, but was established, and is currently operated, in a One Health context. From 2021, the Australian Government Department of Health has begun implementation of a number of structural changes to the operation of the AURA Surveillance System to establish a sustainably funded national One Health surveillance system in Australia (an objective of the National AMR Strategy). These changes will support AMR policy and program development in the animal, agricultural and environment sectors to complement progress to date in human health.

As part of the transition process to a One Health surveillance system, from 1 January 2021, the Australian Government Department of Health assumed responsibility for oversight of AGAR, NAPS and NAUSP as part of AURA. As a result of these arrangements, the Commission will maintain responsibility for coordination and operation of CARAlert and APAS, including further expansion of APAS to cover all parts of Australia, the public and private sectors, and the community and acute sectors. The Department has also assumed overall coordination of AURA during this transition phase, while further consultation occurs.

The Commission will continue its work with the Department, the states and territories, and the private sector, to promote continuing comprehensive and integrated reporting of AMR and AU, and sustainability and continuity of data collection during the transition process. This will ensure that AURA data and reports provide the highest level of utility to stakeholders and the community.

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appendix 1

Appendix 1
Data source description

This appendix describes the data sources used for the Antimicrobial Use and Resistance in Australia (AURA) 2021 report.

A1.1 Data sources for antimicrobial use

This section provides information on the methods used by each of the sources for data on antimicrobial use (AU) in this report, including information on processes and limitations.

National Antimicrobial Prescribing Survey

The Hospital National Antimicrobial Prescribing Survey (NAPS) is a voluntary online audit performed annually by hospitals to assess antimicrobial prescribing practices and appropriateness of prescribing within the hospital. The Hospital NAPS is conducted by the National Centre for Antimicrobial Stewardship (NCAS). Data from the Hospital NAPS are reported annually by NCAS and the AURA National Coordination Unit. Participating hospitals can interrogate their own data and undertake benchmarking using the audit tool. The preferred methodology for the audit is a hospital-wide point prevalence survey. AURA 2021 includes highlights of analyses of 2018 and 2019 Hospital NAPS data.[1,2]

The Surgical NAPS is an audit tool that allows facilities to review their use of procedural and post-procedural surgical antimicrobial prophylaxis. Procedural antimicrobial prophylaxis is defined as any antimicrobial administered either immediately before or during a procedure for the purpose of prophylaxis. Post-procedural antimicrobial prophylaxis is defined as any antimicrobial given immediately after a surgical procedure for the purpose of prophylaxis. In contrast to the Hospital NAPS, the Surgical NAPS captures data on duration of antimicrobial prophylaxis using a time frame of 48 hours rather than 24 hours. The preferred methodology is a retrospective audit. AURA 2021 includes analyses of 2018 and 2019 Surgical NAPS data.[3,4]

The Aged Care NAPS (AC NAPS) is a standardised surveillance tool that can be used to monitor AU and the prevalence of infections in Australian aged care homes. The preferred methodology for the audit is a facility-wide point prevalence survey. AURA 2021 includes highlights of analyses of 2018 and 2019 AC NAPS data.[5,6]

Participants

The number of facilities participating in the Hospital NAPS, Surgical NAPS and AC NAPS has increased each year since surveys commenced, except for the Hospital NAPS in 2017.[7]

Participants in the Hospital NAPS include public and private hospitals from all states and territories, all hospital peer groups and all remoteness areas. In 2018, 326 hospitals (233 public and 93 private) contributed data. In 2019, 377 hospitals (268 public and 109 private) contributed data.

In 2018, 109 hospitals provided data during this period that were included in the analyses. A total of 5,637 surgical episodes were included in the analyses of the 2018 Surgical NAPS, with 4,984 (88.4%) having an incisional procedure. In 2019, 144 public and private facilities contributed data for the Surgical NAPS. A total of 8,063 surgical episodes were included in the analyses, and 7,376 involved an incisional procedure. Every state except Tasmania contributed data in both 2018 and 2019, and a range of hospital peer groups and all remoteness classifications were represented.

In 2018, 407 residential aged care services submitted AC NAPS data; 568 participated in 2019. In both years, all states, remoteness areas and organisation types were represented. In 2019, for the first time since 2015, there were more participating services from other states and territories combined than from Victoria (*n* = 373; 65.7%); 119 (21.0%) participants were from New South Wales. About three-quarters of participating residential aged care services were located in either major cities or inner regional areas. Also for the first time, more than half (*n* = 312; 54.9%) were not-for-profit operated. The percentage of participating residential aged care services increased for most states and territories. Representation within the AC NAPS cohort varied between states and territories, and across remoteness areas.

Considerations

Issues that need to be considered when interpreting NAPS data include the following:

- Participation in the Hospital NAPS, Surgical NAPS and AC NAPS is voluntary. The facilities that choose to participate are not a randomised sample, so the results may not be representative of all Australian hospitals and aged care homes
- The methodology for the NAPS audits has varied each year, so results are not directly comparable from year to year.

Hospital NAPS

For the 2018 and 2019 Hospital NAPS, the data collection periods were the calendar years 1 January to 31 December. However, in 2019, the release of the revised edition of *Therapeutic Guidelines: Antibiotic*[8] had the potential to affect the NAPS results, and targeted communication with users was required to outline how best to participate in 2019. To minimise the possibility of surveyors assessing prescriptions against different versions of *Therapeutic Guidelines: Antibiotic*, some changes were made to how the survey operated in 2019. Facilities could continue to enter survey data at any time throughout 2019. However, only data entered after the release of the new guidelines counted towards the benchmarking for that year. The official benchmarking period was 1 May to 31 December 2019.

Those hospitals using the point prevalence survey or randomised sample survey methodologies, where the hospital normally audits only once per year, were encouraged to plan their audits for the second half of 2019. Smaller hospitals using the repeat point prevalence survey methodology were requested to continue auditing as usual, as their data are collected intermittently over

the calendar year. Only the data entered after the release of the new *Therapeutic Guidelines: Antibiotic* were included in the 2019 benchmarking.

Depending on the audit method selected by sites participating in the Hospital NAPS, patients may be counted more than once. For smaller facilities that choose the option of a repeat point prevalence survey, certain patients may be counted multiple times if they are still an inpatient on a subsequent audit day. This may cause artificial inflation of the prevalence of some indications that require longer durations of treatment, or of the use of the antimicrobials used to treat these conditions.

Individual auditors at each facility are responsible for assessing antimicrobial prescribing appropriateness and compliance with guidelines. Remote expert assessments are conducted by the NAPS support team on request. Because assessments involve some degree of interpretation, standardised appropriateness definitions used by auditors help to moderate subjectivity.

Depending on local antimicrobial stewardship issues, casemix and resources, hospitals may choose to use other audit tools, such as the Surgical NAPS, the Quality Improvement NAPS or a locally designed tool. This may have affected the number of hospitals that chose to participate in the 2018 and 2019 Hospital NAPS.

Surgical NAPS

For the Surgical NAPS, the impact of some of the survey limitations was reduced by data exclusion and cleaning. Specific considerations are as follows:

- The flexible methodology means that the results of the 2018 and 2019 Surgical NAPS are not directly comparable with any previous Surgical NAPS. Comparisons should only be within surgical procedure group and year, because the cohort of contributors varies from year to year, as does the representation of surgical procedure groups
- Each hospital could decide how they performed the survey and which patients or surgical specialties were audited. If directed surveys were performed, patient sampling may not have been random, and auditors may have targeted problem or higher-volume surgical units
- Individual auditors at each participating facility were responsible for assessing the compliance with guidelines and appropriateness of antimicrobial prescribing. These assessments are not completely objective, as they involve some degree of interpretation. Remote expert assessments were conducted by the NAPS support team on request
- To maintain strict time lines during the initial software development of the online survey, data validation or restrictions were not included for some fields. This allowed some data entry inconsistencies and the recording of incongruous results. Data were cleaned before compiling the 2019 results, and the database was redesigned for the 2020 audit period to incorporate validation processes.

Aged Care NAPS

For the AC NAPS, specific considerations include the following.

Data for the period 2016–2018 that were included in the analyses for the 2019 AC NAPS report differed from previous reports. Some data were retrospectively entered, and an extensive data cleaning process was undertaken before commencing analysis. Also, as part of merging the separate 2018 Antimicrobials and Infections data collection forms for the 2019 AC NAPS, some data fields were omitted that may have been previously

included, and some new data fields were included.

For some states and territories, remoteness areas and provider types, there was a relatively small number of participating residential aged care services. Also, unlike aged care homes, multi-purpose services are government operated and provide a range of health services. Over time, different cohorts of residential aged care services have participated in the annual AC NAPS. Each year, the number of participating residential aged care services has increased, new services have participated, and some services that previously participated have chosen not to participate.

For the 2019 AC NAPS, a suspected infection was defined as at least one sign or symptom of infection on the survey day or in the two days before the survey day. In many cases, the prescriptions audited were prescribed more than three days before the survey day. As signs and symptoms are likely to be most significant just before or on commencement of antimicrobial prescriptions, the number of suspected infections defined in the 2019 AC NAPS audit may under-represent the true number of antimicrobial prescriptions for which signs and symptoms were present before the prescription commenced.

Signs and symptoms of infection in older residents may be atypical, so failure to meet the McGeer et al. definitions[9,10] may not fully exclude the presence of a true infection. In addition, the McGeer et al. definitions require microbiological confirmation for some infections (for example, urinary tract infections). This means that these infections will not be confirmed unless microbiological specimens are collected. Specimens for microbiological testing are less likely to be collected in aged care homes than in acute care services. The McGeer et al. definitions for surveillance of infection in long-term care are largely based on signs and symptoms relating to a specific body system (gastrointestinal tract, respiratory tract, urinary tract, skin/soft tissue/mucosal, and systemic). For some definitions, radiological evidence and use of devices (for example, urinary catheters) are also assessed. The McGeer et al. definitions are generally useful to compare the proportion of defined infections between facilities over time, but less useful to rule in or rule out the clinical need for a prescription.

The survey was conducted on a single day during winter. The results may have been different on another day during winter or in another season. Certain respiratory infections, for example, are usually more frequent in winter.

The analysis relied on the validity of local assessments. No external validation was undertaken.

Further information on NAPS can be found on the NAPS website.[11]

National Antimicrobial Utilisation Surveillance Program

The National Antimicrobial Utilisation Surveillance Program (NAUSP), which began in 2004, focuses on standardised measurement of AU in Australian adult acute public and private hospitals. NAUSP is administered by the Infection Control Service of the Communicable Disease Control Branch at SA Health. Development and implementation of NAUSP have been an ongoing collaboration between SA Health and the Australian Commission on Safety and Quality in Health Care (the Commission) since 2013.

Hospitals contribute to NAUSP on a voluntary basis. Pharmacy departments of participating hospitals use dispensing reports to supply NAUSP with aggregate monthly details of antimicrobials issued to individual inpatients

and ward imprest supplies (that is, ward stock managed by the pharmacy). Hospital occupancy data are collected in the form of overnight occupied bed days (OBDs).

NAUSP assigns each contributing hospital a unique code. The code is used to report in a de-identified way on usage rates of selected antimicrobials and therapeutic groups.

NAUSP uses standardised usage density rates, based on the World Health Organization (WHO) Anatomical Therapeutic Chemical (ATC) standards for defined daily doses (DDDs).[12] The denominator is overnight OBDs. Reporting on AU based on DDDs enables total hospital use to be assessed and compared as a rate, and also allows international comparisons.

The NAUSP annual and two-yearly reports cover total in-hospital AU data collected from participating hospitals across Australia. NAUSP also publishes a range of six-monthly reports, and participating hospitals can use the NAUSP portal to produce reports that provide benchmarking data to inform local quality improvement activities.[13] AURA 2021 includes highlights of analyses of 2018 and 2019 NAUSP data.[14-16]

Participants

The number of hospitals that contribute to NAUSP has more than doubled since the endorsement of the National Safety and Quality Health Service Standards in 2011. Participation in NAUSP supports successful implementation of the Preventing and Controlling Infections Standard.

In 2018, 212 adult acute care hospitals (169 public, 43 private), including all Principal Referral Hospitals, contributed data to NAUSP. In 2019, 219 acute hospitals (170 public and 49 private) contributed data that were included in NAUSP analyses. All Australian states and territories, all Principal Referral Hospitals, and approximately 94% of Public Acute Group A and 84% of Public Acute Group B Hospitals were represented in the program in both years. The number of private hospitals participating in NAUSP is slowly increasing.

Considerations

The data collected by NAUSP exclude:

- Most topical antimicrobial formulations (except some inhalations), antimycobacterials (except rifampicin), antivirals, antiparasitics (before 2017), and infusor packs of antibacterials for use outside hospital settings
- AU in paediatric hospitals, and paediatric wards and neonatal units within general hospitals; use in the paediatric population cannot easily be translated into a standard usage density rate based on the WHO definition of DDDs
- AU for outpatient areas, discharge prescriptions and external services (for example, Hospital in the Home), to ensure that data reflect in-hospital AU
- Antimicrobials issued by pharmacies to individuals, and wards classified as psychiatric, rehabilitation, dialysis and day-surgery units.

The AU rates calculated for each NAUSP report are correct at the time of publication, and are contingent on the accuracy of the antibacterial and antifungal quantities, and OBDs supplied by individual contributors, including compliance with NAUSP data definitions. Minor discrepancies between annual reports may occur as a result of data submitted retrospectively by contributing hospitals or by the inclusion of hospitals that were excluded from previous reports due to issues regarding data validity. Until 2016, NAUSP reports were confined to use of antibiotics in Australian hospitals.

Due to smaller numbers of private hospitals contributing data to NAUSP, data from

private hospitals are benchmarked with public hospitals of similar size and acuity. Data from Public Acute Group D, Private Acute Group D, Public Acute Group C and Private Acute Group C are combined for benchmarking.

AU reflects antimicrobials distributed or dispensed from a pharmacy rather than actual patient-level antimicrobial consumption. Reported usage rates are limited to acute-hospital use. Inpatient operating theatre use is included in NAUSP on the assumption that a corresponding OBD is recorded in the inpatient ward to which the patient was transferred following surgery. AU rates for hospitals that are not able to differentiate between use for inpatient surgery as opposed to day surgery need to be interpreted with caution.

Data provided to NAUSP do not include the indication for which antimicrobials are used, or any patient-specific data. Although some contributing hospitals provide data on ward-by-ward antimicrobial consumption, data for specialist areas (except for intensive care units) have not generally been available.

A comprehensive list of antimicrobials for which data are collected by NAUSP, the ATC classification and the DDD for each route of administration are available from the NAUSP website.[13]

The NAUSP cohort is heavily weighted towards large public hospitals, where antimicrobial stewardship activities are generally well established. In 2015, NAUSP removed restrictions on participation that were based on minimum bed numbers. Participating hospitals are required to meet the criteria for categorisation into one of eight Australian Institute of Health and Welfare (AIHW) peer groups: Principal Referral Hospital; Specialist Women's Hospital; Public Acute Group A, B and C Hospitals; and Private Acute Group A, B and C Hospitals.

Newly established hospitals that may not have received an AIHW peer group code are unclassified in some reports.

Additional issues that need to be considered when interpreting NAUSP data include the following:

- Participation is voluntary, and smaller facilities in both the public and private sectors, and private facilities generally, are under-represented
- The DDD, as defined by WHO, occasionally does not match usual daily doses used in Australian hospital clinical practice.

Further information on NAUSP can be found on the NAUSP website.[13]

Pharmaceutical Benefits Scheme and Repatriation Pharmaceutical Benefits Scheme

The Australian Government Department of Health collects data, in the Medicare pharmacy claims database, on antimicrobial dispensing in the community through the Pharmaceutical Benefits Scheme (PBS) and the Repatriation Pharmaceutical Benefits Scheme (RPBS).

The Australian Government Department of Health analyses PBS/RPBS data to inform economic analyses and policy development. Comprehensive medicine usage data are required for a number of purposes, including pharmacosurveillance and targeting, and evaluation of initiatives for quality use of medicines. The data are also needed by regulatory and financing authorities, and the pharmaceutical industry.

Data captured by the PBS/RPBS are extensive. In 2019, a little over 26.6 million prescriptions were supplied under the PBS/RPBS for all antibiotics.

Additional data and analysis

As part of the development of AURA 2021, the Commission engaged the University of South Australia to provide a report on use of antibiotics in Australia. Data were analysed for all antibiotic prescriptions supplied under the PBS/RPBS for 2015–2020.

The Australian Government Department of Health provided a six-year extract of antibiotic prescriptions supplied under the PBS/RPBS. The extract included all antibiotics listed on the PBS/RPBS that were dispensed between 1 January 2015 and 31 December 2020. This included all prescriptions priced under the patient co-payment, which are prescriptions that do not attract a reimbursement. The data did not contain details on any prescriptions supplied privately. The data included the following fields:

- Patient identifier (system-generated unique identifier)
- Patient date of birth (MMYYYY)
- Statistical Area Level 3 (SA3) in which the patient resided
- SA3 in which the prescriber's address was located at the date of supply
- Prescriber type
- Specialty group of prescriber
- PBS item code
- ATC code
- Drug name
- Product form and strength
- Quantity of PBS item supplied
- Date of prescribing
- Date of supply
- Prescription count
- Type of prescription – original, repeat, authority
- Number of repeats ordered
- Number of previous supplies
- Regulation 24 indicator.

The antibiotics included in the analyses presented in this report are shown in Table A1.

Table A1: Antibiotics included in the analyses of PBS/RPBS data for AURA 2021, 2015–2020

ATC codes	Description
J01	Antibacterials for systemic use
A02BD	Combinations for eradication of *Helicobacter pylori*
A07AA09	Vancomycin (intestinal anti-infectives)
A07AA11	Rifaximin (intestinal anti-infectives)
D06AX09	Mupirocin (cream/ointment, RPBS)
D06BA01	Sulfadiazine silver (cream)
S01AA01, S01AA11, S01AA12	Ophthalmological antibiotics: gentamicin, chloramphenicol, tobramycin
S01AE01, S01AE03	Ophthalmological fluoroquinolones: ofloxacin, ciprofloxacin
S02AA01, S02AA15	Otological anti-infectives: chloramphenicol, ciprofloxacin
S03AA	Framycetin (S01AA07 on WHO, but S03AA on www.pbs.gov.au)

ATC = Anatomical Therapeutic Chemical; PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme; WHO = World Health Organization[12]

The following analyses were undertaken:

- Trends in antimicrobials supplied, defined as
  - number of prescriptions per 1,000 inhabitants at national, state and SA3 levels, 2015–2019
  - number of prescriptions per 1,000 inhabitants by class of systemic antibiotic, 2015–2019
  - DDDs per 1,000 inhabitants per day by class of systemic antibiotic (ATC code J01) at national and state levels, 2015–2019
  - DDDs per 1,000 inhabitants per day by class of systemic antibiotic (ATC code J01), 2015–2019

- Number of all antimicrobials dispensed per 1,000 inhabitants by patient age, patient SA3 and state of residence in 2019
- For the top 10 antibiotics supplied in 2019
  - most commonly supplied antibiotics in 2019
  - rate at which original prescriptions are ordered with the maximum number of repeats, as a proportion of all original prescriptions, for the top 10 antibiotics, by prescriber SA3, and by state and territory in 2019
- Rate per 1,000 inhabitants of all antibiotics supplied in winter (June, July, August) 2019, by prescriber SA3, and by state and territory.

The analyses largely focused on the five-year period from 1 January 2015 to 31 December 2019. However, analysis of PBS/RPBS data from 1 January 2019 to 31 December 2020 was also undertaken to explore the potential impacts of the COVID-19 pandemic on AU. This included analysis of the percentage change in monthly AU in 2020 compared with 2019, based on prescription numbers and antimicrobial volume (DDDs per 1,000 inhabitants per day), stratified by:

- Oral antimicrobials predominantly used for upper respiratory tract infections, urinary tract infections and skin conditions
- Type of antibiotic, state and patient age, for antibiotics used for upper respiratory tract infections.

For reporting of age-standardised rates, the reference population was the Australian population in mid-2013. For analyses including population data, the mid-year (30 June) estimates for each calendar year, as provided by the Australian Bureau of Statistics, were used.

Considerations

Issues that need to be considered when interpreting PBS/RPBS data include the following:

- Data include antibiotics dispensed through the PBS and the RPBS; therefore, antibiotics dispensed from some inpatient and outpatient services, some community health services, and some Aboriginal and Torres Strait Islander health services, may not be captured
- Private prescriptions are not included in this dataset
- The data do not indicate the diagnosis or condition of the patient.

Antibiotics may be dispensed from private prescriptions outside the PBS. The reasons for antibiotics being dispensed privately may include:

- The prescriber wishes to prescribe an antibiotic for a non-subsidised indication
- The prescriber does not seek an approval for an antibiotic that requires an authority as the antibiotic is inexpensive (for example, ciprofloxacin)
- The prescriber wishes to prescribe a quantity that exceeds the PBS limit.

In addition, dispensing through the PBS/RPBS does not necessarily equate to consumption. Antibiotic consumption can be overestimated because patients may not comply with therapy recommendations.

Further information on the PBS can be found on the PBS website.[17]

NPS MedicineWise MedicineInsight program

NPS MedicineWise operates a national program called MedicineInsight, which collects longitudinal, de-identified clinical data from participating general practices across Australia.

The program aims to support quality improvement by providing local data to general practices. The data can be benchmarked at local, regional and national levels. Participating practices are offered customised quality improvement activities that support alignment with best practice and identify key areas for improvement.

MedicineInsight data include patient demographic and clinical data entered directly into the system by general practitioners (GPs) and practice staff, or collected from external sources (for example, pathology test results), and system-generated data such as antimicrobial start time and date of a patient encounter. The data can be used to analyse use of medicines, switching of medicines, indications for prescribing, adherence to guidelines, and pharmacovigilance to support post-market surveillance of medicine use in primary care.

Participants

Participation in MedicineInsight is voluntary; the general practices included are not a randomised sample. AURA 2021 includes analyses of data from general practices from all states and territories for 2015–2019; however, the proportion of participating practices varies by state and territory.

Patients are included from the first recording of their clinical data in the participating practices' clinical systems.

Considerations

Dispensing data can differ from prescribing data, because not all prescriptions are dispensed; therefore, these data may not correlate completely with PBS data.

Data are sourced from medical records, and rely on an appropriate level of completeness and accuracy of those records. Specialist prescriptions and GP-issued samples are not included.

Changes since 2019

The program dataset is continually being enhanced to develop capabilities and capacity in data analytics and report presentation, to support prescribers and national surveillance.

Since AURA 2019 was published, NPS MedicineWise has made a number of changes to the underlying MedicineInsight data, and some of the rules and algorithms used in the analysis. These include:

- Selecting antimicrobials by ATC code, rather than active ingredient alone. This functionality was developed by NPS MedicineWise since AURA 2019 was published, and allows systemic antimicrobials to be identified as a group (that is, J01) and as specific antimicrobials of interest. This has resulted in a decrease in the number of antimicrobials included in the analyses available for AURA 2021 compared with AURA 2019
- Restricting the patient count to those who attended the GP practice in the year of analysis, rather than also including the previous year. The analyses by NPS MedicineWise that were published in AURA 2019 counted patients who attended the GP practice in the year of interest, or in the previous year. For AURA 2021, only patients who attended the practice in the year of interest were counted. This has resulted in a decrease in both patient numbers and GP practice numbers
- Restricting reporting on prescribing rates for conditions of interest to prescriptions issued on the same day as the condition being recorded. The analyses by NPS MedicineWise that were published in AURA 2019 captured prescriptions issued to patients with a condition of interest at any time in the year of analysis. The revised approach for AURA 2021 has resulted in a decrease in the estimates for prescribing rates for specific conditions. This is a more

accurate reflection of GP prescribing practices.

These changes have resulted in differences in the number of patients, GP practices and antimicrobial prescribing rates identified in this report compared with AURA 2019. However, NPS MedicineWise regards the methodology as providing a more accurate picture of appropriateness of prescribing.

Data definitions

The following definitions were used for MedicineInsight in relation to the analyses conducted for AURA 2021.

General practice sites: one or more practices that share the same clinical information system (CIS). For example, a site may be one organisation that consists of a number of geographically diverse general practices that share the same CIS, or a site may be a single GP practice.

Patients: patients who had at least one clinical encounter with a GP in the year of analysis (2015, 2016, 2017, 2018, 2019), and were marked as active by the practices, and not recorded as deceased.

Clinical encounter: an encounter provided by a doctor, when the visit type is not administrative (that is, not 'non-visit', 'practice admin' or 'email').

Condition: conditions are described using fields in the CIS that capture the patient's medical history, reason for encounter and reason for prescription. The CIS uses coding systems, such as DOCLE in MedicalDirector or PYEFINCH in Best Practice, for data entered into the system. Medical, pharmaceutical and other experts in the MedicineInsight team develop algorithms to identify specific conditions and measures of interest in the MedicineInsight database, based on commonly accepted definitions.

Systemic antimicrobial: antimicrobials with an ATC code of J01. This excludes antimicrobials that act systemically but are part of a different ATC (such as A02BD – 'Combinations for eradication of *Helicobacter pylori*').

Indication: indications for prescribing are described using the 'reason for prescription' field in the first instance. If an explicit recorded reason for the prescription is missing, an association is assumed between the antibiotic prescribed and the reason for the encounter and/or a diagnosis recorded on the same day as the prescription.

Further information about the NPS MedicineWise MedicineInsight program and associated data can be found on the MedicineInsight website.[18]

A1.2 Data sources for antimicrobial resistance

This section provides information on the methods used by each of the sources for data on antimicrobial resistance (AMR) in this report, including information on processes and limitations.

Australian Group on Antimicrobial Resistance

The Australian Group on Antimicrobial Resistance (AGAR) is a collaboration of clinicians and scientists, with involvement from microbiology laboratories in all Australian states and territories. AGAR has been in operation since 1985, with voluntary participation from key microbiology laboratories.

AGAR operates a series of targeted survey programs each year on the level of AMR in selected bacteria detected from blood cultures.[19] This provides information on AMR in serious infections, and aligns with the European Antimicrobial Resistance

Surveillance Network (EARS-Net).[20] Microbiology laboratories provide laboratory data, demographic data and isolates to two central AGAR reference laboratories, which undertake molecular testing on selected isolates and prepare reports on the data for the following three programs:

- Gram-negative Sepsis Outcome Program (GNSOP)
- Australian Staphylococcal Sepsis Outcome Program (ASSOP)
- Australian Enterococcal Sepsis Outcome Program (AESOP).

In addition to susceptibility test data, most participating laboratories provide demographic and limited outcome data on each episode of bacteraemia. AURA 2021 includes highlights of analyses of 2018 and 2019 AGAR data.[21,22]

Participants

In 2018, 29 laboratories servicing 36 hospitals and their communities participated in GNSOP, ASSOP and AESOP; in 2019, 29 laboratories servicing 39 hospitals and their communities participated in these programs. Each of the three programs includes laboratories from all states and territories. The number of laboratories varies with state and territory, and they provide services for different types of hospitals. The laboratories are mostly public; a small number of private laboratories participate in each program.

Considerations

Issues that need to be considered when interpreting AGAR data include the following:

- Data are not denominator controlled because there is no consensus on an appropriate denominator for these types of surveys
- The surveys are voluntary; the types of resistance likely to be observed are influenced by institution size, throughput, patient complexity and local AU patterns
- There is currently not enough capacity to obtain sufficiently detailed clinical information to judge the clinical significance of resistance
- Data collection requires manual data entry to a web portal, which increases the chance of recording errors
- The level of participation in each program may vary from year to year, depending on available resources.

Further information on AGAR can be found on the AGAR website.[19]

National Neisseria Network

The National Neisseria Network (NNN) is a collaborative association of reference laboratories that contribute to passive laboratory surveillance of the pathogenic *Neisseria* species: *N. gonorrhoeae* and *N. meningitidis*. The NNN conducts two programs: the Australian Gonococcal Surveillance Programme (AGSP) and the Australian Meningococcal Surveillance Programme (AMSP).[23,24]

Infections caused by *N. gonorrhoeae* and *N. meningitidis* are notifiable to the National Notifiable Diseases Surveillance System (NNDSS). Notifications are made to state and territory health authorities under the provisions of the relevant public health legislation. Computerised, de-identified unit records of notifications are supplied to the Australian Government Department of Health daily for collation, analysis and publication on the department's website and in the *Communicable Diseases Intelligence* journal.

Australian Gonococcal Surveillance Programme

The AGSP has monitored AMR in clinical isolates of *N. gonorrhoeae* from public and private laboratories across all Australian states and territories since 1981. It is the longest-running national surveillance

program for gonococcal AMR in the world.[25] Over this time, the AGSP has reported the emergence of resistance to all antibiotics used in the treatment of gonorrhoea, and detected and reported multi- and extensively drug-resistant gonococcal strains in recent years. The importation and spread of ceftriaxone-resistant gonococcal strains, and development of new resistance remains an ongoing concern for disease control strategies, and is a focus of the work of the NNN.

The NNN laboratories report data on gonococcal susceptibility for an agreed core group of antibacterial agents, on a quarterly basis, to the WHO Collaborating Centre for Sexually Transmitted Infections and Antimicrobial Resistance. This laboratory is based in Sydney and publishes an annual report in *Communicable Diseases Intelligence*. The antibacterials that are currently routinely surveyed are azithromycin, ceftriaxone, ciprofloxacin, penicillin and spectinomycin. In 2020, gentamicin data were also reported, in line with the WHO Global Antimicrobial Surveillance System indicators for *N. gonorrhoeae*.

Although most information gathered and reported by the AGSP is based on resistance surveillance of clinical samples, sentinel surveillance is also undertaken in a very limited number of settings in Australia. Sentinel surveillance activity involves patient follow-up and 'test of cure' cultures after treatment, especially for oropharyngeal infections and in high-risk populations. This program is important for detecting treatment failure and informing therapeutic strategies.

Considerations

Relative limitations of the AGSP data relate to the decrease in numbers of isolates for antimicrobial susceptibility testing (AST) due to the increased use of nucleic acid amplification tests (NAAT), either by clinician choice, or by necessity in remote settings. However, nationally, 1 in 3 notified cases have AST performed, which is higher than any other national program. The NNN has developed and implemented NAAT to detect specific AMR genes or specific *N. gonorrhoeae* strains of public health interest. However, at this point, NAAT cannot replace AST to detect novel resistant strains or novel mechanisms for AMR.

Australian Meningococcal Surveillance Programme

The AMSP, established in 1994, provides a national laboratory-based program for examining invasive meningococcal disease caused by *N. meningitidis*.[24] The AMSP monitors and reports AMR detected in clinical isolates of *N. meningitidis*.

The AMSP collects data on the strain phenotype (serogroup, serotype and subserotype) and antibacterial sensitivity of invasive meningococcal isolates, as well as non-culture-based laboratory testing (NAAT and serological examination). The AMSP links the laboratory information with clinical information to provide a comprehensive epidemiological survey.

The incidence of invasive meningococcal disease decreased following introduction to the National Immunisation Program (NIP) in 2003 of a publicly funded serogroup C meningococcal conjugate vaccine. When increases in MenW and MenY serogroup disease occurred in Australia in 2016–2017, time-limited MenACWY vaccination programs were implemented by states and territories for target age groups in 2017 and 2018. From 1 July 2018, there was a change to the NIP to replace MenC vaccine at 12 months of age with a quadrivalent MenACWY vaccine. This change was followed by a decrease in both notifications and proportions of MenW and MenY disease. Invasive meningococcal disease remains a significant public health concern

in Australia, and detailed analysis of locally circulating *N. meningitidis* strains continues to be a priority.

Considerations

Limitations of the AMSP data used for this report are largely process issues relating to data availability for required demographic fields, either because requesting and referring clinicians have not had information available, or data do not fully comply with requirements for notification. Another possible technical limitation is that, in a small proportion of cases, meningococcal infection is detected using only NAAT and culture is negative. Therefore, susceptibility results are not available for these cases.

Further information on the AMSP can be found on the Australian Government Department of Health website.[24]

National Notifiable Diseases Surveillance System

The NNDSS was established in 1990 under the auspices of the Communicable Diseases Network Australia (CDNA).[25] The NNDSS coordinates the national surveillance of more than 50 communicable diseases or disease groups. Under this scheme, notifications are made to state or territory health authorities under the provisions of the public health legislation in that jurisdiction. Computerised, de-identified unit records of notifications are supplied to the Australian Government Department of Health daily by state and territory health authorities for collation, analysis and publication on the department's website and in the *Communicable Diseases Intelligence* journal.

NNDSS data were provided by the Office of Health Protection and Response, Australian Government Department of Health, on behalf of the CDNA.

Australia has a well-established *Mycobacterium tuberculosis* surveillance program. Susceptibility testing is undertaken by the Australian Mycobacterium Reference Laboratory Network (AMRLN), and data on resistance are provided to the NNDSS for publication.[26]

The AMRLN started *M. tuberculosis* reporting in 1986. The network comprises five state-based *Mycobacterium* reference laboratories, which undertake testing for all states and territories. These laboratories use NAAT to detect the presence of *M. tuberculosis* complex.

M. tuberculosis is notifiable under the NNDSS. Notifications are made to state and territory health authorities under the provisions of the relevant public health legislation. Computerised, de-identified unit records of notifications are supplied to the Australian Government Department of Health daily.

Data on *M. tuberculosis* notifications and resistance have been publicly available since 1994. Since 2012, data on *M. tuberculosis* resistance and national notification data have been reported in *Communicable Diseases Intelligence*. The data are also reported annually to the WHO global *M. tuberculosis* surveillance program.

Considerations

AMRLN data included in this report are based on data from each state and territory for 2018 and 2019, provided to the Commission by the Australian Government Department of Health from NNDSS data taken from a snapshot on 8 January 2021. Totals in this report may vary slightly from the totals reported in *Communicable Diseases Intelligence* publications, and state and territory reports.

The quality and completeness of data compiled in the NNDSS are influenced by various factors. Notifications may be required from treating clinicians, diagnostic

laboratories or hospitals. In addition, the mechanism of notification varies between states and territories, and in some cases different diseases are notifiable by different mechanisms. The proportion of cases seen by clinicians that are the subject of notification to health authorities is not known with certainty for any disease, and may vary among diseases, between states and territories and over time.

Further information on the NNDSS and the AMRLN can be found on the Australian Government Department of Health website.[26]

Australian Passive AMR Surveillance

The Australian Passive AMR Surveillance (APAS) system was established by the Commission in 2015 with the support of the Queensland Health OrgTRx information technology infrastructure. APAS collects, analyses and reports on de-identified patient-level AMR data contributed by 10 public and private pathology services across Australia. These laboratories detect AMR in isolates referred from public and private hospitals, aged care homes and community settings. Initially, data were captured from January 2015 from all contributing laboratories. Subsequently, historical data were uploaded by several pathology services. APAS includes more than 77 million AMR records from 2006 to 2020.

The data captured by APAS enable reporting on AMR in the form of:

- Longitudinal datasets for specified organism–antimicrobial combinations
- Cumulative antibiograms showing rates of resistance for a range of organisms from a specified specimen type within a selected time period
- Tabulations showing the resistance profiles of organism strains isolated during a selected time period
- Reporting for individual units within hospitals or health services, or at a statewide level.

Comprehensive antibiogram and resistant-organism reporting from the current APAS contributors has been implemented at the local level, along with national reporting by the Commission.[27]

Participants

The following pathology services currently contribute data to APAS:

- ACT Pathology (all public and some private Australian Capital Territory health services)
- Pathology Queensland (all Queensland Health public hospitals and health services)
- Mater Pathology Brisbane (Queensland public and private patients)
- SA Pathology (public health catchments for South Australia)
- NSW Health Pathology laboratories that provide services to Sydney, South Western Sydney, South Eastern Sydney, Illawarra Shoalhaven, Hunter New England, Mid North Coast and Northern NSW Local Health Districts (LHDs), and the Sydney Children's Hospitals Network (Randwick)
- Royal Hobart Hospital (Tasmania)
- Monash Health (Victoria)
- PathWest Laboratory Medicine (Western Australia).

Historical data from 2006 were available from four of these pathology services: the former Sydney South West Pathology Service that provides services to the Sydney and South Western Sydney LHDs, Mater Pathology Brisbane, Pathology Queensland, and SA Pathology.

Considerations

It is important to note that, for historical data in particular, there may have been changes since 2006 in the number of facilities from which the pathology services have received

isolates, and numbers are likely to have varied from year to year. In addition, a number of public laboratories have been reconfigured or renamed over time; these changes are not addressed in detail in this report.

Data from states and territories with state- or territory-wide public pathology services (Queensland, South Australia, Western Australia and the Australian Capital Territory) are most representative. Queensland, in particular, is comprehensively covered because of the involvement of Mater Pathology Brisbane. Data from Victoria are limited because there is only one contributing site, and data are not available from the Northern Territory. Since APAS commenced, New South Wales has brought together all public laboratories as the statewide service, NSW Health Pathology. Some public laboratories undertake testing for private facilities and in the community.

Passive AMR surveillance involves extracting routine susceptibility testing results from laboratory information systems. Passive AMR surveillance differs in several ways from the targeted AMR surveillance conducted by AGAR for the AURA Surveillance System. These differences include the following:

- The range of agents tested against any given isolate tends to be smaller than for targeted AGAR surveillance
- Although there is some commonality between services, each contributor tests and reports different antimicrobials according to its local practice
- Three different susceptibility testing systems are used in clinical microbiology across Australia, and test results (categorical interpretations) are not always comparable between systems; the AURA Surveillance System acknowledges the differences in the interpretation of results obtained by each method and is working with stakeholders to promote alignment with a single method in Australia
- Only categorical data are available through APAS – namely, the reporting categories of 'susceptible', 'intermediate' and 'resistant'; these categories are defined by interpretive criteria for resistance testing, commonly called breakpoints
- Remoteness area is based on the postcode of the patient's place of residence; not all pathology services were able to provide the postcode.

In addition, the results of duplicate testing are included in the data collected for APAS. Duplicate testing means that the same bacterial strain is tested and reported from repeated specimens and similar specimens from a single infection episode. This is appropriate clinical laboratory practice from a patient management perspective. The impact of these duplicates is minimised for analyses of APAS data by using algorithms based on resistance patterns, and selected time periods for which duplicates are not counted. Only the first isolate for the first specimen of each specimen type per year is included in the dataset for analyses. A repeat isolate from the same specimen type is not included.

Further information on APAS can be found on the Commission's website.[28]

Sullivan Nicolaides Pathology

Sullivan Nicolaides Pathology (SNP) is one of the largest members of the Sonic Healthcare group. As part of its practice, SNP collects data on AMR identified through its laboratory network. Similar to OrgTRx, SNP's AMR data are held centrally, and a range of filtering and reporting mechanisms allow inclusion or exclusion of multiple isolates from the same patient–site combination within a selected time period.

Similar to OrgTRx, SNP has the capacity to generate and report AMR data in the form of:

- Longitudinal datasets for specified organism–antimicrobial combinations
- Cumulative antibiograms showing rates of resistance for a range of organisms from a specified specimen type within a selected time period
- Tabulations showing the resistance profiles of organism strains isolated during a selected time period.

Participants

SNP data presented in this report are from SNP services provided to private hospitals, aged care homes and general practices in Queensland and northern New South Wales.

Considerations

Issues that need to be considered when interpreting SNP data include the following:

- Data provided through SNP for this report are from private hospitals, aged care homes and general practices based in Queensland and northern New South Wales only; these data are complemented by data from the OrgTRx system, which has provided equivalent data for Queensland public hospitals and health services
- Not all antimicrobials are tested against all organisms, because different laboratories may have their own protocols and undertake selective testing of antimicrobials.

Further information on SNP can be found on the SNP website.[29]

National Alert System for Critical Antimicrobial Resistances

The National Alert System for Critical Antimicrobial Resistances (CARAlert) collects data on nationally agreed priority organisms that are resistant to last-line antimicrobial agents, and provides timely information to states and territories to support response action.

All of the following criteria must be met for organisms and resistances to be categorised as a critical antimicrobial resistance (CAR) for reporting to CARAlert:

- Inclusion as a priority organism for national reporting as part of the AURA Surveillance System
- A serious threat to last-line antimicrobial agents
- Strongly associated with resistance to other antimicrobial classes
- At low prevalence in, or currently absent from, Australia and potentially containable
- Data not otherwise collected nationally in a timely way.

The CARAlert system is based on the following routine processes used by pathology laboratories for identifying and confirming potential CARs:

- Collection and routine testing – the isolate is collected from the patient and sent to the originating laboratory for routine testing
- Confirmation – if the originating laboratory suspects that the isolate is a CAR, it sends the isolate to a confirming laboratory that has the capacity to confirm the CAR
- Submission to the CARAlert system – the confirming laboratory advises the originating laboratory of the result of the test, and the originating laboratory reports back to the health service that cared for the patient; the confirming laboratory then submits the details of the resistance and organism to the secure CARAlert web portal.

Generally, CARs are submitted to CARAlert within seven days of the isolate being confirmed as a CAR. However, the results are provided to the originating laboratory as soon as possible after confirmation.

CARAlert generates a weekly summary email alert to report information on confirmed CARs to state and territory health authorities, the Australian Government Department of Health and confirming laboratories.

Participants

All Australian public and private laboratories that have the capacity to confirm CARs were identified through consultation with state and territory health authorities, the Public Health Laboratory Network and AGAR.

Currently, 28 confirming laboratories participate in CARAlert, and there is at least one confirming laboratory in each state and territory. The CARs that each of the confirming laboratories are able to confirm are regularly reviewed.

Considerations

Issues that need to be considered when interpreting CARAlert data include the following:

- Local operating procedures for laboratories may not currently include testing for all the critical resistances included in CARAlert; however, all laboratories are encouraged to actively screen for CARs
- There may be delays in confirming laboratories reporting CARs to CARAlert, which means that the data that were analysed for this report may not be complete for the 2020 calendar year.

More information about CARAlert is available on the Commission's website.[30]

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appendix 2

Appendix 2
Priority organisms

As part of the establishment of the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System, the Australian Commission on Safety and Quality in Health Care (the Commission) worked with a range of clinical and technical experts, and the states and territories, to identify a group of organisms considered to be a priority for surveillance in Australia.

The organisms were selected because of their high public health importance, and/or because they were common pathogens for which the impact of resistance was substantial in both hospital and community settings. International experience of priority organisms was also assessed for relevance to the Australian situation.[1]

The AURA priority organisms were grouped into four sets:

1. Organisms with high public health importance and/or that are common pathogens for which the impact of resistance is substantial in both hospital and community settings
2. Organisms for which the impact of resistance is substantial in the hospital setting
3. Organisms for which resistance is a marker of epidemiological resistance and/or antimicrobial use
4. Organisms for which resistance will be monitored through passive surveillance, and prioritised for targeted surveillance if a signal emerges.

Some of these organisms were not under surveillance in Australia before the priority organisms list was established. Data on most of these organisms are now collected and reported through the AURA Surveillance System. The priority organisms for human health will continue to be monitored to ensure they remain in the appropriate set and determine whether any other changes are required.

Priority set 1: Organisms with high public health importance and/or that are common pathogens for which the impact of resistance is substantial in both hospital and community settings

Species	Core reportable agents
Enterobacterales (especially *Escherichia coli* and *Klebsiella pneumoniae*)	Ampicillin, piperacillin–tazobactam, cefazolin, ceftriaxone/cefotaxime, ciprofloxacin, gentamicin, meropenem
Enterococcus species	Ampicillin, vancomycin, linezolid
Mycobacterium tuberculosis	Isoniazid, ethambutol, pyrazinamide, rifampicin
Neisseria gonorrhoeae	Benzylpenicillin, ceftriaxone/cefotaxime, ciprofloxacin
Neisseria meningitidis	Benzylpenicillin, ceftriaxone/cefotaxime, ciprofloxacin, rifampicin
Salmonella species	Ampicillin, azithromycin, ceftriaxone/cefotaxime, ciprofloxacin
Shigella species	Ampicillin, ciprofloxacin, trimethoprim–sulfamethoxazole, azithromycin
Staphylococcus aureus	Oxacillin (MRSA), cefoxitin (MRSA), ciprofloxacin, clindamycin (including inducible resistance), trimethoprim–sulfamethoxazole, erythromycin, gentamicin, tetracycline, vancomycin, linezolid (if tested), daptomycin (if tested)
Streptococcus pneumoniae	Benzylpenicillin, ceftriaxone/cefotaxime, meropenem

MRSA = methicillin-resistant *Staphylococcus aureus*

Priority set 2: Organisms for which the impact of resistance is substantial in the hospital setting

Species	Core reportable agents
Acinetobacter baumannii complex	Meropenem
Enterobacter cloacae complex and *E. aerogenes*	Ceftriaxone/cefotaxime, ciprofloxacin, gentamicin, meropenem
Pseudomonas aeruginosa	Ceftazidime, ciprofloxacin, gentamicin/tobramycin, piperacillin–tazobactam

Priority set 3: Organisms for which resistance is a marker of epidemiological resistance and/or antimicrobial use

Species	Core reportable agents
Campylobacter jejuni or *C. coli*	Ciprofloxacin

Priority set 4: Organisms for which resistance will be monitored through passive surveillance, and prioritised for targeted surveillance if a signal emerges

Species	Core reportable agents
Clostridioides difficile	Moxifloxacin
Haemophilus influenzae type b	Ampicillin, ceftriaxone/cefotaxime, ciprofloxacin
Streptococcus agalactiae	Benzylpenicillin, erythromycin, clindamycin
Streptococcus pyogenes	Benzylpenicillin, erythromycin, clindamycin

The priority organisms list was used by the Commission as the basis of work to identify resistances to be monitored through the National Alert System for Critical Antimicrobial Resistances (CARAlert). CARAlert was established by the AURA National Coordination Unit in 2016.

The development of CARAlert also involved a broad consultation process with clinicians, states and territories, and included:

- Determining the criteria for identifying a critical antimicrobial resistance of national priority
- Understanding the capacity of laboratories across Australia to undertake confirmatory testing of critical antimicrobial resistances
- Developing and supporting the health system to use CARAlert.

CARAlert is regularly reviewed by the AURA National Coordination Unit, in collaboration with states and territories, and relevant experts, to ensure that it meets the needs of the population and the health system. The most recent comprehensive review in 2018 resulted in additional resistances being included for monitoring from 2019. A further comprehensive review will be undertaken later in 2021.

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appendix 3

Appendix 3
Terminology

A3.1 Abbreviations

Term	Definition
ABS	Australian Bureau of Statistics
ACH	aged care home
AC NAPS	Aged Care National Antimicrobial Prescribing Survey
ACT	Australian Capital Territory
AESOP	Australian Enterococcal Sepsis Outcome Program
AGAR	Australian Group on Antimicrobial Resistance
AGSP	Australian Gonococcal Surveillance Programme
AHMAC	Australian Health Ministers' Advisory Council
AIHW	Australian Institute of Health and Welfare
AMR	antimicrobial resistance
AMRLN	Australian Mycobacterium Reference Laboratory Network
AMS	antimicrobial stewardship
AMSP	Australian Meningococcal Surveillance Programme
APAS	Australian Passive AMR Surveillance
ASSOP	Australian Staphylococcal Sepsis Outcome Program
AST	antimicrobial susceptibility testing
ATC	Anatomical Therapeutic Chemical
AU	antimicrobial use
AURA	Antimicrobial Use and Resistance in Australia
AURA NCU	AURA National Coordination Unit
AWaRe	Access, Watch and Reserve
β-lactamase inhibitors	beta-lactamase inhibitors
CA-MRSA	community-associated methicillin-resistant *Staphylococcus aureus*
CAP	community-acquired pneumonia
CAR	critical antimicrobial resistance

Term	Definition
CARAlert	National Alert System for Critical Antimicrobial Resistances
CARSS	Canadian Antimicrobial Resistance Surveillance System
CCLHD	Central Coast Local Health District
CDARS study	*Clostridioides difficile* Antimicrobial Resistance Surveillance study
CDI	*Clostridioides difficile* infection
CDNA	Communicable Diseases Network Australia
CDS	calibrated dichotomous sensitivity
CHC	COAG Health Council
CI	confidence interval
CIS	clinical information system
CLSI	Clinical and Laboratory Standards Institute
COAG	Council of Australian Governments
Commission	Australian Commission on Safety and Quality in Health Care
COPD	chronic obstructive pulmonary disease
COVID-19	coronavirus disease 2019
CPE	carbapenemase-producing *Enterobacterales*
DDD	defined daily dose
EARS-Net	European Antimicrobial Resistance Surveillance Network
EEA	European Economic Area
EMM	electronic medication management
eMR	electronic medical record
ESAC-Net	European Surveillance of Antimicrobial Consumption Network
ESBL	extended-spectrum β-lactamase
EU	European Union
EUCAST	European Committee on Antimicrobial Susceptibility Testing
FN-Q	far north Queensland
FN-WA	far north Western Australia
GBS	group B *Streptococcus*
GLASS	Global Antimicrobial Resistance Surveillance System
GNSOP	Gram-negative Sepsis Outcome Program
GP	general practitioner
GP NAPS	General Practice National Antimicrobial Prescribing Survey
HAI	healthcare-associated infection
HA-MRSA	healthcare-associated methicillin-resistant *Staphylococcus aureus*
HHS	Hospital and Health Service

Term	Definition
HLR	high-level resistance
ICU	intensive care unit
IV	intravenous
LHD	Local Health District
LIS	laboratory information system
LLR	low-level resistance
LRTI	lower respiratory tract infection
MBS	Medicare Benefits Schedule
MCR	transmissible resistance to colistin
MDR	multidrug-resistant
MDR-TB	multidrug-resistant tuberculosis
MIC	minimum inhibitory concentration
MRSA	methicillin-resistant *Staphylococcus aureus*
NAAT	nucleic acid amplification test
NAPS	National Antimicrobial Prescribing Survey
NAUSP	National Antimicrobial Utilisation Surveillance Program
NCAS	National Centre for Antimicrobial Stewardship
NCU	National Coordination Unit
NFRC	National Federation Reform Council
NIP	National Immunisation Program
NNDSS	National Notifiable Diseases Surveillance System
NNN	National Neisseria Network
NSQHS	National Safety and Quality Health Service
NSQIP	National Surgical Quality Improvement Program
NSW	New South Wales
NT	Northern Territory
OBD	occupied bed day
OECD	Organisation for Economic Co-operation and Development
pAmpC	plasmid-borne AmpC
PBS	Pharmaceutical Benefits Scheme
Priority Antibacterial List	Priority Antibacterial List for Antimicrobial Resistance Containment
PRN	as needed
QI NAPS	Quality Improvement National Antimicrobial Prescribing Survey
Qld	Queensland
QSAMSP	Queensland Statewide Antimicrobial Stewardship Program

Term	Definition
RACS	Royal Australasian College of Surgeons
RfP	Reason for Prescription
RMT	ribosomal methyltransferase
RPBS	Repatriation Pharmaceutical Benefits Scheme
RT	ribotype
SA	South Australia
SA3	Statistical Area Level 3
SAP	surgical antimicrobial prophylaxis
SNP	Sullivan Nicolaides Pathology
Tas	Tasmania
URTI	upper respiratory tract infection
UTI	urinary tract infection
VCPS	virtual clinical pharmacy service
Vic	Victoria
VICNISS	Victorian Healthcare Associated Infection Surveillance System
VRE	vancomycin-resistant enterococci
WA	Western Australia
WHO	World Health Organization
XDR-TB	extremely drug-resistant tuberculosis

A3.2 Common terms

Term	Definition
acquired resistance	Reduction in susceptibility by acquiring resistance genes from other bacteria or through mutation.
aged care home	A special-purpose facility that provides accommodation and other types of support to frail and aged residents, including assistance with day-to-day living, intensive forms of care and assistance towards independent living. In AURA 2016, aged care homes were referred to as residential aged care facilities.
Anatomical Therapeutic Chemical (ATC) classification	An internationally accepted classification system for medicines that is maintained by the World Health Organization. Active substances are divided into different groups according to the organ or system on which they act, and their therapeutic, pharmacological and chemical properties.
antimicrobial	Chemical substances that inhibit the growth of, or destroy, bacteria, fungi, viruses or parasites. They can be administered therapeutically to humans or animals. In this report, 'antimicrobial' is used when the surveillance data include antibiotic, antifungal, antiviral and antiparasitic agents. When the surveillance data include only antibiotics, the term 'antibiotic' is used. The terms antibacterial and antibiotic have the same meaning.

Term	Definition
antimicrobial resistance (AMR)	Failure of an antimicrobial to inhibit a microorganism at the antimicrobial concentrations usually achieved over time with standard dosing regimens.
antimicrobial stewardship (AMS)	An ongoing effort by a health service organisation to reduce the risks associated with increasing antimicrobial resistance and to extend the effectiveness of antimicrobial treatments. It may incorporate a broad range of strategies, including monitoring, reviewing and promoting appropriate antimicrobial use.
antimicrobial susceptibility test	A procedure used to determine which antimicrobials are effective at inhibiting the growth of, or destroying, an infecting microorganism.
broad-spectrum antimicrobials	A single antimicrobial, or class of antimicrobials, that affects many organisms.
community onset	Description applied to an organism that is acquired by a patient at least 48 hours before they are admitted to a hospital, or to specimens collected in the community, outpatient clinics or emergency departments.
DDDs per 1,000 occupied bed days (OBDs)	Antimicrobial use in hospitals is usually measured as a rate using OBDs. Antimicrobial use (in DDDs) is the 'numerator' and bed occupancy is the 'denominator'. Bed occupancy is a measure of clinical activity in the hospital. The definition of a bed day may differ between hospitals or countries, and bed days should be adjusted for occupancy rate. In hospitals that contribute to the National Antimicrobial Utilisation Surveillance Program, OBDs are the total number of hospital inpatient bed days during the period of interest (for example, a month), taken from a count of hospital inpatients every day at about midnight. This measure excludes subacute bed days. DDDs are defined by the World Health Organization.
DDDs per 1,000 people per day	Sales or prescription data about medicine use in the community can be expressed as DDDs per 1,000 people per day to give a population estimate for use of a medicine (or group of medicines). For example, 10 DDDs per 1,000 people per day means that, on a given day, 1% of the population received a medicine (or group of medicines). This estimate is most useful for medicines that treat chronic illnesses for which the DDD and the average prescribed daily dose are similar.
defined daily dose (DDD)	The assumed average maintenance dose per day to treat the main indication for an average adult patient, as defined by the World Health Organization. The DDD is a technical unit of measurement that is widely accepted in international surveillance programs because it enables comparison of antimicrobial use within and between countries. DDDs are only assigned for medicines given an Anatomical Therapeutic Chemical (ATC) code.
Enterobacterales	Recent taxonomic studies have narrowed the definition of the family *Enterobacteriaceae*. Some previous members of this family are now included in other families within the order *Enterobacterales*, and this term is now used across AURA publications, including AURA 2021.[1]
Enterobacteriaceae	*See Enterobacterales*
extended-spectrum β-lactamase	An enzyme that is produced by some gram-negative bacteria. Bacteria that produce these enzymes are usually found in the bowel and urinary tract, and are considered to be multidrug-resistant organisms because they are resistant to a large number of antibiotics.
hospital	All public, private, acute and psychiatric hospitals; free-standing day hospital services; and alcohol and drug treatment centres. Includes hospitals specialising in dentistry, ophthalmology and other acute medical or surgical care. It may also include hospitals run by the Australian Defence Force and corrections authorities, and those in Australia's offshore territories. It excludes outpatient clinics and emergency departments.
hospital onset	Description applied to an organism that is acquired by a patient at least 48 hours after being admitted to a hospital.

Term	Definition
hospital peer group	Grouping of Australian public and private hospitals according to a classification system developed by the Australian Institute of Health and Welfare. Hospitals are assigned to peer groups based on the nature of the services they provide. Peer grouping of hospitals supports valid comparisons that reflect the purpose, resources and role of each hospital. The peer groups in the analyses for AURA 2021 are: • Principal Referral Hospital • Specialist Women's Hospital • Public Acute Group A Hospital • Public Acute Group B Hospital • Public Acute Group C Hospital • Private Acute Group A Hospital • Private Acute Group B Hospital • Private Acute Group C Hospital.
intrinsic resistance	Natural lack of susceptibility to the antimicrobial used for treatment.
isolate	An organism that is grown in a laboratory culture from a patient sample.
J01	A code within the Anatomical Therapeutic Chemical (ATC) classification system that is applied to the group labelled 'Antibacterials for systemic use'.
McGeer et al. criteria	For the Aged Care National Antimicrobial Prescribing Survey (AC NAPS), the criteria for an infection are based on the McGeer et al. infection surveillance definitions[2], which were revised in 2012.[3] The definitions are largely based on signs and symptoms localised to a specific body system (gastrointestinal tract, respiratory tract, urinary tract, skin/soft tissue/mucosal or systemic). For some definitions, radiological evidence and use of devices (for example, urinary catheters) are also assessed.
multidrug-resistant organism	Microorganisms that are resistant to one or more classes of antimicrobial agents.
narrow-spectrum antimicrobials	A single antimicrobial, or class of antimicrobials, that affects few organisms and contributes less to antimicrobial resistance than broad-spectrum antimicrobials.
National Safety and Quality Health Service (NSQHS) Standards	Standards developed by the Australian Commission on Safety and Quality in Health Care to drive the implementation of safety and quality systems, and improve the quality of health care in Australia. The NSQHS Standards provide a nationally consistent statement about the standard of care that consumers can expect from their health service organisations.
NAUSP hospital contributor code	The National Antimicrobial Utilisation Surveillance Program (NAUSP) assigns each contributing hospital a unique code. The code is used to report peer group performance on usage rates of selected antimicrobials and therapeutic groups in a de-identified way. Each contributing hospital is able to benchmark its own usage rate to that of other hospitals.
occupied bed days (OBDs)	The total number of bed days of all admitted patients accommodated during the reporting period, taken from a count of inpatients at about midnight each day. For hospitals contributing to the National Antimicrobial Utilisation Surveillance Program (NAUSP), subacute beds are excluded from the calculation of OBDs.
OrgTRx	The Queensland Health information technology platform that is used for the Australian Passive AMR Surveillance system.
passive surveillance	Use of data that are already collected and designed for a broader purpose, but when a subset of the data can be used for secondary analysis. In this report, it refers to broader collections from which data on antimicrobial use and resistance can be extracted.
Pharmaceutical Benefits Scheme (PBS)	An Australian Government program that subsidises medicines.

Term	Definition
Principal Referral Hospitals	Public acute hospitals that provide a very broad range of services, have a range of highly specialised service units and have very large numbers of patients. The term 'referral' recognises that these hospitals have specialist facilities not usually found in smaller hospitals, such as: • 24-hour emergency department • Intensive care services • All or most of the following specialised units – cardiac surgery, neurosurgery, infectious diseases, bone marrow transplant, organ (kidney, liver, heart, lung or pancreas) transplant and severe burn units.[4]
Repatriation Pharmaceutical Benefits Scheme (RPBS)	An Australian Government program that subsidises medicines for veterans.
Statistical Area Level 3 (SA3)	Geographical areas designed for the output of regional data, including 2016 Census data. SA3s create a standard framework for analysing Australian Bureau of Statistics data at the regional level by clustering groups of Statistical Areas Level 2 (SA2) that have similar regional characteristics.[5]
susceptibility	Where there is a high likelihood of therapeutic success using a standard dosing regimen of the agent, or there is a high likelihood of therapeutic success because exposure to the agent is increased by adjusting the dosing regimen or its concentration at the site of infection.
targeted surveillance	Data collection designed for a specific and targeted purpose. In this report, it refers to collections specifically designed for the surveillance of antimicrobial-resistant organisms.
therapeutic group or class	A category of medicines that have similar chemical structure.
topical (medication)	A medication that is applied to body surfaces such as the skin or mucous membranes; includes creams, foams, gels, lotions and ointments.

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appendix 4

Appendix 4
Key findings and messages

Chapter 1: Introduction

- Antimicrobial resistance (AMR) continues to be an increasing risk to patient safety because it reduces the number of antimicrobials available to treat infections. AMR increases morbidity and mortality associated with infections caused by multidrug-resistant organisms. AMR may limit future capacity to perform medical procedures such as organ transplantation, cancer chemotherapy, diabetes management and major surgery, because of a lack of effective antimicrobials.
- The Australian Commission on Safety and Quality in Health Care established the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System in 2014. This has enabled national coordination of data collection, analyses and public reporting.
- This improved understanding of local and national patterns and trends in antimicrobial use (AU) and AMR across Australia provides clinicians, policymakers and health system managers with a breadth and depth of information that were not previously available to inform clinical policy and practice.
- Comprehensive, coordinated and effective surveillance of AMR and AU enables effective strategies to be developed to prevent and control AMR at the local level, by all states and territories and by the private sector.
- In 2020, the Australian Commission on Safety and Quality in Health Care worked with the Australian Group on Antimicrobial Resistance to prepare aggregated resistance data for submission to the World Health Organization Global Antimicrobial Resistance Surveillance System. Data for six out of eight potential priority pathogens and two of the four priority specimens were submitted.
- AURA 2021 is the fourth report of its type on AMR and AU in Australia. It includes data about organisms that have been determined to be a priority for Australia, the volume of AU, the appropriateness of antimicrobial prescribing, key emerging issues for AMR, and a comparison of Australia's situation with other countries.
- During 2020, in response to COVID-19, Australia experienced substantial decreases (between 22% and 49%) in PBS dispensing for several antimicrobials, including amoxicillin, cefalexin and doxycycline.

Chapter 2: Data sources and methods

- The Antimicrobial Use and Resistance in Australia (AURA) Surveillance System is Australia's national surveillance system. It captures data on antimicrobial use (AU) and antimicrobial resistance (AMR) from

hospital and community settings using both passive and targeted systems.

- The Australian Commission on Safety and Quality in Health Care (the Commission) has managed the AURA Surveillance System since it established the system in 2014.
- Data on AU and appropriateness of prescribing are sourced from the National Antimicrobial Prescribing Survey, the National Antimicrobial Utilisation Surveillance Program, the NPS MedicineWise MedicineInsight program, the Pharmaceutical Benefits Scheme and the Repatriation Pharmaceutical Benefits Scheme.
- Data on AMR are sourced from the Australian Group on Antimicrobial Resistance, Australian Passive AMR Surveillance, the National Neisseria Network, the National Notifiable Diseases Surveillance System, Sullivan Nicolaides Pathology and the National Alert System for Critical Antimicrobial Resistances.

Chapter 3: Antimicrobial use and appropriateness

Hospitals

- In 2019, the total-hospital antibiotic use in hospitals that participated in the National Antimicrobial Utilisation Surveillance Program increased by 2.8% in comparison with the previous year. The usage rate increased from 848.2 defined daily doses (DDDs) per 1,000 occupied bed days (OBDs) in 2015 to 883.0 DDDs per 1,000 OBDs in 2019.
- The Priority Antibacterial List is a categorisation system used to stratify antibiotics according to preferred use to contain antimicrobial resistance in human health in Australia. This tool enables Australian hospitals to benchmark their use of antibiotics against other similar hospitals and to monitor their use over time. There is variability between states and territories and peer groups in the use of antibacterials with a higher risk of contributing to the development of antimicrobial resistance.
- The overall appropriateness of prescribing across all peer groups that participated in the National Antimicrobial Prescribing Survey (NAPS) was 75.8% in 2019. Overall appropriateness of prescribing has essentially remained static since 2013. However, appropriateness varied widely between peer groups, with improvements in some and deterioration in others.
- The Surgical NAPS demonstrated that documentation of antimicrobial administration time and incision time were the main issues for procedural surgical prophylaxis. For post-procedural surgical prophylaxis, the main issues were incorrect duration, dose and frequency of administration.
- Inappropriate topical antimicrobial use for surgical prophylaxis was identified by the Surgical NAPS. In 2019, 75.5% of topical antimicrobials used in procedural prophylaxis were deemed inappropriate, and 65.2% used in post-procedural prophylaxis were deemed inappropriate.

Community: primary care

- In 2019, 40.3% (n = 10,227,693) of the Australian population had at least one antimicrobial dispensed under the Pharmaceutical Benefits Scheme (PBS) or the Repatriation Pharmaceutical Benefits Scheme (RPBS).
- Between 2015 and 2019, there was a gradual annual decline in the rate of antibiotic dispensing and a 14.8% decrease in the age-standardised rate of PBS/RPBS prescriptions per 1,000 people.

- The most commonly supplied antibiotics under the PBS/RPBS continue to be cefalexin, amoxicillin and amoxicillin–clavulanic acid.
- In patients aged less than 65 years, the highest rate of dispensing was for children aged 2–4 years.
- Approximately 50% of all antibiotic prescriptions were ordered with repeats; of those repeats, approximately half were filled within 10 days of the original prescription.
- The rate of systemic antimicrobial prescribing in participating MedicineInsight practices has steadily declined since 2010. However, antimicrobials continue to be overprescribed compared with guideline recommendations.
- In 2019, 31.2% of patients from participating MedicineInsight practices were prescribed systemic antimicrobials.
- A very high percentage of patients from participating MedicineInsight practices were prescribed antimicrobials for conditions for which there is no evidence of benefit, including acute bronchitis (81.5% of patients with this condition recorded) and sinusitis (80.1% of patients with this condition recorded).
- Differences in prescribing were found among age groups in participating MedicineInsight practices. Children aged 0–4 years were most commonly prescribed amoxicillin, and people aged 90–94 years were most commonly prescribed cefalexin. The most common indications for cefalexin prescribing were skin and wound infections, and urinary tract infections.

Community: residential aged care services

- Approximately 20% of antimicrobial prescriptions in residential aged care services that participated in the Aged Care National Antimicrobial Prescribing Survey (AC NAPS) were for prophylaxis. This is concerning because there are relatively few indications for antimicrobial use as prophylaxis in the aged care setting.
- Topical antimicrobials accounted for almost one-third (30.4%) of all prescriptions and almost 90% of PRN (as required) prescriptions. The most commonly prescribed antimicrobial was clotrimazole (74.1%).
- Almost 1 in 6 (15.0%) antimicrobials for residents of services that contributed to AC NAPS were prescribed for PRN administration. This may reduce clinical review of antimicrobial choice at the time of onset of infection, and delay decisions about treatment duration, leading to extended duration of treatment.
- Although there is variation from year to year in the cohort of AC NAPS contributors, there is no indication that the overall safety of antimicrobial use in services that contribute to AC NAPS has improved since 2015. However, there was an improvement in documentation of antimicrobial review or stop dates for residents of services that contributed to AC NAPS in 2019 (64.7%, compared with 58.9% in 2018).
- The most common clinical indications for antimicrobial prescriptions were cystitis; skin, soft tissue or mucosal infections; pneumonia; tinea; and non-surgical wound infections. Many of these conditions can be prevented by managing hydration and providing good basic hygiene, rather than prescribing antimicrobials.

- Cefalexin, topical clotrimazole, amoxicillin–clavulanic acid, trimethoprim and doxycycline were the most commonly prescribed antimicrobials. Narrower-spectrum agents (for example, amoxicillin) are recommended over cefalexin or amoxicillin–clavulanic acid for many infections because they are less likely to promote antimicrobial resistance.

Chapter 4: Antimicrobial resistance

- National rates of resistance for many priority organisms have not changed substantially from those reported in AURA 2019. However, several changes in resistance are important to consider in the context of infection prevention and control, and antimicrobial prescribing.
- In *Escherichia coli*, resistances to common agents used for treatment continue to increase. Resistance to ciprofloxacin and other fluoroquinolones has continued to rise in isolates from community-onset infections, despite restriction of access to these agents on the Pharmaceutical Benefits Scheme. These changes in resistance may mean increasing treatment failures and greater reliance on last-line treatments such as carbapenems. Meropenem resistance has remained low.
- In *Enterobacterales*, rates of resistance were somewhat lower in the community than in hospitals for most agents with available data. There were no major differences between rates in public versus private hospitals. Rates in aged care homes were often as high as, or higher than, rates in hospitals.
- Carbapenem resistance in *Enterobacterales* remains uncommon, but is found more often in the *Enterobacter cloacae* complex than in *E. coli* or *Klebsiella pneumoniae.*
- In *Enterococcus faecium*, the overall rates of vancomycin resistance are declining nationally, but are still above 40%.
- In *Neisseria gonorrhoeae*, rates of azithromycin resistance have declined since 2017, with resistance at 4.6% in 2019. However the total number of notifiable cases continues to increase.
- In *Neisseria meningitidis*, the number of notifiable cases has decreased since 2017. Reduced susceptibility to benzylpenicillin has declined from 44.9% in 2017 to 21.0% in 2019. Full resistance to benzylpenicillin is now found in less than 1% of isolates.
- In *Salmonella*, ciprofloxacin resistance in typhoidal species (*Salmonella* Typhi and *Salmonella* Paratyphi) exceeded 78% in 2019, confirming that ciprofloxacin should no longer be relied on for empirical treatment.
- In *Staphylococcus aureus*, patterns of methicillin resistance continue to evolve. Clones that were previously dominant are being replaced by other clones, and community-associated methicillin-resistant *S. aureus* has become prominent everywhere, but especially in remote and very remote regions. This demonstrates a need for a renewed focus on infection prevention and control in both community and acute settings.
- In *Shigella sonnei*, resistance to ceftriaxone, ciprofloxacin and ampicillin increased rapidly compared with the 2017 rates noted in AURA 2019.
- In *Streptococcus agalactiae*, resistance to erythromycin and clindamycin has steadily increased to around 33% in 2019.
- Macrolide resistance in *Streptococcus pyogenes* has doubled since 2017 to 9% in 2019, reducing the utility of these second-line agents.

Chapter 5: National Alert System for Critical Antimicrobial Resistances (CARAlert)

- Carbapenemase-producing *Enterobacterales* (CPE) was the most commonly reported critical antimicrobial resistance (CAR) in 2020.
- Three carbapenemase types (IMP, NDM and OXA-48-like) accounted for 96% of all *Enterobacterales* with a confirmed carbapenemase, either alone or in combination, in both 2019 and 2020.
- CARs reported from aged care settings were predominantly CPE or daptomycin-nonsusceptible *Staphylococcus aureus*.
- Of CARs reported from bloodstream specimens, 83% were CPE. Oral therapies may not be available for many of these infections, and hospital-based intravenous therapy is the only treatment option.
- There were large increases in multidrug-resistant *Shigella* species (from 104 isolates in 2018 to 331 isolates in 2019), followed by a small decline in 2020 (*n* = 299 isolates).
- There were sporadic reports of ceftriaxone-nonsusceptible *Neisseria gonorrhoeae*.
- *Candida auris* was reported from three states and territories in 2019 and 2020.
- There was a sharp fall in the monthly number of CARs reported from April 2020 onwards, notably in reports of multidrug-resistant *Shigella* species. This fall correlated with the introduction of COVID-19 restrictions throughout Australia.

Chapter 6: Focus areas

Antimicrobial resistance in northern Australia

- The HOTspots resistance surveillance program monitors antimicrobial resistance in the far north of Australia. The program shows that resistance rates of some important pathogens are higher in this region than in other parts of the country. Inclusion of resistance data from the Northern Territory (NT), for the first time, is an important development for the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System, increasingly incorporating data from across Australia and broadening the representativeness of the data.
- Methicillin-resistant *Staphylococcus aureus* is prevalent in northern Australia. In 2019, aggregate rates for northern Australia were 27.7% for blood isolates, compared with 17.7% nationally. Rates were higher for skin and soft tissue isolates (34.7%) than for blood isolates, and higher for community-based isolates (41.1%) than for hospital-based isolates (31.9%). Rates were higher in far north Western Australia (WA; 46.9%) than in the NT (34.6%) and far north Queensland (29.6%).
- In 2018–19, rates of resistance to fluoroquinolones in *Escherichia coli* in northern Australia were similar to national figures (HOTspots, 14.6–14.8%; national, 11.4–13.7%). In contrast, rates of resistance to third-generation cephalosporins (ceftriaxone or cefotaxime) were, in general, higher in northern Australia (8.3–18.2%) than nationally (8.0–11.9%). There have been upward trends in both of these resistances since 2015.

- Rates of erythromycin-resistant *Streptococcus pyogenes* have remained low (<2%) in far north WA, but have risen from 1.2% in 2015 to 8.0% in 2019 in far north Queensland.
- Rates of resistance to erythromycin and tetracycline in *Streptococcus pneumoniae* have been falling in far north WA, but remained stable in far north Queensland over the period 2015–2019.

Impact of COVID-19 on antibiotic use in Australia during 2020

- Pharmaceutical Benefits Scheme data indicate that the COVID-19 pandemic had a profound impact on antimicrobial use in 2020, with a 40% drop in antimicrobials dispensed between March and April; use remained at this lower level for the rest of the year. The change was largely the result of a drop in antimicrobial dispensing for seasonal respiratory viral infections. These infections decreased as a result of COVID-19 community control measures.

International comparisons of antimicrobial resistance

- Although Australia's rates of fluoroquinolone resistance in *Escherichia coli* and *Klebsiella pneumoniae* remain very low compared with most European countries, resistance has increased since the establishment of AURA, when compared with some countries. Rates of resistance to third-generation cephalosporins in these two species in Australia are lower than the European average.
- Compared with European countries, rates of resistance in key gram-positive pathogens are moderate to high in Australia. The prevalence of vancomycin resistance in *Enterococcus faecium* remains higher in Australia than in more than 30 European countries, even though rates have levelled off in recent years.

International comparisons of antimicrobial use

- Australian hospital antimicrobial use, based on defined daily doses per 1,000 occupied bed days, is nearly four times that of the European country with the lowest use, the Netherlands, and considerably higher than that of Canada, which has a comparable healthcare system.
- Australia ranks seventh compared with European countries in its community use of antibacterial agents (defined daily doses per 1,000 people per day).

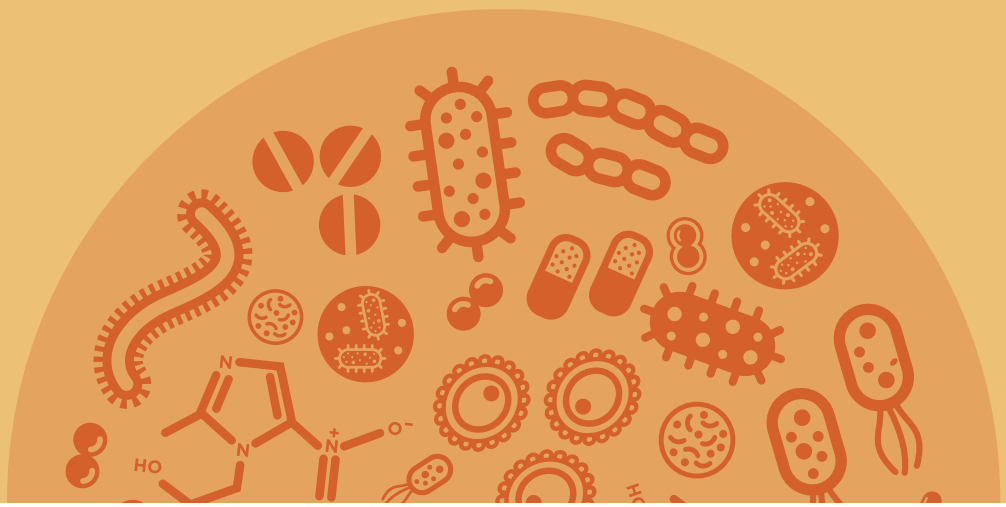
Clostridioides infection in Australia

- *Clostridioides difficile* infection (CDI) in Australia is characterised by a heterogeneous strain population, dominated by PCR ribotype (RT) 014 – the most common *C. difficile* strain type in humans and pig herds in Australia.
- Over the survey period, the majority of *C. difficile* in Australia did not show reduced susceptibility to antimicrobials recommended for treatment of CDI (vancomycin, metronidazole and fidaxomicin). Fidaxomicin demonstrated superior in vitro activity to vancomycin and metronidazole.
- Resistance to carbapenems and fluoroquinolones was low, and multidrug-resistant *C. difficile* was uncommon. However, clindamycin resistance was common, and one epidemic fluoroquinolone-resistant RT027 strain was detected.
- Continued surveillance of current and emerging *C. difficile* strains and antimicrobial resistance phenotypes is a key component in the strategy to understand and ultimately reduce the burden of CDI on global healthcare systems.

Chapter 7: Conclusions and future developments

- Since 2013, when the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System was established, antimicrobial resistance (AMR) has continued to increase. AMR remains a risk to patient safety because it reduces the number and effectiveness of antimicrobials available to treat infections, increases morbidity and mortality associated with infections caused by multidrug-resistant organisms, and may limit future capacity to perform medical procedures such as organ transplantation, cancer chemotherapy, diabetes management and major surgery.
- The AURA Surveillance System has provided data that have improved understanding of local and national patterns and trends in antimicrobial use (AU) and AMR across Australia. It has provided clinicians, policymakers and health system managers with data on AMR and AU to inform clinical practice and policy development. AURA is now a world-class surveillance program, and in one important respect is more comprehensive than other national programs as it is able to monitor, and report on, appropriateness of use in both hospitals and the community.
- AURA 2021 complements the findings of previous national AURA reports and other focused reports on AMR and AU from the Australian Commission on Safety and Quality in Health Care (the Commission). Each report provides additional information, provided by all states and territories and the private sector, to support development of more targeted and effective strategies for appropriate antimicrobial prescribing, and to prevent and control AMR nationally.
- Resistance rates for many priority organisms have not changed substantially since AURA 2019. However, several changes in resistance have been highlighted, and are important to consider at the local, state and territory, and national levels.
- In gram-negative pathogens, it is of serious concern that resistances to common agents used for treatment continue to increase in *Escherichia coli.* Carbapenem resistance in *Enterobacterales* remains uncommon. Rates of resistance in *Enterobacterales* to most agents were lower in the community than in hospitals. However, rates in aged care homes were often as high as, or higher than, rates in hospitals.
- In *Staphylococcus aureus*, the epidemiology of methicillin resistance continues to evolve. Previously dominant clones are being replaced by other clones, and community-associated methicillin-resistant *S. aureus* has become prominent, especially in rural and remote regions. This demonstrates the need for a renewed focus on infection prevention and control in both community and hospital settings.
- Overall rates of vancomycin resistance in *Enterococcus faecium* are declining nationally, but are still greater than 40%, which highlights the ongoing need for focused response strategies.
- Generally, reports of critical antimicrobial resistances (CARs) to the National Alert System for Critical Antimicrobial Resistances (CARAlert) remain at very low levels. However, there have been fluctuations since 2016 in reports of community-associated CARs such as multidrug-resistant *Shigella* species and ceftriaxone-nonsusceptible or azithromycin-nonsusceptible *Neisseria gonorrhoeae.* Ongoing monitoring and prevention and control strategies are essential to ensure that levels of CARs continue to remain low in Australia.

- The gradual decrease in the volume of AU in the community continued in 2019. There was a 40% drop in Pharmaceutical Benefits Scheme dispensing in 2020 during the response to the COVID-19 pandemic, which suggests that there are opportunities to intervene to sustain these lower levels of AU.
- The gradual increase of AU in hospitals continued in 2019, although the direct cause of this shift in volume remains unclear. While there have been changes in its coordination role in relation to AU, the Australian Commission on Safety and Quality in Health Care (the Commission) will continue to work with relevant stakeholders to monitor changes and develop appropriate response strategies.
- The overall appropriateness of antimicrobial prescribing in hospitals and residential aged care services that participated in the National Antimicrobial Prescribing Survey was static. However, in hospitals, appropriateness of prescribing varies widely between peer groups: smaller hospitals have higher rates of inappropriate prescribing, and appropriateness of prescribing appears to have deteriorated in private hospitals.
- Key areas of focus for the Commission in 2022 will be to support the relevant lead organisations in the aged care and primary care sectors, and clinicians and carers, to understand the reasons for inappropriate prescribing and improve prescribing practice.
- AURA 2021 data provide increased capacity to identify patterns and trends in resistance in the priority organisms for Australia in acute care, residential aged care services and the community. These data inform targeted responses to specific resistances in specific settings. The Commission will consult further with clinical and technical experts to provide this information in the most accessible form.
- AURA 2021 includes, for the first time, data from the HOTspots surveillance program, which monitors AMR in far north Australia, and also the inclusion of data on *Clostridioides difficile.* The Commission's AURA team will continue to integrate resistance data such as these to inform implementation of Australia's National AMR Strategy: 2020 and Beyond, and state, territory and private sector AMR response strategies.



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