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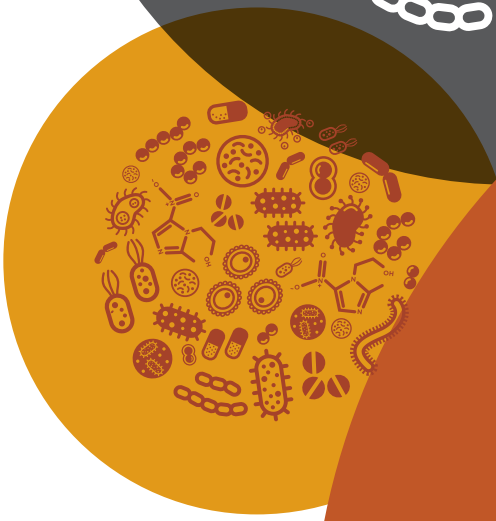
AURA
Antimicrobial Use and Resistance in Australia



2023 AURA

Fifth Australian report on antimicrobial use and resistance in human health

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Fifth Australian report on antimicrobial use and resistance in human health

Contents

Summary

Summary

Antimicrobial resistance (AMR) is a public health priority due to its serious and growing impact. Hundreds of people in Australia die each year as a result of AMR.[1,2]

AMR occurs when a microorganism develops resistance to an antimicrobial that was previously an effective treatment, and it continues to be one of the most significant challenges for healthcare services in Australia and worldwide. Antimicrobial use (AU) is a key factor in the development of AMR. The more antimicrobials are used, the more likely it is AMR will develop.[3] This presents a risk to patient safety by reducing the range of antimicrobials available to successfully treat infections, and increases the morbidity and mortality associated with infections caused by multidrug-resistant organisms.

Australian data on AMR and AU in human health are collected by the Antimicrobial Use and Resistance in Australia Surveillance System (AURA) and are analysed to detect and monitor trends and regularly report on AU and AMR. AURA also provides local and national data on AMR and AU for all levels of the Australian healthcare system, across the acute care and community sectors, and the public and private sectors.

The *Fifth Australian report on antimicrobial use and resistance in human health* (AURA 2023) complements a series of national reports developed by the Australian Commission on Safety and Quality in Health Care (the Commission), the Australian Government Department of Health and Aged Care (the Department) and surveillance programs that contribute to AURA (AURA program partners). These reports provide essential information to inform strategies for preventing and containing AMR in human health, and improving AU and appropriateness across acute and community settings.

AURA 2023 reports on the analyses of AURA data from 2020–2022, highlights trends and areas of concern, and suggests priorities for action.

Key conclusions

Acute care

- The volume of AU in Australian hospitals is high; it is substantially higher than in comparable European countries and Canada.
- Variation between states and territories in the volume of use between antibacterial categories continues, as does a concerning proportion of use of antibacterials with high AMR selection potential in private hospitals compared to public hospitals.
- Ongoing lack of improvement in the appropriateness of prescribing in public and private hospitals.
- High rates of inappropriate prescribing of antimicrobials for the treatment of chronic obstructive pulmonary disease (COPD) continue.

- There are opportunities to address the high continued inappropriate use of surgical prophylaxis in hospitals that contribute to AURA.
- There are increasing rates of critical antimicrobial resistances (CARs) in hospitals, particularly carbapenemase-producing *Enterobacterales* (CPE).
- Antifungal resistance is rarely detected in common *Candida* group species and *Aspergillus fumigatus* complex; nevertheless, there is increasing antifungal use in hospitals, which could drive resistance in the future.

Community: primary care

- The number of antimicrobial prescriptions supplied under the Pharmaceutical Benefits Scheme (PBS) and Repatriation PBS (RPBS) decreased by 25.3% from 2019 to 2021. While it increased by almost 10% from 2021 to 2022, it remains 18.1% lower than 2019.
- There is an increasing proportion of private prescriptions for antimicrobials (i.e. prescriptions that are not subsidised under the PBS or RPBS) and there are limited reporting and monitoring mechanisms in place, which continues to be a gap in AU surveillance in Australia.
- Ciprofloxacin resistance in *Escherichia coli* declined nationally from 2020 to 2021, following a steady increase in *E. coli* resistance to fluoroquinolones from 2013 to 2020. A reduction in *E. coli* resistance may be associated with the reduction in community AU, and the reduction in international travel during the COVID-19 response.
- Rates of azithromycin non-susceptibility in *Neisseria gonorrhoeae* have declined since 2017, and the total number of notified cases also declined in 2021; in *Shigella sonnei*, the rates of resistance to ceftriaxone, ciprofloxacin and ampicillin have reduced since 2020, and were similar to the 2017 rates in 2021, after rapid increases in 2018 and 2019.

Community: residential aged care

- While the overall number of AMR infections reported in aged care homes was low, AMR rates were as high as, or higher than, rates in hospitals for *Enterobacterales* and methicillin-resistant *Staphylococcus aureus* (MRSA).
- Improved surveillance of AMR and infections, and effective infection prevention and control and antimicrobial stewardship (AMS) programs, are required because of the sustained high rates of AU that is not consistent with guidelines.

Priorities for action

Acute care

- Promoting local AMS interventions to address variations in the volume of AU between states and territories.
- Improving the appropriateness of antimicrobial prescribing in public and private hospitals, including antibacterials with high rates of use and high AMR selection potential.
- Improving the appropriateness of COPD prescribing.
- Promoting quality improvement actions that target high-volume surgical procedures with high rates of inappropriate antimicrobial prescribing.
- Continuing to monitor CARs in hospitals, particularly CPE, and promote effective infection prevention and control and outbreak responses.
- Continuing to monitor antifungal use and emerging antifungal resistances.

Community: primary care and residential aged care

- Sustaining improvements in the volume and appropriateness of antimicrobial prescribing in primary care.
- Continuing to explore opportunities to increase the capacity to monitor private antimicrobial prescribing, repeat prescriptions for antimicrobials and the indications for which antimicrobials are prescribed.
- Informing consumers of the role of antimicrobials in AMR, the effects of antibacterials on beneficial and harmful bacteria, and the potential for their use to increase the risk of the development of chronic conditions in children and adults.[4]
- Promoting ongoing surveillance of AMR in sexually transmissible infections – in particular *N. gonorrhoeae* and *Shigella* species – as well as continuing prevention and control programs for these infections, and implementing outbreak response strategies.
- Supporting improved antimicrobial prescribing in residential aged care.
- Promoting improved surveillance of infections and AMR in the community and in residential aged care settings.
- Supporting the enhancement of infection prevention and control capacity in residential and community-based aged care services.

Overall

In collaboration with the Department and AURA program partners, the Commission will:

- Continue to support ongoing surveillance of AMR and AU, and the use of these data in the health and aged care sectors, to inform improvements in practice and in the quality of care provided to patients and older people
- Support health and aged care services to prevent and control AMR and use antimicrobials appropriately through the implementation of strategies that address the quality statements of the Antimicrobial Stewardship and Sepsis Clinical Care Standards, and reduce unwarranted variations in care
- Ensure that the clinical care standards in development for COPD and emergency laparotomy include quality statements on the appropriate use of antimicrobials
- Continue to use data on AU and AMR in conjunction with data on healthcare-associated complications and potentially preventable hospitalisations to develop strategies to prevent and control urinary tract infections, cellulitis and other infections that may require treatment with antimicrobials
- Continue to work with Therapeutic Guidelines Limited and other expert guideline development groups to support the ongoing review of prescribing guidance in light of current and emerging resistances.

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Chapter 1

Introduction

Introduction

Antimicrobial resistance (AMR) continues to be one of the biggest challenges internationally to the provision of safe, high-quality health services. This *Fifth Australian report on antimicrobial use and resistance in human health* (AURA 2023) has been prepared by the Australian Commission on Safety and Quality in Health Care (the Commission) to report on current and longitudinal trends. This work has been undertaken with funding provided by the Australian Government Department of Health and Aged Care (the Department).

This chapter provides the background and context for this important public health and public policy challenge. The chapter also outlines the current Australian strategic context and the contribution of the Antimicrobial Use and Resistance in Australia Surveillance System (AURA) 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.

About the AURA Surveillance System

AURA is Australia's national surveillance system for antimicrobial use (AU) and AMR in human health. It provides essential information to inform strategies for preventing and containing AMR in human health and improving AU across acute and community settings. AURA is funded by the Australian Government.

In 2013, the Department engaged the Commission to set up a nationally coordinated system for the surveillance of AU and AMR for human health. AURA is Australia's first nationally coordinated surveillance system for gathering such data. Since 2021, the Department has coordinated the AURA Surveillance System.[1]

AURA provides a picture of AU and AMR across Australia to allow:

- Detection of emerging resistances and trends
- Identification of links between AU and AMR
- Identification of areas for action to address inappropriate use of antimicrobials.

The key functions of AURA include:

- Coordinating and supporting data collection from public and private hospitals, aged care and primary care settings
- Providing coordinated and strategic direction for AMR prevention and control and antimicrobial stewardship (AMS)
- Engaging with providers to help them use AURA data to improve clinical practice, promote the appropriate use of antimicrobials (especially antibiotics) and prevent and contain AMR

- Raising awareness of AMR among the public.

AURA programs and partners

The key AURA surveillance programs (AURA program partners) are:

- Australian Group on Antimicrobial Resistance (AGAR)
- Australian Passive AMR Surveillance (APAS)
- National Alert System for Critical Antimicrobial Resistances (CARAlert)
- National Antimicrobial Prescribing Survey (NAPS)
- National Antimicrobial Utilisation Surveillance Program (NAUSP).

Additionally, the HOTspots program that contributed data to AURA 2021[2] and AURA 2023 was piloted by the Department as part of AURA. The Department funds these surveillance programs and also Australia's national coordinating centre for the World Health Organization's (WHO) Global Antimicrobial Resistance and Use Surveillance System (GLASS), which reports AURA data to GLASS.

Elements of the AURA framework are described in Figure 2.1 in Chapter 2.
In addition to the AURA program partners listed above, data and reports are collated from:

- The National Neisseria Network, which conducts two programs: the Australian Gonococcal Surveillance Programme (on *Neisseria gonorrhoeae*) and the Australian Meningococcal Surveillance Programme (on *N. meningitidis*)
- The National Notifiable Diseases Surveillance System on *Mycobacterium tuberculosis*
- The Pharmaceutical Benefits Scheme (PBS) and the Repatriation Pharmaceutical Benefits Scheme (RPBS) on the volume of antimicrobials dispensed
- The MedicineInsight program on the prescribing of antimicrobials by general practitioners (GPs)
- Sullivan Nicolaides Pathology (SNP) on the rates of AMR from the community and private hospital settings.

Each of the AURA program partners provides valuable data on either AU or AMR that cover selected antimicrobials or organisms from the community and hospitals. These 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.

Each of these programs operates within the framework of AURA to provide an integrated and coordinated picture of AU and AMR in Australia that continuously improves as a result of increased participation and representativeness. The AURA program partners continue to take a systematic approach to improve data representativeness, collection, analytics and accessibility by identifying gaps and targeting those areas for expansion.

It is important to note that state and territory health departments also provide funding for AURA through their support for laboratory testing services and the voluntary collation and submission of data to each of the AURA program partner surveillance programs.

About the Department of Health and Aged Care

The Department supports the Australian Government to lead and shape Australia's health and aged care system and sporting outcomes through evidence-based policy, well-targeted programs, and best-practice regulation.

The Department's objectives include protecting the health of the Australian community through national leadership and capacity-building to detect, prevent, prepare for and respond to threats to public health and safety, including those arising from communicable diseases.[3]

One of the Department's key activities is providing a nationally coordinated response to detect, address and minimise the threat of AMR and implement *Australia's National AMR Strategy – 2020 and Beyond*[4] (the 2020 AMR Strategy), including the development of supporting action plans.

About the Commission

The Commission is a corporate Commonwealth entity and is part of the health portfolio of the Australian Government. As such, it is accountable to the Australian Parliament and the Minister for Health and Aged Care.

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's purpose is to lead and coordinate national improvements in the safety and quality of health care. This continuously improves health outcomes and experiences for all patients and consumers, and improves 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 appropriate care.

The Commission works in four priority areas:

- Safe delivery of health care
- Partnering with consumers
- Partnering with healthcare professionals
- Quality, value and outcomes.

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[5] 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 infections, medication safety, comprehensive care, communicating for safety, blood management, and recognising and responding to acute deterioration.

The Preventing and Controlling Infections Standard requires health service organisations to monitor patterns of healthcare-associated infections (HAIs), AU and AMR, and use this information to guide AMS practices and meet infection prevention and control requirements. Data from AURA directly support this standard.

The Commission has also developed the National Safety and Quality Primary and Community Healthcare Standards[6] (Primary and Community Healthcare Standards) for services that deliver health care in primary and/or community settings,

and a standard on Clinical Care as a part of the current review of the Aged Care Quality Standards.[7] These standards include actions to prevent and control infections and to support AMS.

The Commission consults with the Department and stakeholders about additional reports and analyses of AURA data to inform policy and practice. Since 2014, AURA publications have reported on increasingly comprehensive and complex aspects of AU and AMR in public and private hospitals, aged care and primary care 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 the containment of AMR. The Commission uses AURA data to identify priorities for infection prevention and control and AMS quality improvement programs, and develop implementation support resources.

Australia's National Antimicrobial Resistance Strategy – 2020 and Beyond

In 2020, the Australian Government released Australia's second strategy on AMR.[4] 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. AURA supports the human health surveillance component of this One Health approach.

Together, AURA, the NSQHS Standards (especially the Preventing and Controlling Infections Standard), the Primary and Community Healthcare Standards and the Aged Care Clinical Standard support safe and effective health and aged 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 combatting resistance
- Objective 4: Appropriate usage and stewardship practices
- Objective 5: Integrated surveillance and response to resistance and usage.

AURA data and reporting

Several detailed reports on AU and AMR have been published by the Commission since 2014, in addition to four comprehensive national reports in 2016, 2017, 2019 and 2021.[2,8–10] The patterns and trends identified in AURA reports guide improvements in infection control, AMS and antimicrobial prescribing practices.

AURA has created the capacity to compare AU and AMR in Australia with data from some other countries, as described in Chapter 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 data were included in Australia's submission to the WHO GLASS for the first time in 2020, and Australia's enrolment in GLASS and first data submission were in 2019.[11]

From 2020, in addition to data submitted by the National Neisseria Network about

Neisseria gonorrhoeae data from genital swabs, AGAR Surveillance Outcome programs data were submitted to GLASS on five pathogens from blood (*Staphylococcus aureus*, *Klebsiella pneumoniae*, *Escherichia coli*, *Acinetobacter* species and *Salmonella* species). From 2021, APAS data on five pathogens from blood, urine and/or stool (*Streptococcus pneumoniae*, *K. pneumoniae*, *E. coli*, *Salmonella* species and *Shigella* species) isolates were submitted to GLASS.

1.2 Australian healthcare system: governance and context

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.

Governance of the Australian healthcare system is a shared responsibility of the Australian Government and state and territory governments.[12] 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.[13] As a result, the COAG Health Council and AHMAC were respectively replaced with the National Cabinet Reform Committee – Health and the Health Chief Executive Forum.

State and territory governments license and regulate private hospitals, which are primarily owned by large for-profit and not-for-profit organisations. There are also large public and private pathology laboratories, which must meet the standards and requirements set by the National Pathology Accreditation Advisory Council (NPAAC) in order to be accredited providers of Medicare rebateable services. The National Association of Testing Authorities assesses laboratories against these standards. The Commission, in partnership with the NPAAC, is currently undertaking a review of the national pathology accreditation 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. The Australian Government also funds Primary Health Networks.

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 among 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 GPs or specialists. 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 and 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 Impact of antimicrobial resistance

AMR occurs when a microorganism develops resistance to an antimicrobial that was previously an effective treatment. AU is a key factor in the development of AMR. The more antimicrobials are used, the more likely it is that microorganisms will develop resistance.[14] As a result, infections caused by resistant organisms may need to be treated with other antimicrobials, either in hospital or in the community, which may have more severe side effects, be more expensive or take longer to work. People with infections caused by more resistant microorganisms spend longer time in hospitals, and their infections take longer to resolve. In some severe infections, there are no currently available treatments for resistant organisms, causing patient morbidity and mortality to increase.

AMR occurs when a microorganism develops resistance to an antimicrobial that previously provided 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.

International evidence consistently demonstrates the effect that AMR is having on human health. Studies confirm that increasing numbers of infections in health service organisations and in the community are caused by resistant pathogens. Hundreds of people in Australia die each year as a result of AMR.[15,16]

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 Organisation for Economic Co-operation and Development (OECD). The most recent OECD estimate is that AMR will cost the health systems of the United States, Canada and Australia a combined total of approximately $74 billion in United States dollar purchasing power parity between 2015 and 2050.[16] Moreover, the safety of medical procedures will be affected across all countries surveyed by the OECD.

One Australian study, which used Queensland data to model the national cost of premature death from five healthcare-associated resistant infections, estimated that the cost was more than $438 million and that there was a loss of more than 27,000 quality-adjusted life years (QALYs) due to these five AMR pathogens. This is compared to the total hospital cost for these infections of more than $71 million in 2020.[17]

Another recent modelling study estimated that over 10 years, reducing AMR for three gram-negative pathogens in three HAIs by 95% in Australia would result in gains of more than 10,000 life-years and almost 9,000 QALYs, save just over 9,000 bed-days and avoid more than 6,600 defined daily doses of antimicrobials. The monetary benefit to health care in Australia was estimated to be over $412 million.[18]

1.4 Importance of surveillance

Comprehensive and coordinated surveillance is a critical requirement of efforts to control AMR. The information generated through AURA 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.[11,16] 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 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.

Ready access to relevant data on AU and AMR will more effectively inform policy decisions, such as the development or revision of antimicrobial prescribing guidelines. It will also help identify priorities for public health action, such as education campaigns and regulatory measures. For example, the Commission routinely works with the developers of *Therapeutic Guidelines: Antibiotic*[19] to provide a variety of AURA data to inform the review of antimicrobial treatment protocols.

A lack of surveillance data, and 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 AURA to policymakers and clinicians will have positive effects at all levels of the health system.

1.5 AURA 2023 report overview

AURA 2023 is the fifth national AURA report. It builds on four national reports from 2016, 2017, 2019 and 2021.[2,8–10] AURA 2023 includes data and analyses on patterns and trends:

- For antimicrobial prescribing and dispensing in hospitals and the community (primary care and aged care homes)
- For the appropriateness of antimicrobial prescribing in hospitals and the community (primary care and aged care homes)
- For resistance to key antimicrobials in priority organisms in acute care, aged care homes and other community settings.

Together, these provide evidence to inform state and territory AMR prevention and containment strategies.

AURA 2023 includes analyses of the impact of COVID-19 on AU, highlights issues for AU and AMR in Australia, and provides comparisons with other countries. The report also includes antifungal resistance data for the first time.

This report integrates data from many programs and organisations. It 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.

This report would not be possible without the voluntary contributions of data by each of the organisations and networks that collaborate with the AURA program partners, the Department and the Commission. This ongoing participation contributes to the overall value and effectiveness of AURA, and to the many reports that support AMR prevention and containment strategies across Australia.

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Chapter 2

Data sources and methods

Data sources and methods

The overall objective of the Antimicrobial Use and Resistance in Australia Surveillance System (AURA) is to provide representative data by maximising geographic coverage across the community and acute health sectors, and the private and public health sectors. Participation in each of the surveillance programs has progressively increased and improved the utility of the system over time. The collection methods, analyses and documentation of any limitations of the use of the data will continue to be refined.

Effective coordination, timely analysis and accurate reporting continue to inform strategies for local, state and territory, and national health systems. Opportunities to enhance AURA 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 included in AURA.

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

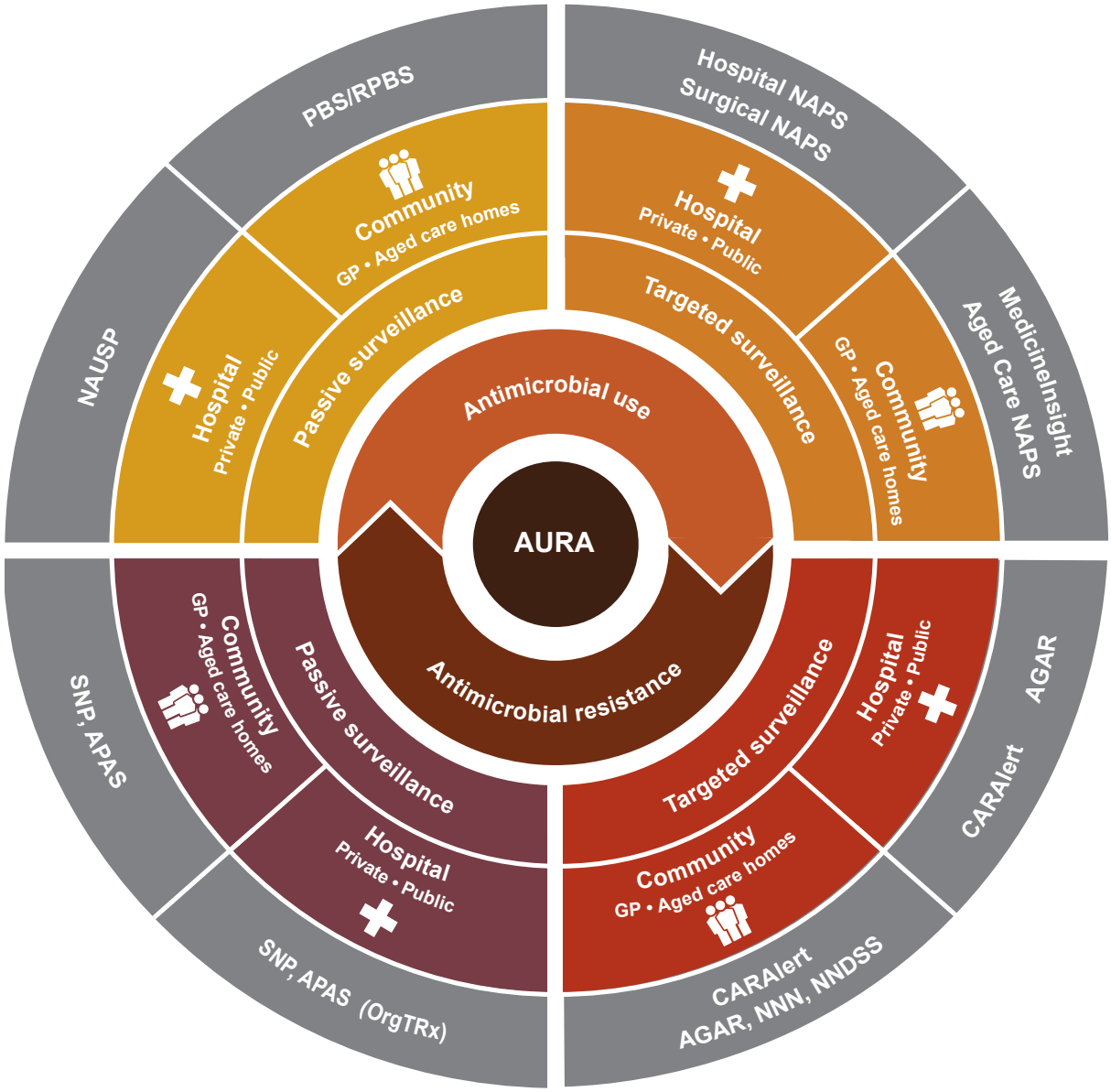
The framework for AURA is shown in Figure 2.1, along with data sources. This report includes available and validated data, predominantly from 2020 and 2021. However, to review patterns of antimicrobial use (AU) in the community, Pharmaceutical Benefits Scheme (PBS) and Repatriation Pharmaceutical Benefits Scheme (RPBS) data from between 2015 and 2022 are included, as well as 2022 data from the National Alert System for Critical Antimicrobial Resistances (CARAlert).

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 AU and AMR. Targeted surveillance is the collection of data to identify trends and patterns in AU and AMR.

As shown in Figure 2.1, surveillance data are collected from the hospital and community (primary care and aged care homes) sectors. 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 2023. Further detail on the data sources for this report, including details of collection methods, is provided in Appendix 1.

Figure 2.1: The AURA Surveillance System



AGAR = Australian Group on Antimicrobial Resistance; APAS = Australian Passive Antimicrobial Resistance Surveillance; AURA = Antimicrobial Use and Resistance in Australia; CARAlert = National Alert System for Critical Antimicrobial Resistances; GP = general practice; 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

In AURA 2023, Northern Territory data from the HOTspots program, which is a passive AMR surveillance system, have also been included in the analyses presented in Chapter 4. The Australian Government Department of Health and Aged Care (the Department) piloted the HOTspots program as part of AURA for 2022–23.

Table 2.1: Data sources for the AURA 2023 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: 480 general practices, 2,291,604 patients • 2016: 493 general practices, 2,413,269 patients • 2017: 498 general practices, 2,560,823 patients • 2018: 502 general practices, 2,726,115 patients • 2019: 502 general practices, 2,726,115 patients • 2020: 503 general practices, 2,581,255 patients • 2021: 504 general practices, 2,788,848 patients
	Aged Care National Antimicrobial Prescribing Survey	Appropriateness of prescribing, prescribing volume, infections	Australian aged care homes and multi-purpose services	• All states and all territories since 2018 • 2017: 271 facilities • 2018: 397 facilities • 2019: 638 facilities • 2020: 826 facilities • 2021: 689 facilities

continues

Table 2.1: *continued*

Subject and type of surveillance	Data source	Type of data	Setting	Coverage
 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 • 2017: 319 hospitals (233 public, 86 private) • 2018: 327 hospitals (234 public, 93 private) • 2019: 378 hospitals (268 public, 110 private) • 2020: 409 hospitals (285 public, 124 private) • 2021: 407 hospitals (291 public, 116 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: 110 hospitals (59 public, 51 private) • 2018: 115 hospitals (66 public, 49 private) • 2019: 150 hospitals (79 public, 71 private) • 2020: 157 hospitals (75 public, 82 private) • 2021: 181 hospitals (90 public, 91 private)
 Antimicrobial use Passive Community	Pharmaceutical Benefits Scheme and Repatriation Pharmaceutical Benefits Scheme	Dispensed volume, trends	Australian general practices and community health services	• National • 2015: 29,264,932 prescriptions for all antimicrobials • 2016: 27,324,648 prescriptions for all antimicrobials • 2017: 26,553,451 prescriptions for all antimicrobials • 2018: 26,229,366 prescriptions for all antimicrobials • 2019: 26,669,561 prescriptions for all antimicrobials • 2020: 20,095,926 prescriptions for all antimicrobials • 2021: 19,931,271 prescriptions for all antimicrobials • 2022: 21,848,005 prescriptions for all antimicrobials

continues

Table 2.1: *continued*

Subject and type of surveillance	Data source	Type of data	Setting	Coverage
 Antimicrobial use Passive Hospital	National Antimicrobial Utilisation Surveillance Program	Dispensed volume	Australian public and private hospitals	• All states and territories, public and private hospitals* • 2017: 192 hospitals • 2018: 209 hospitals • 2019: 217 hospitals • 2020: 234 hospitals • 2021: 265 hospitals
 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 • 2020: 30 laboratories servicing 49 hospitals and their communities • 2021: 30 laboratories servicing 48 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 • 2020: 30 laboratories servicing 49 hospitals and their communities • 2021: 30 laboratories servicing 48 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
	HOTspots†	Rates of resistance	Community	Northern Territory private laboratories
	Sullivan Nicolaides Pathology	Rates of resistance	Community and aged care homes	Queensland and northern New South Wales

continues

Table 2.1: *continued*

Subject and type of surveillance	Data source	Type of data	Setting	Coverage
 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
	HOTspots†	Rates of resistance	Northern Territory	All Northern Territory public hospitals
	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

* Not all participating hospitals have provided data consistently to the National Antimicrobial Utilisation Surveillance Program for the duration of their registration with the program

† The Department of Health and Aged Care piloted the HOTspots program as part of AURA for 2022–23

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. **MedicineInsight**

   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.

2. **National Antimicrobial Prescribing Survey (NAPS)**

   The Hospital and Surgical NAPS are standardised web-based auditing tools available to Australian health service organisations to assess the quality of their antimicrobial prescribing, including an assessment of the appropriateness of the prescription. The Aged Care NAPS is a standardised surveillance tool that all Australian aged care homes and multi-purpose services (aged care facilities) can use to monitor the prevalence of infections and antimicrobial use, provide feedback to key clinicians and administrators, and

measure the effectiveness of infection prevention and control and antimicrobial stewardships programs.

The program is voluntary for hospitals and most aged care facilities; participation has been mandatory for aged care facilities operated by the Victorian Government since 2017. Participating hospitals and aged care facilities can interrogate their own data and undertake benchmarking using the audit tool. For the Hospital NAPS, since 2015, there have been minor changes to the program, but allows for comparisons year to year. The Surgical NAPS dataset varies each year according to the procedures audited and therefore the results are not directly comparable from year to year.

3. **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 their own data and generate reports on local practice at any time. National data are reported annually, and NAUSP analyses and reports on AU data every six months for states and territories, and hospital peer groups. This further supports benchmarking.

4. **Pharmaceutical Benefits Scheme (PBS) and Repatriation Pharmaceutical Benefits Scheme (RPBS)**

   Data on antimicrobials dispensed under the PBS and RPBS schemes are analysed for AURA reports. For AURA 2023, these data were obtained from Services Australia with approval from the Department of Health and Aged Care and the Australian Government Department of Veterans' Affairs.

Together, these data sources reflect AU and the appropriateness of prescribing across public and private hospitals and in the community throughout 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 selected priority organisms: *Enterococcus* species, *Staphylococcus aureus* and gram-negative organisms. Data are reported nationally for three AGAR Surveillance Outcome Programs annually, both individually and in a compiled report prepared by the Commission in collaboration with AGAR.

2. **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.

3. **HOTspots program**

   The HOTspots program is a longitudinal surveillance platform that provides reporting on and analysis of AMR in remote northern parts of Australia.

4. **National Neisseria Network (NNN)**

   The 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). 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 Commission to provide AMR reports since the AURA Surveillance System was developed.

Chapter 5 includes reporting on critical antimicrobial resistances (CARs) by:

1. **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.

2.4 Considerations for interpreting the data

AURA continues to expand the breadth of AU and AMR 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 detail on each of these data sources, including considerations for interpreting the data, is provided in Appendix 1.

Percentages and other data relating to 2015–2022 may have changed compared to previous reports as more data have become available.

HOTspots program data have been included to improve understanding of AMR in remote northern Australia.

With the continued maturation of the datasets available through AURA, long-term trend analyses are available for some programs, including AGAR and APAS. However, there are not yet sufficient 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 Department and the Commission continue to work with health service organisations and states and territories to expand the range of data provided, but participation in AURA remains voluntary.

Denominator data

Denominator data are not available for all of 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 resistant proportion of 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 and RPBS 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 and RPBS database is separate from the Medicare Benefits Schedule database, with the same privacy considerations related to data linkage.

As a result, the Commission 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 differences between the populations served by each laboratory.

Antimicrobial resistance

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

Variations in testing practice exist such that many hospital patients have susceptibility testing performed if a specimen is accessible, while few community patients have susceptibility testing performed, even if a specimen is accessible.

Antimicrobial use

Both NAPS and NAUSP rely on the voluntary contribution of data through agreements with both the public and private sectors. The number of contributors to each program has steadily increased each year.

In this report, community prescribing data are captured by the MedicineInsight program and dispensing data are captured by the PBS and RPBS. PBS and RPBS data include

a broader range of antimicrobials (Anatomical Therapeutic Chemical [ATC] codes J01, A02BD, A07AA09, A07AA11, D06AX09, D06BA01, P01AB01, S01AA01, S01AA11, S01AA12, S01AE01, S01AE03, S02AA01, S02AA15, and S03AA) than MedicineInsight, which captures data solely on antibacterials for systemic use (ATC code J01).

Community 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, sometimes under the instruction of the treating doctor not to have the prescription filled unless the condition worsens. Similarly, dispensing data may differ from consumption data because not all prescriptions dispensed are consumed, as patients may not use all or any of the antimicrobials provided.

The proportion of prescriptions written in the community that are captured by the PBS and RPBS is estimated[1] to be more than 90%, although the exact percentage is not known. The PBS and RPBS data 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.

The MedicineInsight program relies on voluntary participation and submission of data from general practices. The proportion of participating practices in each state and territory varies monthly due to connection issues, practice involvement and other issues, so comparisons between different states and territories should be interpreted carefully.

2.5 Data governance

The Commission's Data Governance Framework provides guidance on data acquisition, maintenance, reporting, publication, and sharing and permissions.[2]

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 AURA. The framework covers:

- Key data governance concepts, including the 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.

AURA has established protocols to ensure the integrity and security of the data it uses, as part of its partnership approach and contracting arrangements. 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 collection 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 the 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 AURA 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 the AURA program partners and suppliers of data and reports to improve standardisation of data definitions, comparability of data items, and the development of new data items and analytical methodologies. The Commission will also continue to identify opportunities to reduce the duplication of, and effort associated with, data systems and the provision of data by health services, and to increase the utility of these systems.

References

1. Drug Utilisation Sub Committee (DUSC). Antibiotics: PBS/RPBS utilisation, Oct 2014 and Feb 2015. [Internet] Canberra: Department of Health and Aged Care; 2015 [cited March 2023] Available from: https://www.pbs.gov.au/info/industry/listing/participants/public-release-docs/antibiotics/antibiotics-oct-14-feb-15.
2. Australian Commission on Safety and Quality in Health Care. ACSQHC Data Governance Framework 2023. Sydney: ACSQHC, 2023.

Chapter 3

Antimicrobial use and appropriateness

Antimicrobial use and appropriateness

Key findings

Hospitals: acute care

- In 2021, the National Antimicrobial Utilisation Surveillance Program (NAUSP) data showed that the aggregate usage rate for total-hospital systemic antibacterials for all acute care hospitals was 739.4 defined daily doses (DDD) per 1,000 occupied bed days (OBD), excluding emergency department and operating theatre usage.
- In Australian acute care hospitals, the most used oral antibacterials in 2021 were amoxicillin–clavulanic acid, doxycycline, cefalexin and amoxicillin. The use of broad-spectrum antibacterials such as amoxicillin–clavulanic acid has the potential to increase antimicrobial resistance.
- Systemic antifungal usage in Australian hospitals has increased annually since reporting commenced in 2017, which increases the risk of resistance, particularly to the azole class of antifungals.
- In 2021, the Hospital National Antimicrobial Prescribing Survey (Hospital NAPS) data showed the overall appropriateness of prescribing in Australian hospitals to be 74.5%, which was similar to previous years. Considerable variation in the appropriateness of antimicrobial prescribing was observed across hospital peer groups.
- In 2021, the Surgical National Antimicrobial Prescribing Survey (Surgical NAPS) data showed compliance with Therapeutic Guidelines or local guidelines for 68.3% of antimicrobials administered for procedural surgical prophylaxis and 39.1% of antimicrobials administered for post-procedural surgical prophylaxis.

Community: primary care

- In 2022, just over one-third (36.6%) of the Australian population had at least one antimicrobial supplied under the Pharmaceutical Benefits Scheme (PBS) or Repatriation Pharmaceutical Benefits Scheme (RPBS); up from 32.9% in 2021.
- In 2022, 21,848,005 antimicrobial prescriptions were supplied under the PBS and RPBS, a 9.6% increase compared with 2021. This was still 18.1% below the volume of antimicrobials dispensed in 2019 (*n* = 26,669,561) before the COVID-19 pandemic.
- The average number of antibacterial prescriptions in participating MedicineInsight practices more than halved from 16 per 100 general practitioner (GP) visits in 2019 to 7 per 100 GP visits in 2020 and 2021.

continues

- Antibacterials were prescribed at a lower rate in telehealth consultations compared with face-to-face consultations in participating MedicineInsight practices in 2020 and 2021.
- Private (non-PBS and non-RPBS) prescriptions for antibacterials more than doubled from 2.5% in 2015 to 5.3% in 2021 in participating MedicineInsight practices.
- Prescribing rates for respiratory-related illnesses in participating MedicineInsight practices were higher than expected as antimicrobials are rarely required in respiratory illnesses that are usually viral, but showed improvement in appropriateness; for example, only 4.9% of cefalexin prescriptions were for respiratory-related conditions in 2020 and 2021.
- In 2022, prescribing rates for urinary tract infections (UTIs) and acute otitis media remained high while appropriateness of prescribing for these conditions remained low in participating MedicineInsight practices.

Community: residential aged care

- In 2021, the Aged Care National Antimicrobial Prescribing Survey (Aged Care NAPS) data showed that on the survey day 13.7% of residents were receiving antimicrobials, there was a steady increase from 2017 to 2021 in the prevalence of residents prescribed one or more antimicrobials (from 9.2% to 13.7%), and 3.1% had signs and/or symptoms of a suspected infection.
- Prolonged antimicrobial usage (more than six months) was observed for 42.1% of prescriptions, which is rarely recommended.
- Just over one-third (35.1%) of antimicrobials prescribed were for pro-re-nata (as required or PRN) administration, which is inconsistent with guidelines.
- Around one-fifth (22.3%) of all antimicrobials prescribed were for prophylactic use, which is recommended only in limited circumstances.

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

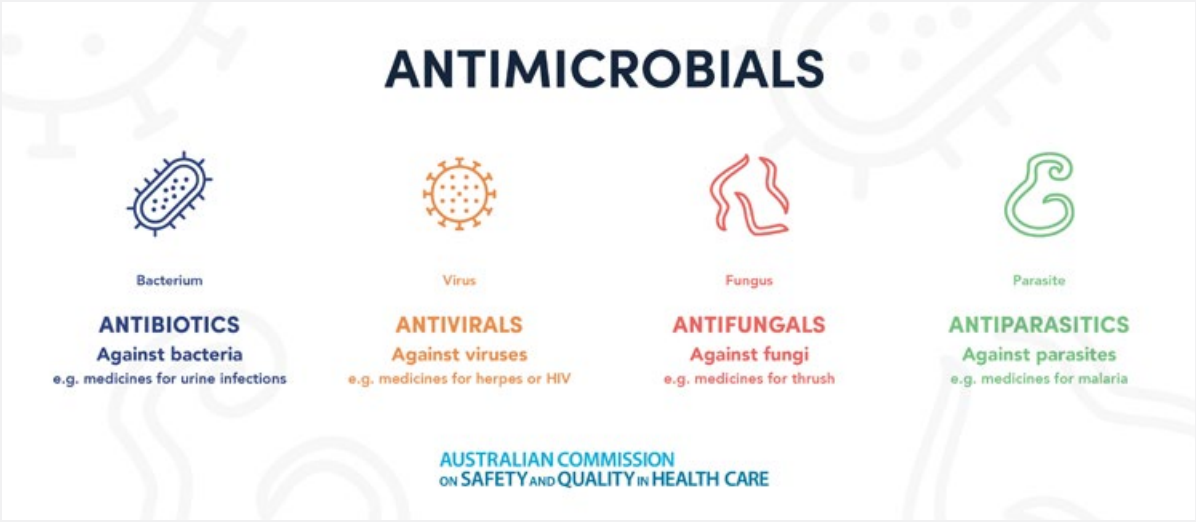
The terms antimicrobial, antibacterial and antibiotic can cause confusion. Antimicrobials include all antibiotics, antifungals, antivirals and antiparasitic agents. The terms antibacterial and antibiotic have the same meaning. In this chapter, the term antibiotic refers to antibacterials, except in relation to the Priority Antibacterial List for Antimicrobial Resistance Containment (Priority Antibacterial List)[1] and NAUSP data; and the term antimicrobial is used unless the data in discussion relate specifically to antibiotics.

This chapter provides an analysis of data on AU, including dispensing and appropriateness of prescribing in acute care (public and private hospitals) and in the community (primary care and aged care). It includes historical comparisons of data between and within states and territories, and comparisons of usage rates between hospital peer groups for selected antimicrobial classes.

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 and NAUSP data, the term antibiotic is used to refer to antibacterials; the term antimicrobial is used unless the data being discussed relate specifically to antibiotics.



3.1 Antimicrobial use in hospitals

Data for this chapter are sourced from NAUSP, which is conducted by SA Health, and the Hospital NAPS, which is conducted by the Royal Melbourne Hospital Guidance Group and the National Centre for Antimicrobial Stewardship (NCAS). Antibacterial usage is defined as the number of DDD per 1,000 OBD.

Care is required when interpreting NAUSP data where the World Health Organization (WHO) DDD does not accurately reflect the Australian setting. If routine doses used in the Australian setting are higher or lower than the WHO-assigned DDD, this may contribute to the usage rates being underestimated or overestimated.

Highlights of the analyses of data on the volume and appropriateness of AU from the Hospital NAPS, Surgical NAPS, Aged Care NAPS and NAUSP reports from 2020 and 2021 are included in this chapter.[2-7]

More information on the NAPS and NAUSP programs, and considerations for interpreting these data, can be found in Appendix 1.

Recent changes to the National Antimicrobial Utilisation Surveillance Program

In January 2021, NAUSP underwent a suite of upgrades to capture AU in more hospital settings. New denominator types were introduced to enable benchmarking in settings where OBD do not accurately measure hospital activity, such as in operating theatres (OT)/recovery and emergency departments (ED).

In summary, the changes introduced to NAUSP in 2021 include:

1. Expansion of data definitions to capture all antimicrobials, including agents used for the treatment of tuberculosis and malaria, and antimicrobial agents not registered in Australia
2. Introduction of alternate denominators for benchmarking usage in OT and ED, since ED presentations and OT case numbers are more appropriate denominators (compared to OBD) to benchmark usage between sites. The use of OT cases as a denominator for antimicrobial benchmarking in OTs enables day-only surgical facilities to participate in NAUSP, thereby allowing more relevant benchmarking between sites without having to interpret rates subject to proportional day surgery rates. The new denominators for calculating usage in these settings from January 2021 are:
    - ED usage reported relative to ED presentations
    - OT usage reported relative to the number of OT cases or procedures
3. Surveillance of antimicrobial use in sub-acute hospital settings and the inclusion of dedicated rehabilitation and psychiatric facilities. NAUSP portal functionality was expanded to enable contributors to report antimicrobial usage in non-acute settings including mental health, palliative care, long-term rehabilitation and long-stay aged care wards
4. Inclusion of Hospital in the Home (HITH) as a stand-alone data location
5. Intensive care unit and high dependency unit surveillance data were combined and are now reported as critical care use.

Information about the rationale for these changes is included in the 2021 NAUSP report.[4]

Total annual hospital usage rates

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

The annual total-hospital systemic antibacterial usage rate reported by NAUSP contributor hospitals decreased from 870.3 DDD per 1,000 OBD in 2017 to 862 DDD per 1,000 OBD in 2020, the last year of the previous data collection methodology (Table 3.2).

From 2021, the aggregate usage rate excludes usage in ED and OT settings. While there was an observed drop in the reported aggregate usage rate in acute care hospitals contributing to NAUSP in 2021, it is not possible to compare the 2021 rate with the rates previously reported due to the methodology changes.

Table 3.1: Hospitals registered to participate in NAUSP by state or territory, 2021

Hospital AIHW peer group	NSW and ACT*	Vic	Qld and NT*	SA	WA	Tas
Principal Referral	12	6	7	2	3	1
Public Acute Group A	21	13	13	3	5	2
Private Acute Group A	2	1	6	2	1	1
Public Acute Group B	16	7	7	4	4	1
Private Acute Group B	6	2	2	4	2	0
Public Acute Group C	28	2	9	9	14	0
Private Acute Group C	2	3	4	0	2	1
Public Acute Group D	7	0	0	6	0	0
Private Acute Group D	0	0	1	1	0	0
Women's/combined women's and children's	0	1	1	1	1	0
Very small hospitals	0	0	0	2	0	0
Unpeered hospitals†	2	3	1	0	1	0
Public rehabilitation hospitals	0	1	0	0	0	0
Other acute specialised hospitals	0	2	0	0	0	0
Mixed sub-acute/non-acute hospitals	0	2	1	0	0	0
Mixed day procedure hospitals	0	0	1	0	0	0
Total	**96**	**43**	**53**	**34**	**43**	**33**

AIHW = Australian Institute of Health and Welfare; NAUSP = National Antimicrobial Utilisation Surveillance Program
* Jurisdictions with only a small number of participating hospitals are grouped with a larger jurisdiction for benchmarking
† Unpeered hospitals are hospitals that have not been assigned a peer group by the AIHW
Note: This table shows the number of hospitals that are registered to participate and that have provided data to NAUSP. Not all 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.
Source: NAUSP[4]

Table 3.2: Annual total-hospital systemic antibacterial usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, 2017–2021

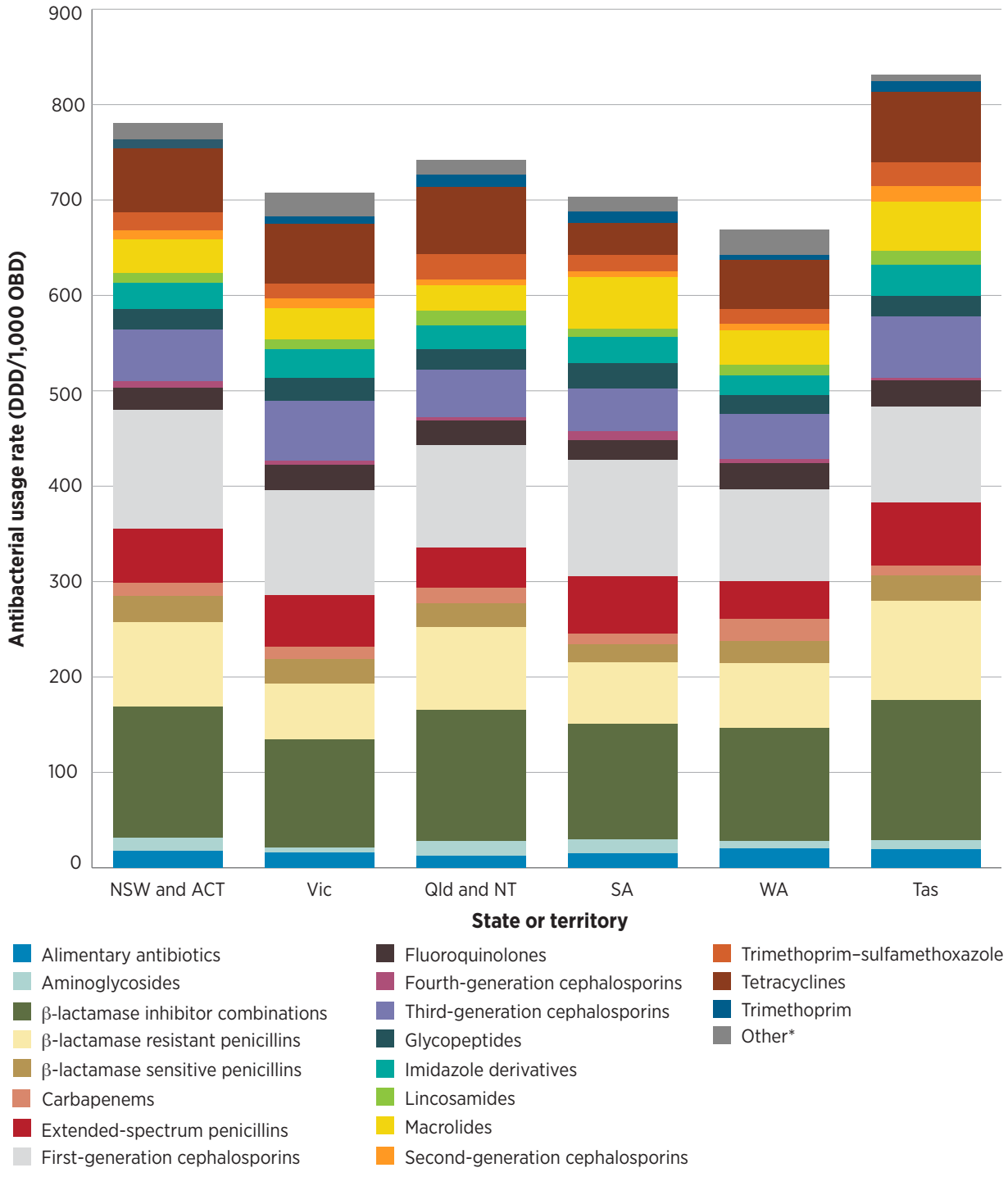
Year	2017 *n* = 162	2018 *n* = 177	2019 *n* = 183	2020 *n* = 193	2021 *n* = 200
Total	870.3	874	893.5	862	739.4

DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Notes:
1. 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.
2. Acute usage rate for 2021 excludes emergency department and operating theatre/recovery.
Source: NAUSP[4]

Hospital antibacterial usage rates by state and territory

Figure 3.1 illustrates total-hospital antibacterial use for NAUSP contributors nationally and by state and territory in 2021. Western Australia (WA) showed the highest rate of usage for the carbapenem class of antimicrobials. Consistent with previous years, the most prescribed oral antibacterials in NAUSP contributor hospitals were amoxicillin–clavulanic acid, doxycycline, cefalexin and amoxicillin.

Figure 3.1: Aggregate total-hospital antibacterial usage rates by class in NAUSP contributor hospitals, by state and territory, 2021



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
* Other = Antimycobacterial antibiotics, antibacterials for *Helicobacter pylori*, intermediate acting sulfonamides, monobactams, nitrofurans, nitroimidazole derivatives, other antibacterials and combinations, other cephalosporins and penems, polymyxins, steroids, streptogramins, streptomycins
Note: Acute usage rate excluding emergency department and operating theatre/recovery.
Source: NAUSP[4]

Priority Antibacterial List for Antimicrobial Resistance Containment

The Priority Antibacterial List[1] was developed by the Australian Commission on Safety and Quality in Health Care (the Commission) in 2020 as a tool to support antimicrobial stewardship (AMS) (Table 3.3). The Priority Antibacterial List aims to promote improved prescribing and reduce the total quantity of AU. It can be used for the analysis of AU in terms of preferred or optimal prescribing choices, and to support analyses of usage volume data. It may also be used for local AMS programs in hospital and community settings.

Using the Priority Antibacterial List provides additional information that complements usage volume data for trend analyses. For example, over time, the volume of use measured in DDD per 1,000 OBD can be constant, while the proportionate use of Review category antimicrobials may vary.

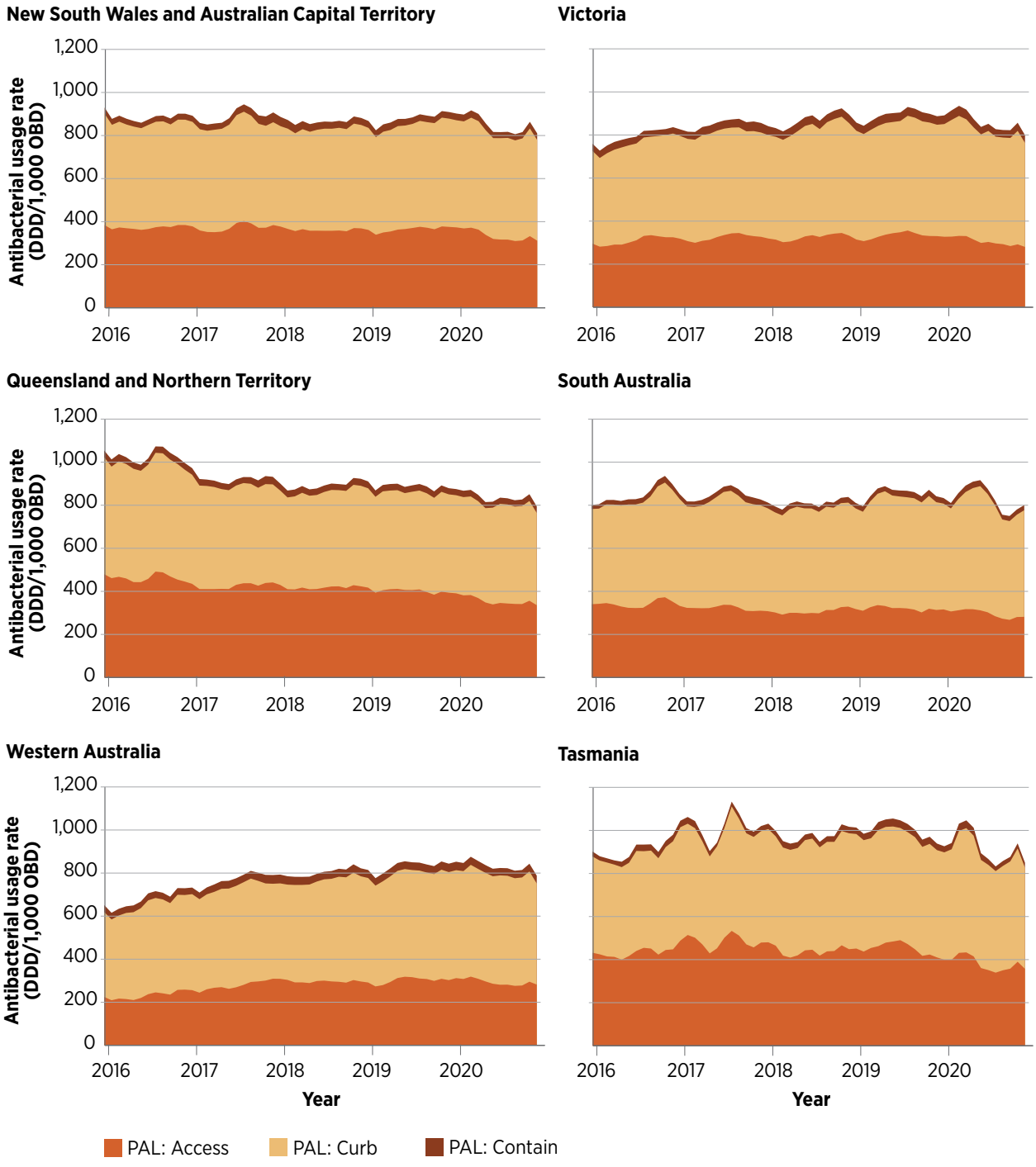
Figure 3.2 illustrates the trend in total-hospital antibacterial usage from 2016 to 2020 for the Priority Antibacterial List categories (Access, Curb, Contain) for NAUSP contributor hospitals across Australian states and territories. Total antibacterial usage decreased in 2020 in most states and territories, after an initial surge in distribution to wards in March and April at the start of the COVID-19 pandemic.

Table 3.3: Priority Antibacterial List categories

Category		Inclusion criteria
Access		• Antibacterials recommended as first-line treatment for common infections with a lower potential for AMR; and • Antibacterials not recommended as first-line treatment for common infections but with a lower AMR potential
Review	Curb	• Antibacterials recommended as first-line agents for common bacterial infections, despite a high AMR potential; and • Antibacterials not recommended as first-line treatment but with moderate to high AMR potential; and • Antibacterials only recommended as first-line for prophylaxis as opposed to treatment
	Contain	Antibacterials with high AMR potential that are not recommended as first-line options for common bacterial infections

AMR = antimicrobial resistance
Source: Priority Antibacterial List for Antimicrobial Resistance Containment[1]

Figure 3.2: Aggregate antibacterial usage rates (DDD/1,000 OBD) by Priority Antibacterial List category in NAUSP contributor hospitals, by state and territory, 2016–2020

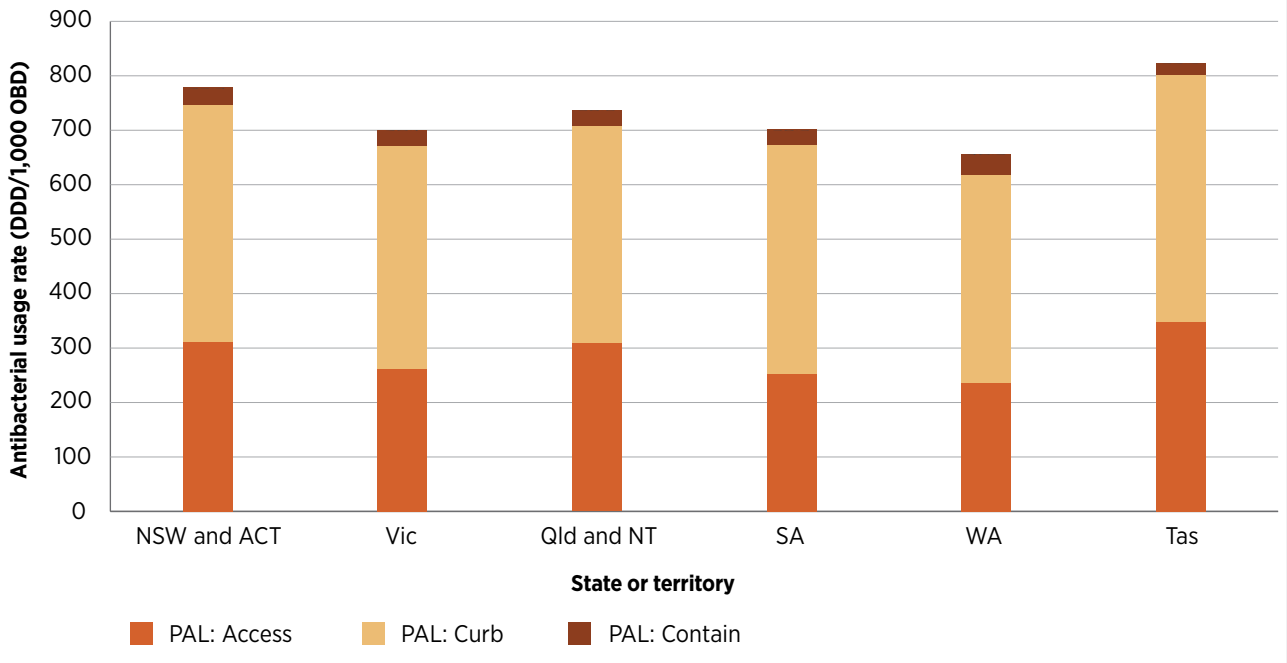


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day; PAL = Priority Antibacterial List
Source: NAUSP[3]

Figure 3.3 demonstrates the variation in AU by Priority Antibacterial List categories between states and territories in 2021.

As shown in Table 3.4, WA reported the highest proportion of use in the Contain category.

Figure 3.3: Acute hospital antibacterial usage rates by Priority Antibacterial List category in NAUSP contributor hospitals, by state and territory, 2021



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day; PAL = Priority Antibacterial List
Note: Acute usage rate excluding emergency department and operating theatre/recovery.
Source: NAUSP[4]

Table 3.4: Acute hospital antibacterial usage rates by DDD/1,000 OBD and percentage by Priority Antibacterial List category in NAUSP contributor hospitals, by state and territory, 2021

	Usage rate (DDD/1,000 OBD) (%)					
PAL category	**NSW and ACT***	**Vic**	**Qld and NT***	**SA**	**WA**	**Tas**
Access	311.3 (40%)	261.7 (37.4%)	308.3 (41.8%)	251.9 (35.9%)	235.4 (35.8%)	347.9 (42.3%)
Curb	434.6 (55.8%)	408.8 (58.4%)	400.2 (54.3%)	420.8 (60%)	381.6 (58.1%)	451.8 (54.9%)
Contain	32.4 (4.2%)	30.1 (4.3%)	28.5 (3.9%)	28.2 (4%)	40.2 (6.1%)	23.3 (2.8%)

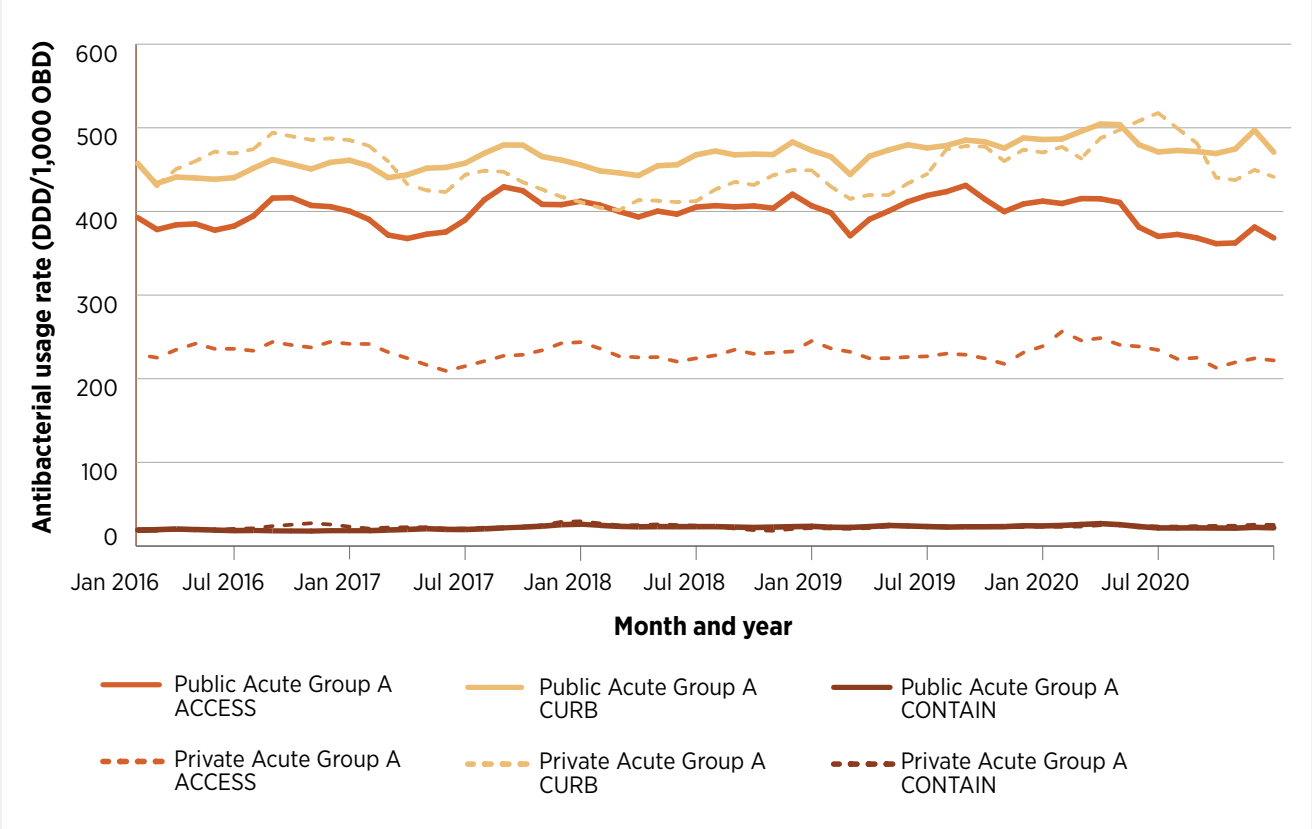
DDD = defined daily dose; PAL = Priority Antibacterial List; OBD = occupied bed day
Note: Acute usage rate excluding emergency department and operating theatre/recovery.

Hospital antibacterial use by peer group

Figures 3.4–3.6 show antibacterial usage rates according to the Priority Antibacterial List categories (Access, Curb and Contain) for NAUSP contributor hospitals for each Australian Institute of Health and Welfare (AIHW) hospital peer group.[8]

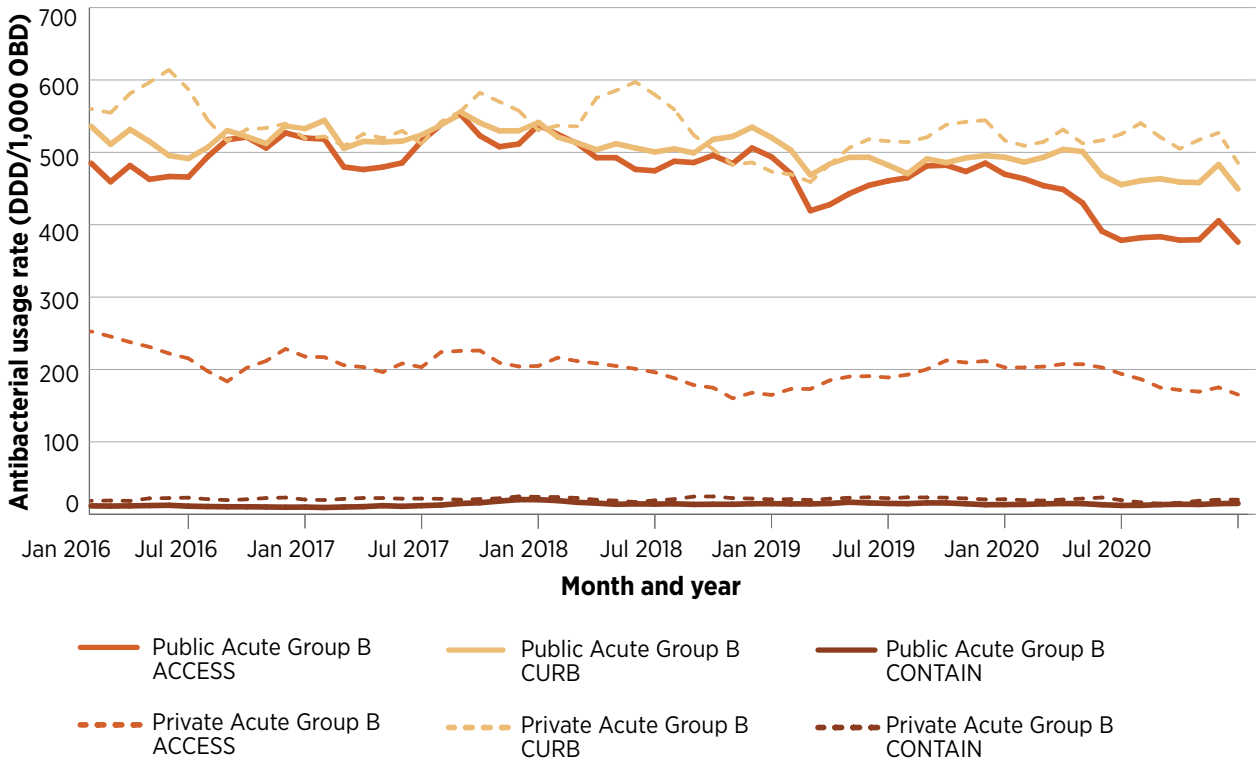
Figure 3.4 shows that the usage of Access category antibacterials in Private Acute Group A hospitals was almost half the rate of peer group public hospitals. On average, the monthly Access usage in Private Acute Group A hospitals was 231.2 DDD/1,000 OBD between 2016 and 2020 compared with 397.6 DDD/1,000 OBD in peer public hospitals. For public hospitals, Access usage was (on average) 44.9% of the total monthly antibacterial usage, compared with 32.8% in private hospitals.

Figure 3.4: Aggregate total-hospital antibacterial usage by Priority Antibacterial List category in NAUSP contributor Public Acute Group A and Private Acute Group A hospitals, 2016–2020



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day; PAL = Priority Antibacterial List
Source: NAUSP[3]

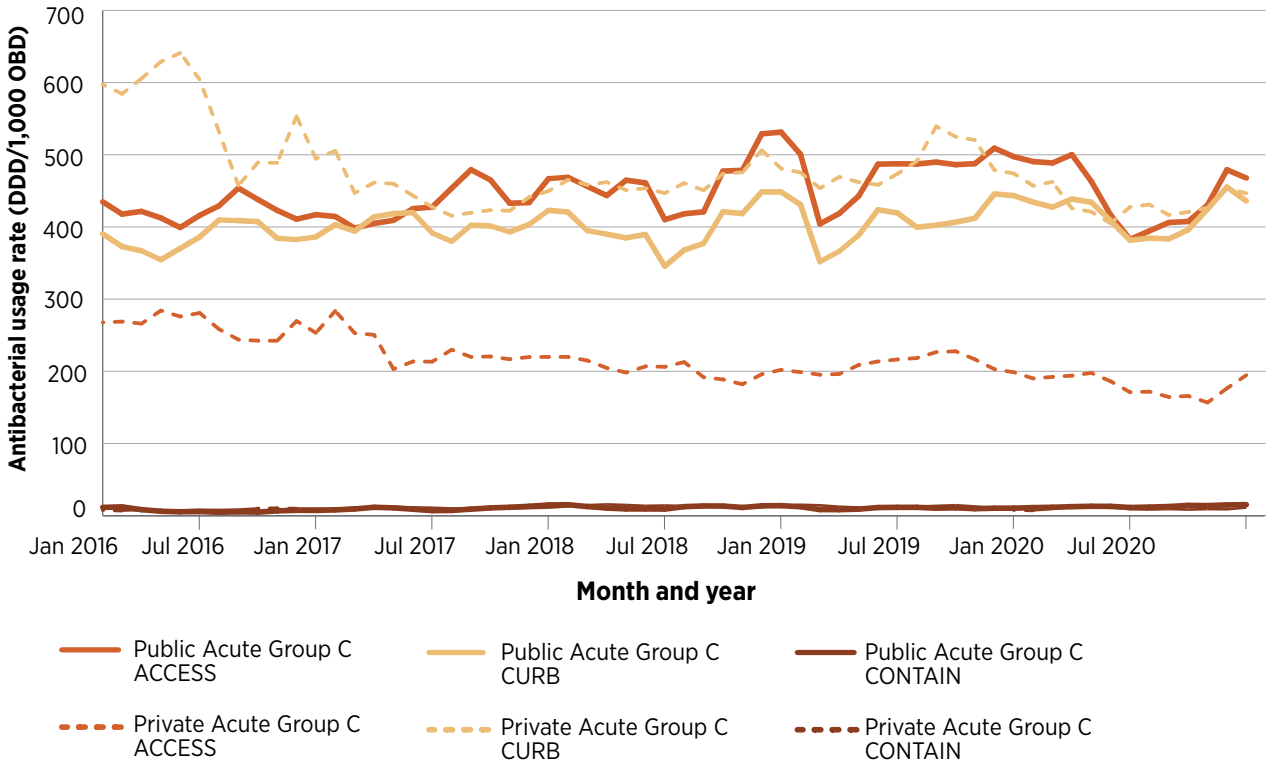
Figure 3.5: Aggregate total-hospital antibacterial usage by Priority Antibacterial List category in NAUSP contributor Public Acute Group B and Private Acute Group B hospitals, 2016–2020



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Source: NAUSP[3]

In 2020, the overall antibacterial usage in Public Acute Group B hospitals (893.2 DDD/1,000 OBD) was higher than in Private Group B hospitals (724.6 DDD/1,000 OBD). The proportion of usage of Access category antibacterials in Public Group B hospitals was almost double that of usage of Private Group B hospitals (Figure 3.5).

Figure 3.6: Aggregate total-hospital antibacterial usage by Priority Antibacterial List category in NAUSP contributor Public Acute Group C and Private Acute Group C hospitals, 2016–2020



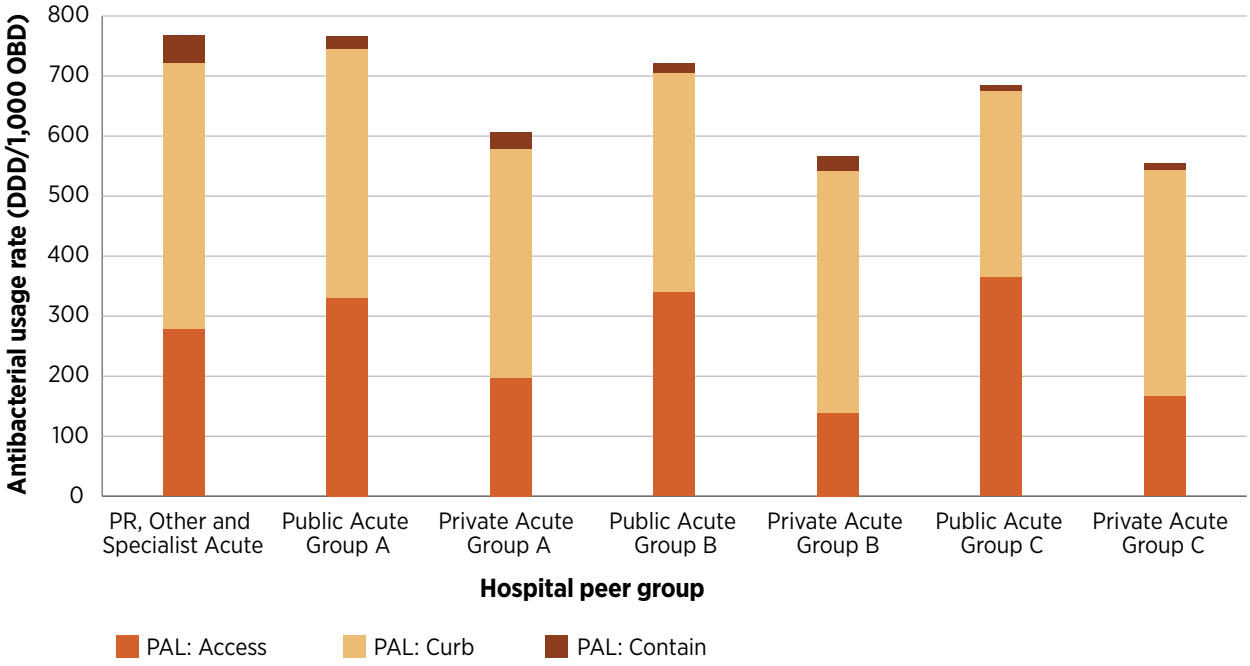
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Source: NAUSP[3]

Similar to Acute Group A and B hospitals, the monthly usage rate for Access antibacterials in Private Acute Group C hospitals was approximately half the Access usage rate observed in Public Acute Group C hospitals (Figure 3.6).

Although usage rates for Access and Curb agents were similar in Public Acute Group A, B and C hospitals over the period 2016–2020, there was a disproportionate use of Curb agents compared with Access agents in Private Acute Group A, B and C hospitals. This was most likely due to the higher rates of surgical procedures requiring cefazolin for prophylaxis in the private sector. Cefazolin is a Curb agent which is often a first-line choice for surgical prophylaxis.

In 2016–2020, there was a disproportionate use of Curb agents in Private Acute Group A, B and C hospitals compared with Access agents, most likely due to the higher rates of surgical procedures requiring cefazolin for prophylaxis in the private sector.

Figure 3.7: Aggregate acute antibacterial usage rates (DDD/1,000 OBD) by Priority Antibacterial List category in NAUSP contributor hospitals, by hospital peer group, 2021

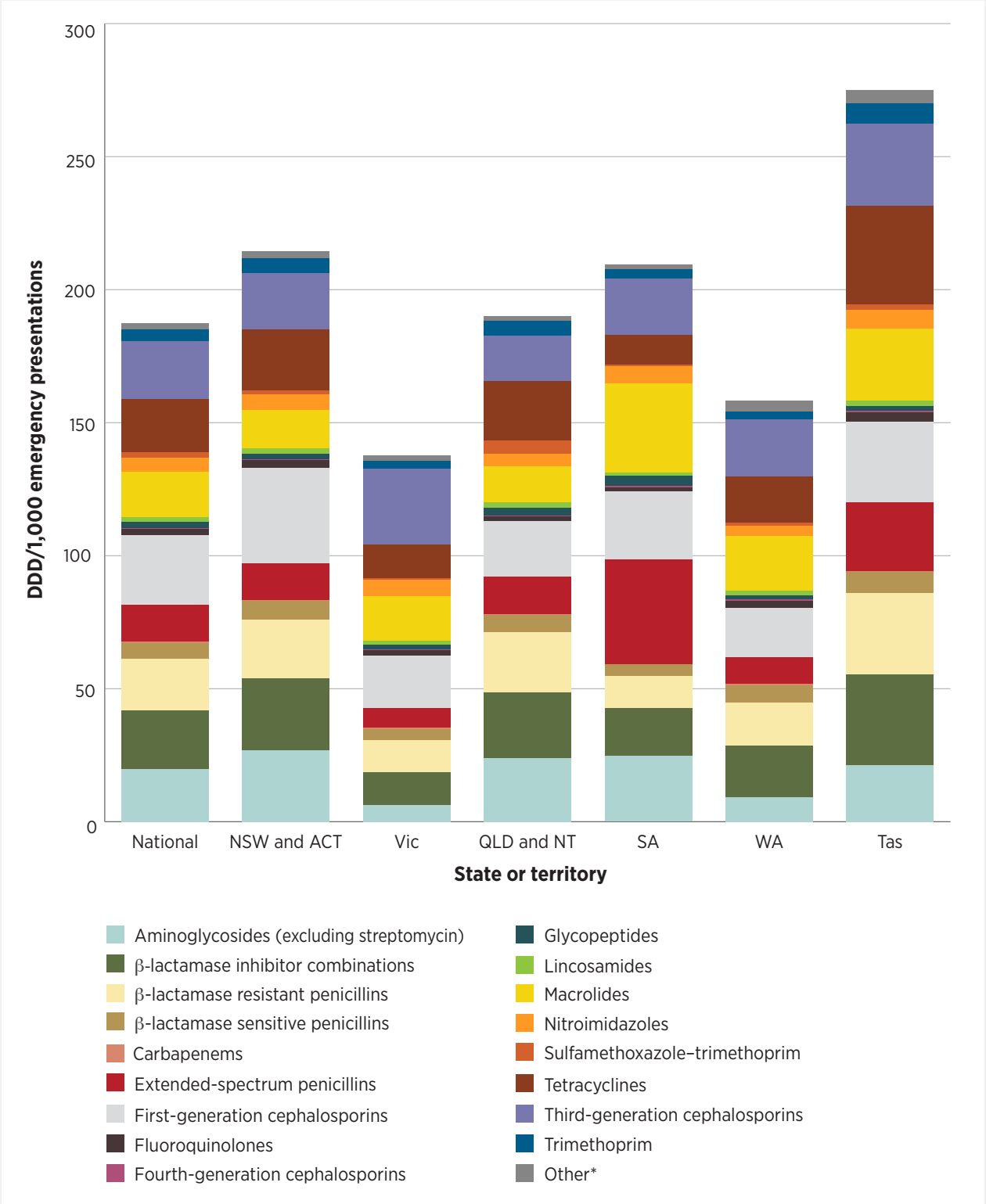


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day; PAL = Priority Antibacterial List; PR = Principal Referral
Note: Acute usage rate excluding emergency department and operating theatre/recovery.
Source: NAUSP[4]

Figure 3.7 illustrates the comparative annual acute-care usage rates by Priority Antibacterial List category across all hospital peer groups.[8] Principal Referral hospitals demonstrated the highest usage rates for the Contain category. This could be explained by the casemix and higher acuity of patients in these settings. Patients requiring treatment with last-line antibacterials are more commonly treated in or referred to larger facilities due to the complexity of their care requirements.

There was substantial variation in ED usage and the classes of antibacterials used between states and territories; usage in Tasmania (the highest) was almost double that of Victoria (the lowest) (Figure 3.8). Differences in distribution practices in this setting may account for some of this variation between states and territories. For example, ED stock may be used as an after-hours supply when the pharmacy is closed, some sites do not label pre-packs for outpatient use and therefore cannot distinguish inpatient from outpatient use, and some sites distribute stock for hospital-in-the-home from ED.

Figure 3.8: Aggregate emergency department antibacterial usage rates (DDD/1,000 emergency presentations) by class in NAUSP contributor hospitals, by state and territory, 2021



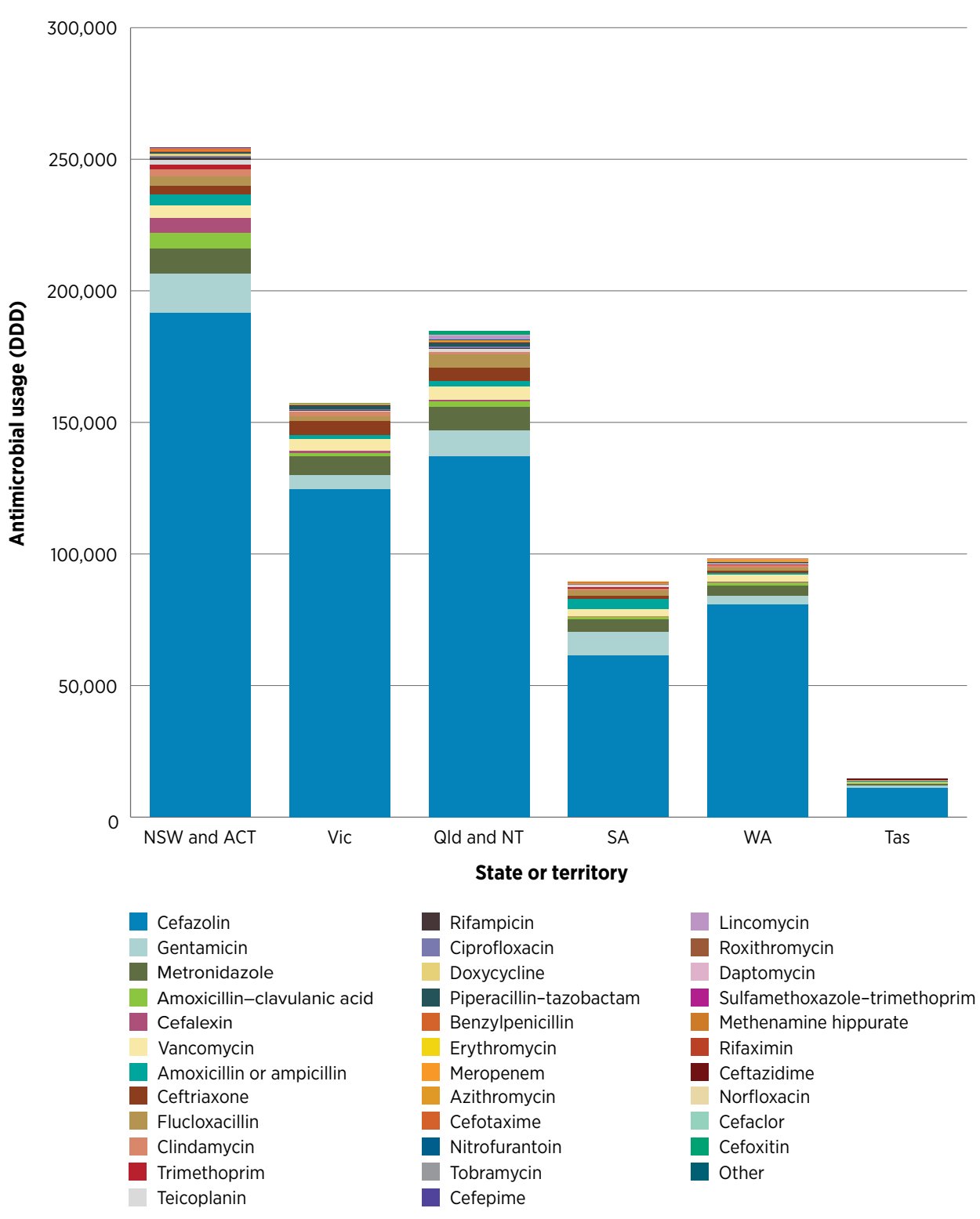
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program
* Other = Combination products for the eradication of *Helicobacter pylori*, cycloserine, rifampicin, rifabutin, monobactams, nitrofurans, polymyxins, sodium fusidate, streptogramins, other cephalosporins, fosfomycin, linezolid, daptomycin, tedizolid
Source: NAUSP[4]

Most common antimicrobials used in operating theatre and recovery

In Australian hospital OT settings in 2021, the most commonly used antimicrobials by volume (DDD) were cefazolin (75.9%), followed by gentamicin (5.4%) and metronidazole (4.4%) (Figures 3.9A and 3.9B). Vancomycin was also in the top five most used antimicrobials in OT and recovery settings.

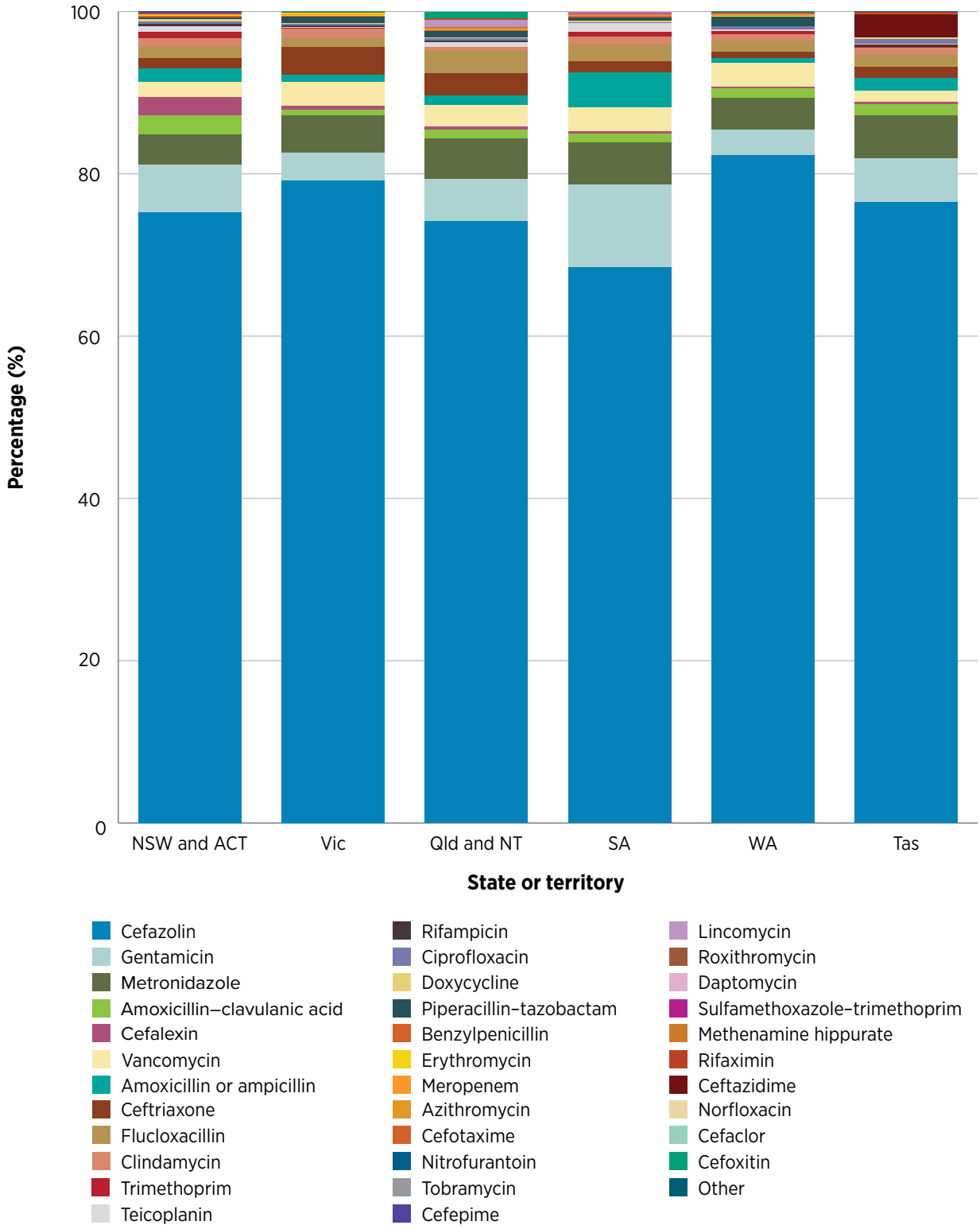
A high proportion of cefazolin usage is expected because it is used for prophylaxis for many surgical procedures. The total volume of use of antimicrobials across the states and territories reflects the distribution of the population and surgical activity. The volume of use of vancomycin is likely to be under-reported in 2021 OT data, as the prophylactic infusion of vancomycin may be commenced on the ward in some hospitals.

Figure 3.9A: Usage (DDD) of antibacterials in operating theatres/recovery in NAUSP contributor hospitals, 2021



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program
Source: NAUSP

Figure 3.9B: Proportionate usage (DDD) of antibacterials in operating theatres/recovery in NAUSP contributor hospitals, 2021

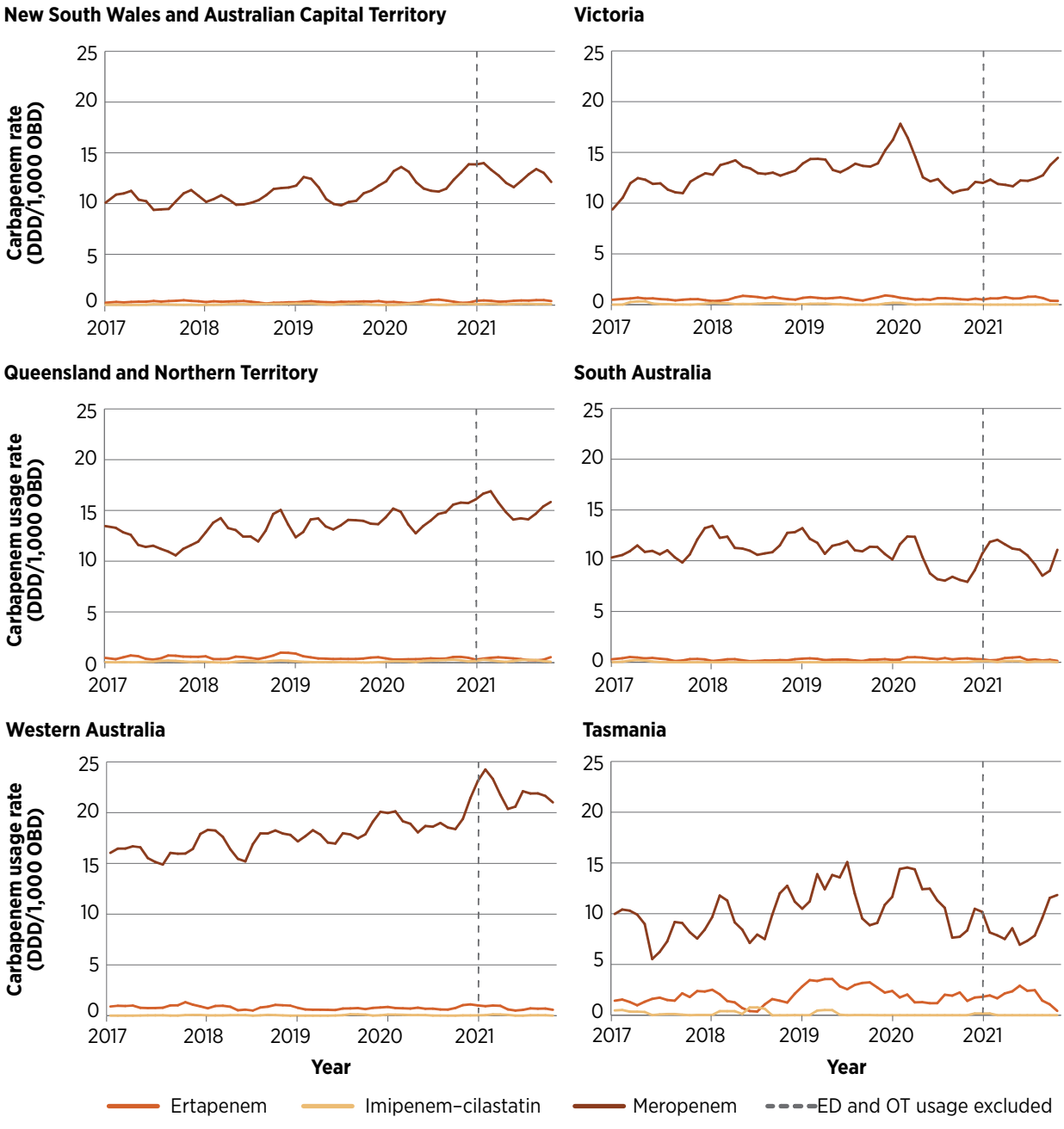


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program
Source: NAUSP[4]

Carbapenem usage

Carbapenem usage is increasing globally due to the spread of extended-spectrum β-lactamase-producing bacteria that are resistant to most other antibacterials, and this remains an AMR concern.[9] Figure 3.10 shows the carbapenem usage rates in NAUSP contributor hospitals by state and territory.

Figure 3.10: Carbapenem usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2017–2021 (3-month moving average)



DDD = defined daily dose; ED = emergency department; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day; OT = operating theatre/recovery
Note: Data for ED and OT are not included in Figure 3.10 after January 2021 as marked.
Source: NAUSP[4]

In 2021, the average monthly meropenem usage rate in NAUSP contributor hospitals ranged from 9 DDD/1,000 OBD in Tasmania to 22 DDD/1,000 OBD in WA. Meropenem usage has gradually increased across most states and territories since 2017.

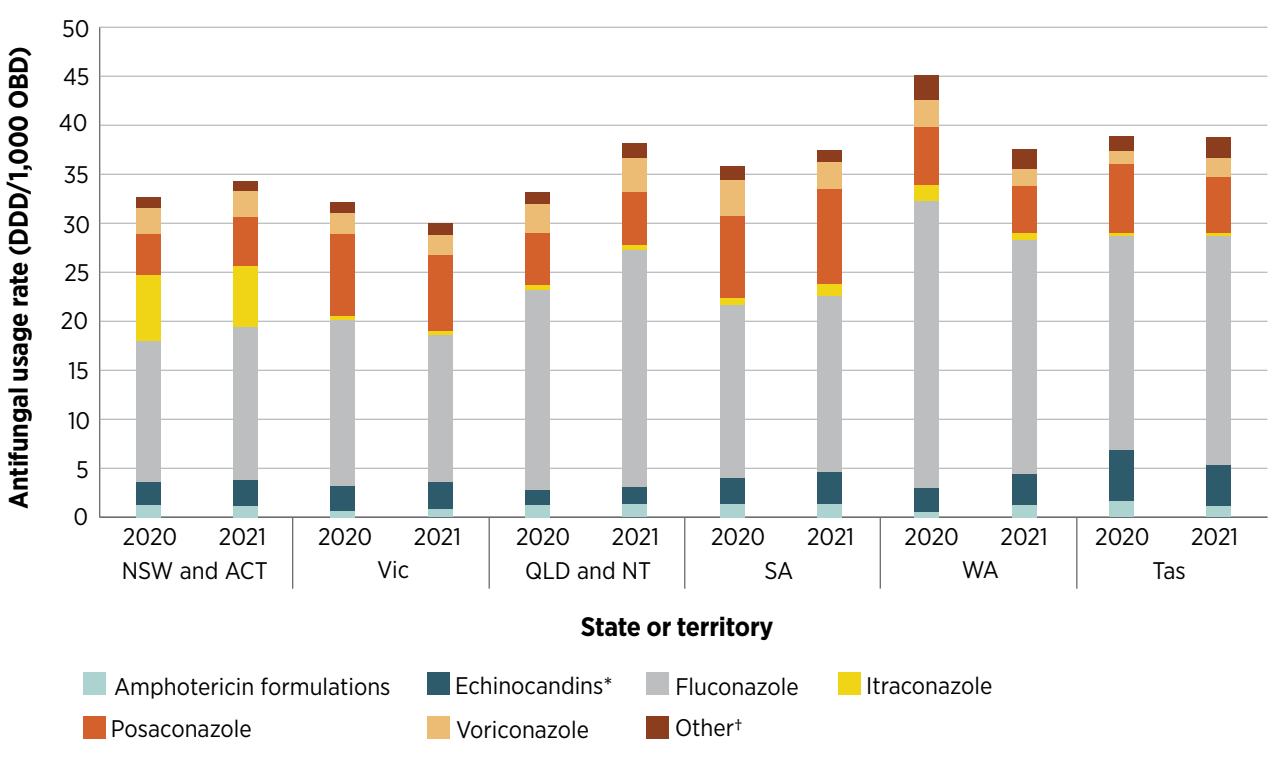
Antifungal usage

Systemic antifungal usage rates increased in 2021 compared with 2020 in New South Wales (NSW) and the Australian Capital Territory (ACT) (5%), Queensland and the Northern Territory (NT) (13.2%) and in South Australia (SA) (4.3%). In other states, a decrease in annual usage was reported (Figure 3.11).

There continue to be notable differences in the prescribing of antifungal agents between the states and territories. In 2021, triazole antifungals (fluconazole, itraconazole, posaconazole and voriconazole) accounted for 85.6% of systemic antifungals used in NAUSP contributor hospitals. Fluconazole use accounted for more than half of all antifungal use in these hospitals, and posaconazole usage increased in the ACT and NSW, the NT and Queensland, and SA.

In 2020 and 2021, antifungal usage rates were slightly lower in Victoria (decrease of 6.7%) and WA (decrease of 16.7%) and slightly higher in the NT and Queensland (increase of 15.2%) and SA (increase of 4.5%). In NSW and the ACT, itraconazole use was substantially higher than in other states and territories.

Figure 3.11: Antifungal usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2020–2021



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
* Echinocandins = anidulafungin, caspofungin and micafungin
† Other = flucytosine, griseofulvin, isavuconazole, ketoconazole and terbinafine
Note: Acute usage rate for 2021 excludes emergency department and operating theatre/recovery.
Source: NAUSP[4]

3.2 Appropriateness of prescribing in Australian hospitals

Australian hospitals undertake targeted surveillance of the appropriateness of antimicrobial prescribing using the Hospital NAPS and the Surgical NAPS.

Quality Statement 6 of the AMS Clinical Care Standard requires that when a patient is prescribed an antimicrobial, the indication, active ingredient, dose, frequency, route of administration and intended duration or review plan are documented in the patient's healthcare record.[10] Accurate documentation of an antimicrobial's indication and review or stop date are vital measures to ensure that all clinicians treating a patient clearly understand the reasons for the antimicrobial prescription and when it should be reassessed or ceased

Participation in Hospital NAPS has almost tripled since 2013 across prescriptions, patients and facilities (Table 3.5). While participation in the Hospital NAPS is voluntary, representativeness across most hospital peer groups continued to be high in 2021, especially for large public hospitals. Therefore, the results can be presumed to be a true reflection of prescribing practices across Australian public hospitals.

Participation in Hospital NAPS has almost tripled since 2013 across prescriptions, patients and facilities, suggesting that these data are representative of hospitals across the country.

Appropriateness of prescribing was 74.5% across all peer groups in 2021, and has essentially remained static since 2015. It is important to note that there was considerable variation in appropriateness of antimicrobial prescribing across hospital peer groups (Figure 3.12). The quality of prescribing is improving across all public hospital peer groups, presumably as AMS programs have matured and AMS principles have become embedded into routine practice since 2015[13], in association with the implementation of the National Safety and Quality Health Service Standards.

Overall, documentation of indication was 85.7% in 2021 (Table 3.6). In public hospitals, the indication documentation rate was 89.9%, compared with 68.9% in private hospitals.

Overall documentation of review or stop date was 50.8% in 2021 (Table 3.6). In public hospitals, documentation of review or stop date was 49.5%, compared with 56.3% in private hospitals.

The following long-term improvements in only two key indicators of appropriateness of antimicrobial prescribing monitored by the Hospital NAPS were observed in 2021:

- Improvement in the documentation of indication from 70.5% in 2013 to 85.7% in 2021
- Improvement in the documentation of antimicrobial review or stop date from 34.8% in 2015 (when this indicator was first reported) to 50.8% in 2021.

Appropriateness of prescribing was 74.5% across all peer groups in 2021. Since 2013, appropriateness has improved in some measures – for example, documentation of review or stop date.

Conversely, appropriateness decreased across all private hospital peer groups between 2013 and 2021 (Figure 3.13). This is likely due to increasing private hospital participation each year and the tendency for prescribing quality to be lower in the first years of conducting the Hospital NAPS audit, as it takes time for hospitals to implement initiatives to improve prescribing.

Table 3.5: Participation in Hospital NAPS, 2013–2021

Year	Prescriptions (*n*)	Patients (*n*)	Facilities (*n*)
2013	11,645	7,299	137
2014	19,750	12,526	232
2015	26,167	16,993	301
2016	25,530	16,949	326
2017	26,950	17,810	319
2018	27,372	18,336	327
2019	31,454	20,983	378
2020	31,263	21,495	409
2021	29,305	20,473	407

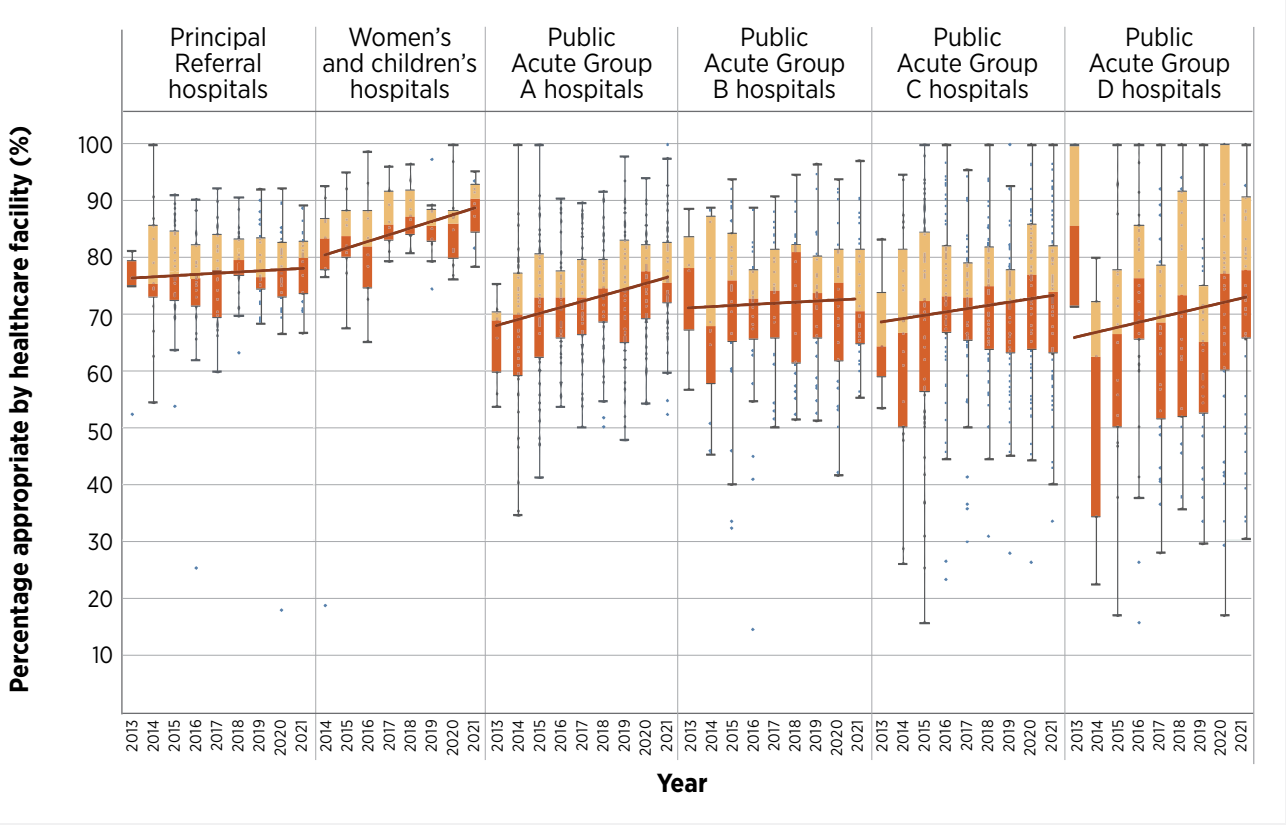
NAPS = National Antimicrobial Prescribing Survey
Sources: Hospital NAPS 2021 report, Hospital NAPS 2020 report and AURA 2021 report[2,6,11]

Table 3.6: Hospital NAPS key indicators for assessable prescriptions, 2017–2021

Key indicator	Percentage of total prescriptions (%)				
	2017	2018	2019	2020	2021
Indication documented in medical notes (best practice >95%)	77.6%	80%	84.2%	84.6%	85.7%
Review or stop date documented (best practice >95%)	40.7%	45.1%	48.1%	51.8%	50.8%
Compliant with *Therapeutic Guidelines: Antibiotic* or local guidelines*	67.4%	67.6%	65.5%	67.1%	67.5%
Appropriate (optimal and adequate)†	76.6%	77.8%	75.8%	77.1%	77.2%

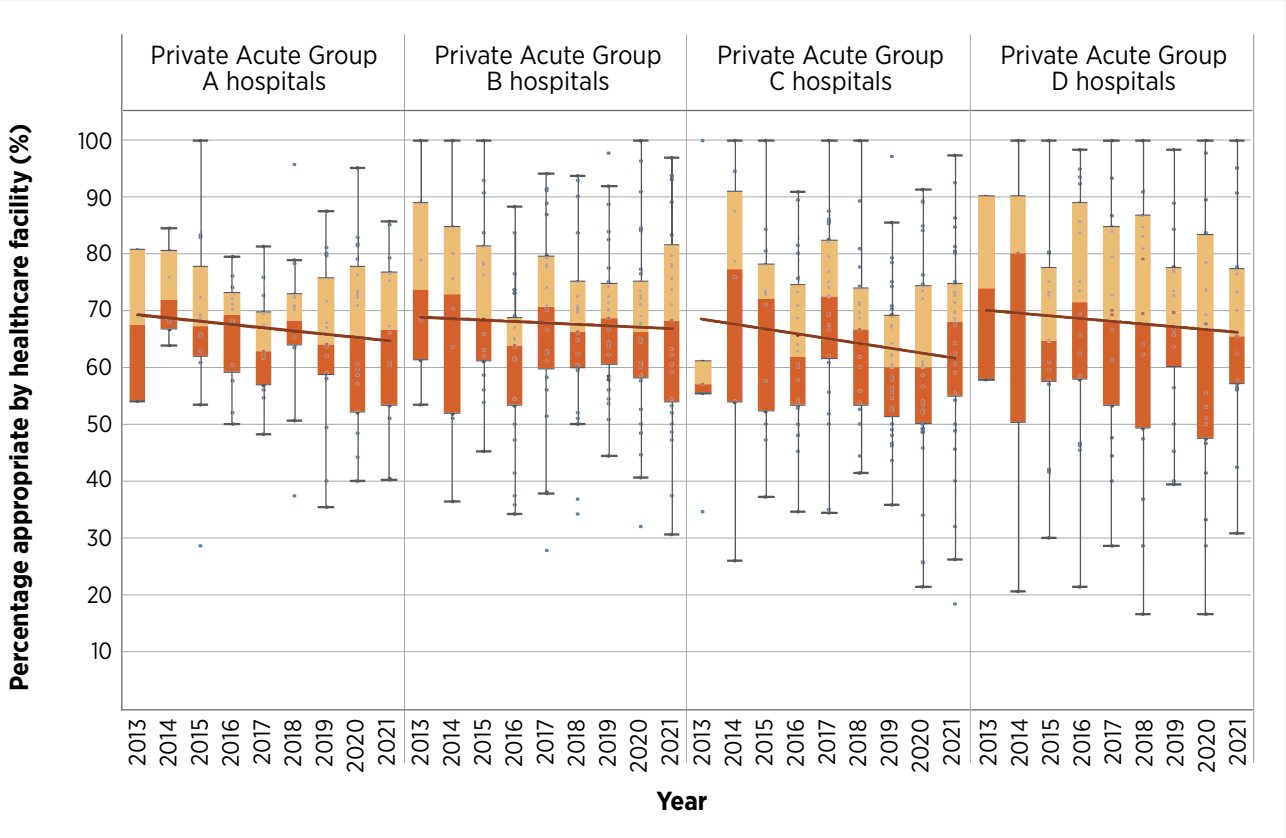
NAPS = National Antimicrobial Prescribing Survey
* Aggregate of Compliant with *Therapeutic Guidelines: Antibiotic*[12] and Compliant with Local Guidelines. Excludes Directed Therapy, Not Available and Not Assessable
† Aggregate of Optimal and Adequate. Excludes Not Assessable
Sources: Hospital NAPS 2021 report, Hospital NAPS 2020 report and AURA 2021 report[2,6,11]

Figure 3.12: Appropriateness of antimicrobial prescribing across public healthcare facilities in the Hospital NAPS, 2013–2021



NAPS = National Antimicrobial Prescribing Survey
Source: Hospital NAPS 2021[2]

Figure 3.13: Appropriateness of antimicrobial prescribing by private healthcare facilities in the Hospital NAPS, 2013–2021



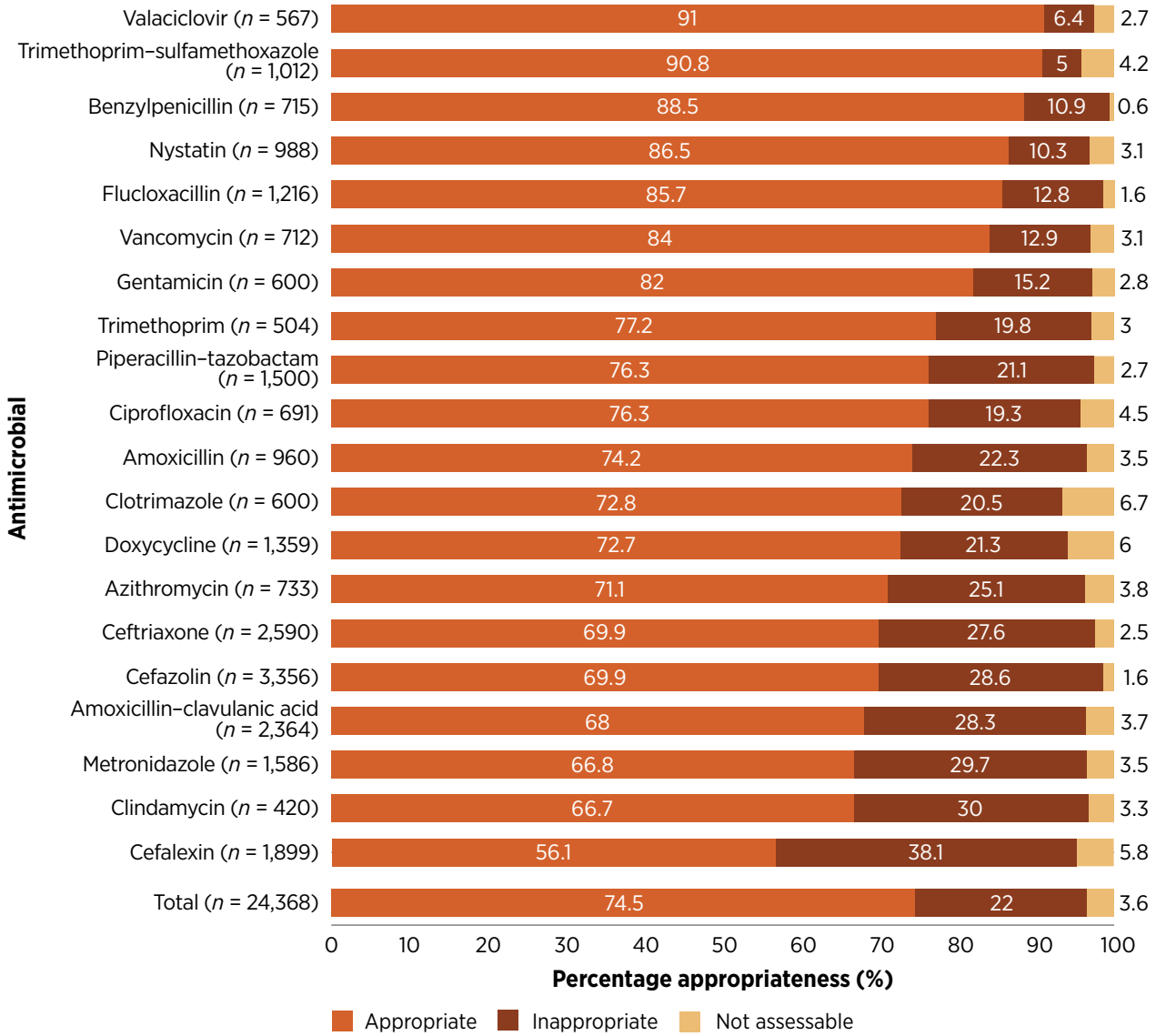
NAPS = National Antimicrobial Prescribing Survey
Source: Hospital NAPS 2021[2]

When a prescription was assessed as inappropriate for an indication where antimicrobials were required (*n* = 4,985), the most common reasons for inappropriateness were spectrum too broad (30.4%), incorrect duration (29.7%) and incorrect dose or frequency (27.9%).

The most common indications for antimicrobial use remained consistent from 2013 to 2021. The five antimicrobials with the highest rates of inappropriateness (cefazolin, ceftriaxone, amoxicillin–clavulanic acid, cefalexin and metronidazole) were also the most commonly prescribed antimicrobials (Figure 3.14).

In 2021, cefalexin continued to be the most inappropriately prescribed antimicrobial, with 38.1% of all prescriptions deemed to be inappropriate. The most common indication for cefalexin prescription was cystitis (31.1%).

Figure 3.14: Appropriateness for the 20 most commonly prescribed antimicrobials in Hospital NAPS contributor hospitals, 2021

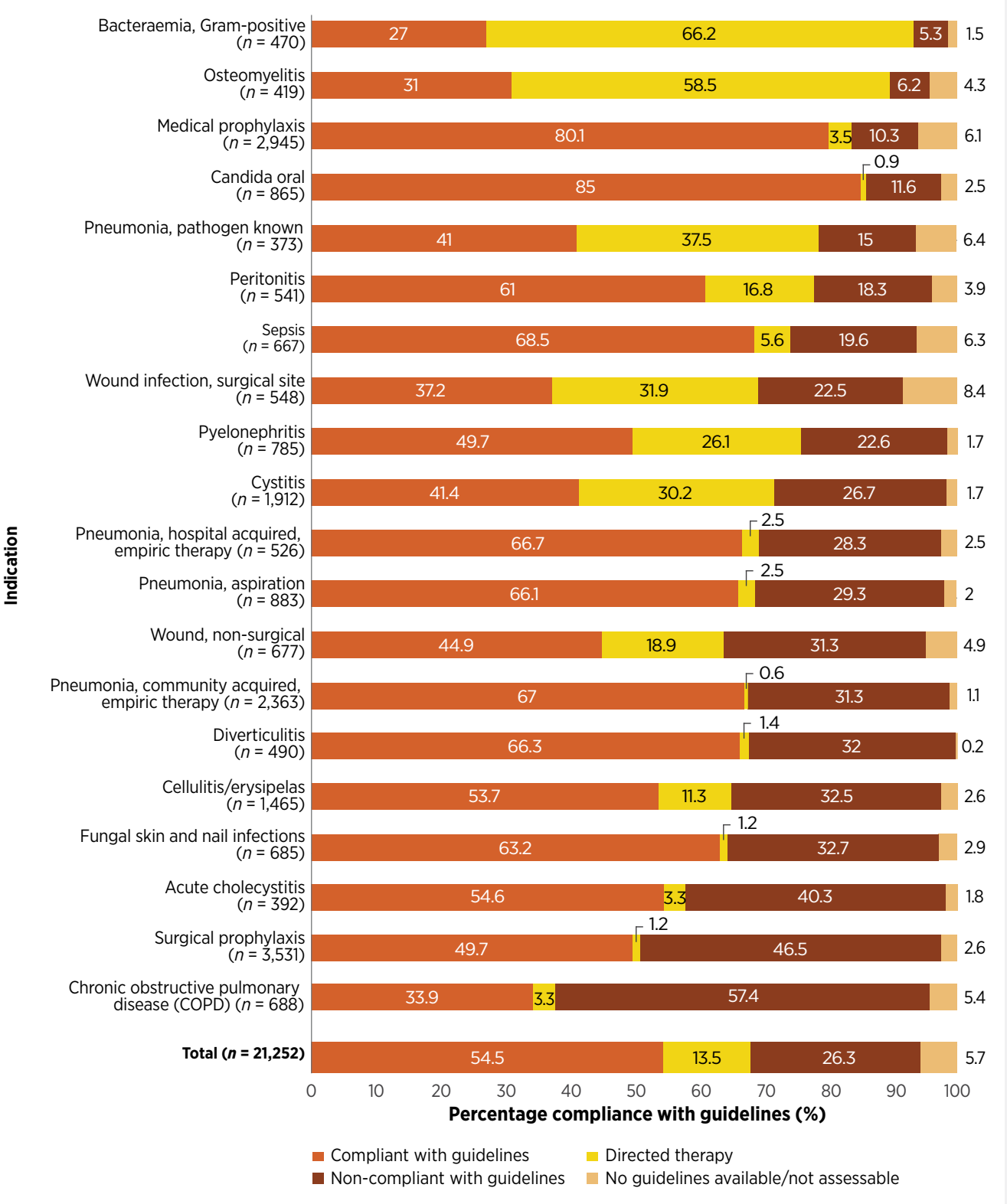


NAPS = National Antimicrobial Prescribing Survey
Source: Hospital NAPS 2021[2]

In 2021, of the 20 most common indications for prescribing, the indications with the highest rates of guideline noncompliance continued to be chronic obstructive pulmonary disease (COPD), surgical prophylaxis and acute cholecystitis (Figure 3.15). This distribution has remained unchanged for several years.

In 2021, cefalexin continued to be the most inappropriately prescribed antimicrobial in hospital, with 38.1% of all prescriptions deemed to be inappropriate, and it was most commonly prescribed for cystitis. The highest rates of inappropriate prescribing continued to be for COPD, surgical prophylaxis and acute cholecystitis, as per previous years.

Figure 3.15: Compliance with guidelines for the 20 indications most commonly requiring antimicrobials in Hospital NAPS contributors, 2021

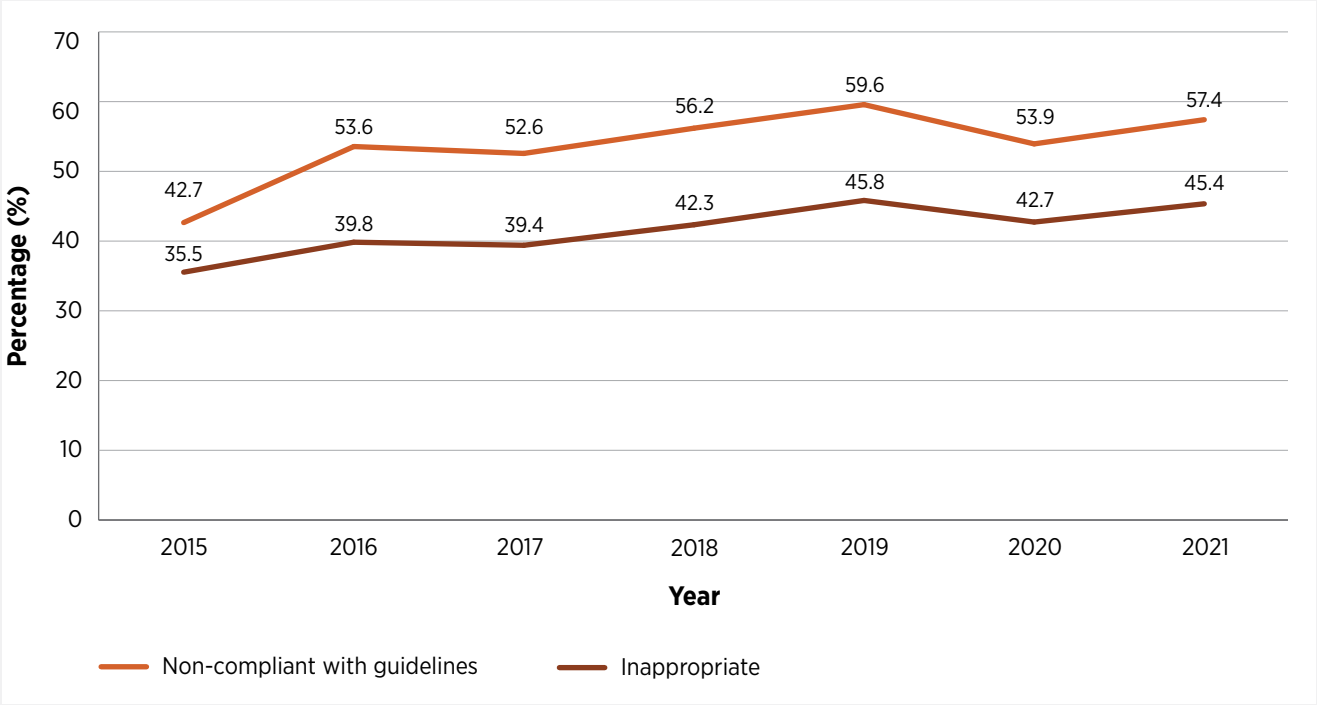


NAPS = National Antimicrobial Prescribing Survey
Note: Excludes prescriptions where the indication for prescribing was unknown (*n* = 635).
Source: Hospital NAPS 2021[2]

In 2021, high rates of non-compliance with guidelines for specific indications (particularly COPD) continued, with a rate of 26.3% (Figure 3.15). The highest rate of non-compliance of prescribing was for COPD at 57.4%.

From 2015 to 2021, the rates of non-compliance with guidelines and inappropriateness of prescriptions for COPD remained consistently high and followed an upward trend (Figure 3.16).

Figure 3.16: Inappropriateness of prescribing for chronic obstructive pulmonary disease (COPD), 2015–2021



Source: Hospital NAPS 2021[2]

Surgical NAPS terminology	
Procedural antimicrobial prophylaxis	Any antimicrobial administered either immediately before or during a procedure for purposes of prophylaxis.
Post-procedural antimicrobial prophylaxis	Any antimicrobial administered after a surgical procedure for the purposes of surgical prophylaxis.
Surgical episode	Any individual procedure or set of multiple procedures performed together during a session and the subsequent post-procedural care associated with the procedure(s).

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. In 2021, 181 hospitals (90 public and 91 private) submitted data on 10,927 surgical episodes, with 9,599 procedural and 5,634 post-procedural prescriptions to the Surgical NAPS database.

Procedural surgical prophylaxis

Key indicators for procedural surgical prophylaxis are documented at the time of antimicrobial administration and incision. Documentation facilitates the optimal administration time and concentration of antimicrobials at the time of incision to minimise the risk of surgical site infection. In 2021:

- 90.8% of initial procedural doses of antimicrobial prophylaxis had a documented administration time
- 76.6% of surgical incisions had the time of incision documented.

In 2021, 68.3% of procedural surgical prophylaxis prescriptions were compliant with *Therapeutic Guidelines: Antibiotic* or local guidelines (Figure 3.17). Where no procedural antimicrobials were prescribed (*n* = 2,610), guideline compliance was high (85.7%) with either *Therapeutic Guidelines: Antibiotic* or local guidelines.

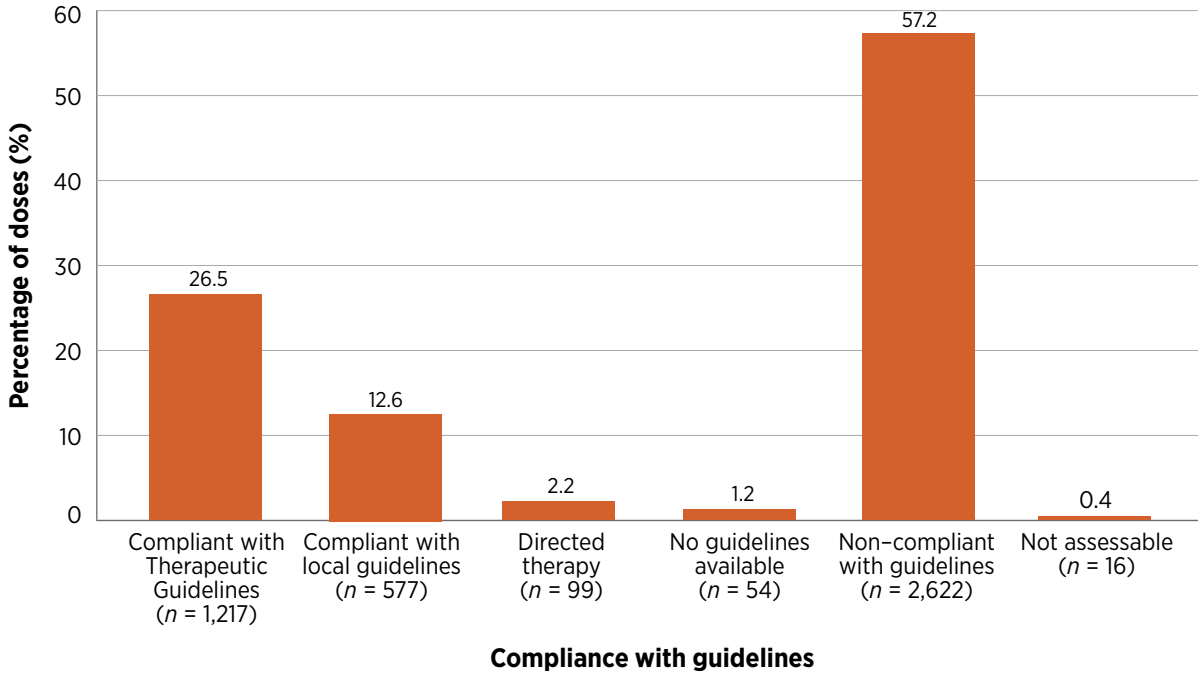
Figure 3.17: Percentage of procedural antimicrobial doses* that were compliant with guidelines, Therapeutic Guidelines† and local, Surgical NAPS contributor facilities, 2021

NAPS = National Antimicrobial Prescribing Survey
* *n* = 9,599 procedural antimicrobial doses
† Antibiotic Expert Group. *Therapeutic Guidelines: Antibiotic*. Version 16. Melbourne: Therapeutic Guidelines Limited; 2019. https://www.tg.org.au/
Source: Surgical NAPS 2021[5]

Post-procedural surgical prophylaxis

Compliance with national prescribing guidelines continues to be poor, generally due to prolonged durations of post-procedural oral, ocular and topical antimicrobial use. In 2021, 39.1% of post-procedural surgical prophylaxis prescriptions were compliant with *Therapeutic Guidelines: Antibiotic* or local guidelines (Figure 3.18). Where post-procedural antimicrobials were not prescribed, non-compliance with guidelines was infrequent (0.4%).

Figure 3.18: Percentage of post-procedural antimicrobial doses* that were compliant with guidelines, Therapeutic Guidelines† and local, Surgical NAPS contributor facilities, 2021



NAPS = National Antimicrobial Prescribing Survey
* *n* = 4,585 post-procedural antimicrobial doses
† Antibiotic Expert Group. *Therapeutic Guidelines: Antibiotic*. Version 16. Melbourne: Therapeutic Guidelines Limited; 2019.
Source: Surgical NAPS 2021[5]

In the 2021 Surgical NAPS, one-quarter (24.4%) of all prophylaxis for surgical episodes was assessed as inappropriate (Figure 3.19). Where procedural doses that were required were deemed inappropriate (*n* = 1,716), the most common reasons were incorrect timing (50.2%), spectrum too broad (22.4%) and incorrect dosing (19.5%).

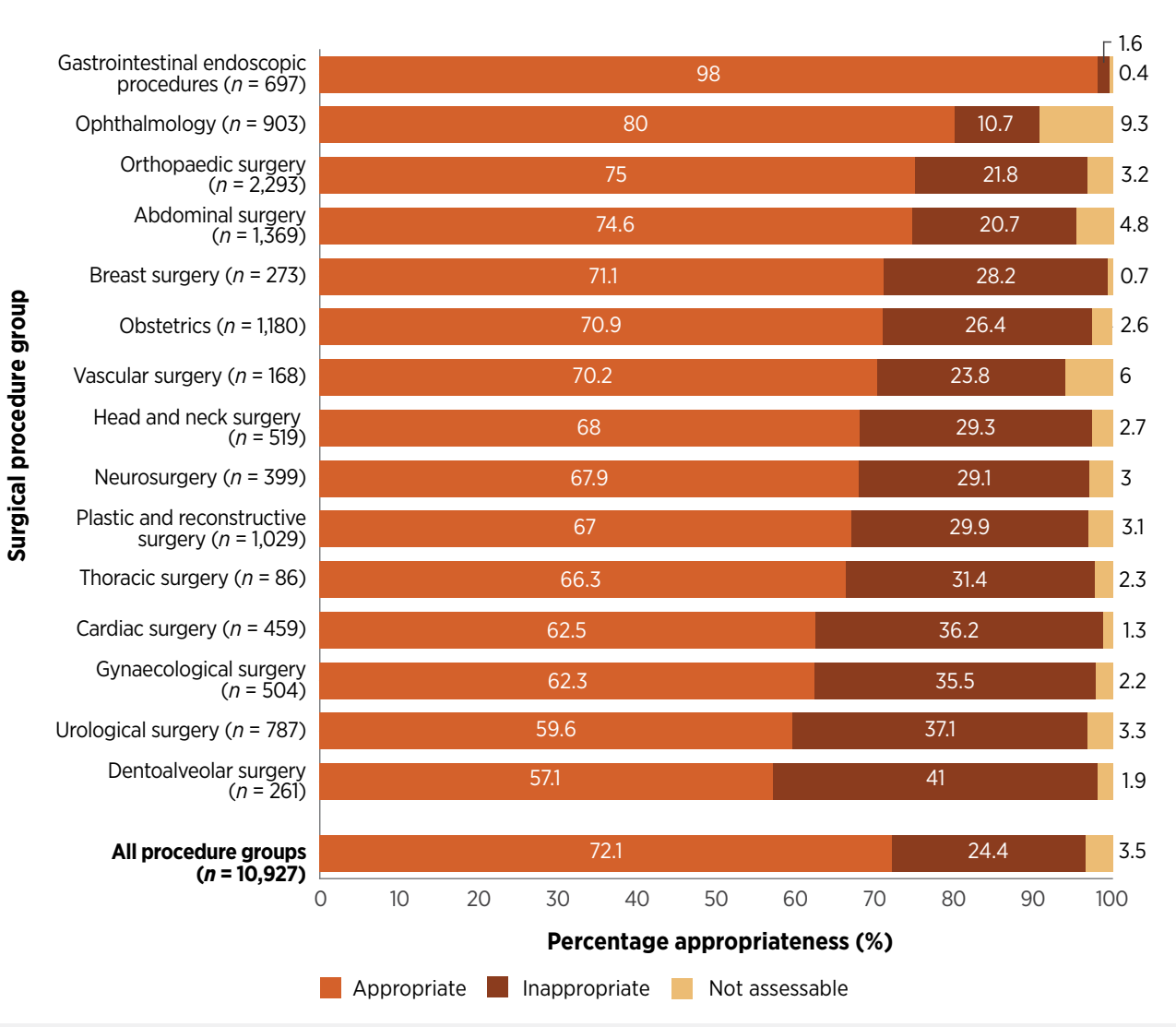
Where procedural surgical prophylaxis was required, it was not prescribed for 3.3% of episodes (*n* = 259/7,749).

Where procedural surgical prophylaxis was not required, it was prescribed for 28.8% of episodes (*n* = 951/3,302).

Almost one-quarter of all procedural prescribing for surgical episodes were assessed as inappropriate, including those procedures for which no antimicrobial was prescribed (Figure 3.19). Dentoalveolar surgery, urological surgery and cardiac surgery had the highest proportions of surgical episodes deemed inappropriate (41.0%, 37.1% and 36.2% respectively).

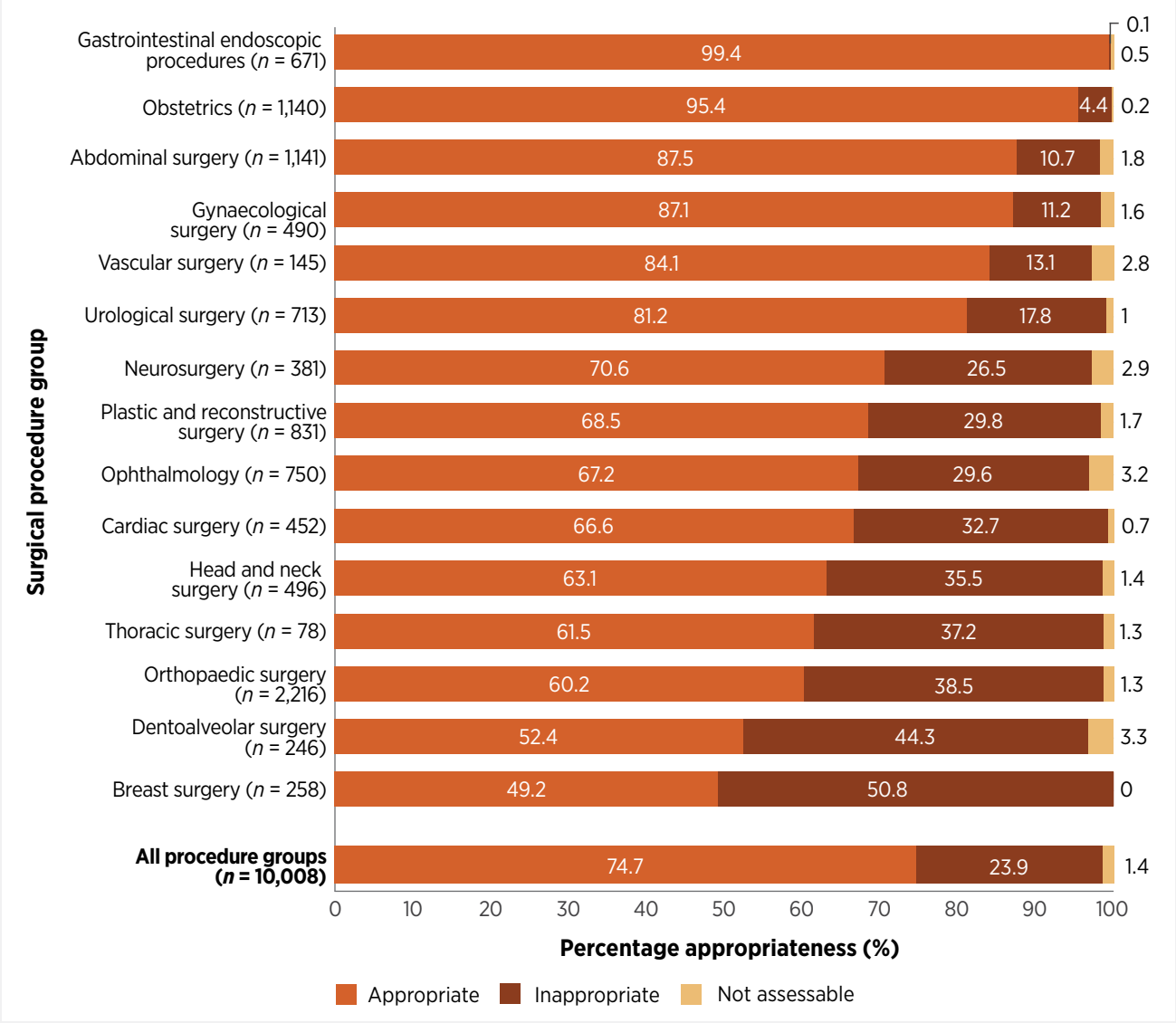
In 2021, one-quarter of all procedural prophylaxis was deemed inappropriate for surgical episodes. Over one-third of procedural prescribing was inappropriate for prophylaxis in four surgery types – dentoalveolar, urological, gynaecological and cardiac.

Figure 3.19: Percentage of procedural prescribing appropriateness for surgical episodes by procedure group, Surgical NAPS contributor facilities, 2021



NAPS = National Antimicrobial Prescribing Survey
Source: Surgical NAPS 2021[5]

Figure 3.20: Percentage of post-procedural prophylactic prescribing appropriateness for surgical episodes by procedure group, Surgical NAPS contributor facilities, 2021



NAPS = National Antimicrobial Prescribing Survey
Source: Surgical NAPS 2021[5]

In the 2021 Surgical NAPS, less than one-quarter (23.9%) of all post-procedural surgical episodes were assessed as inappropriate, including when antimicrobials were prescribed and not prescribed post-procedurally (Figure 3.20). The procedure groups with the most post-procedural prescribing deemed inappropriate overall were breast surgery (50.8%), dentoalveolar surgery (44.3%) and orthopaedic surgery (38.5%).

Of the 2,772 surgical episodes where post-procedural prophylaxis was required, it was not prescribed for 1% of episodes (*n* = 28).

Of the 7,327 surgical episodes where procedural prophylaxis was not required, it was prescribed for 18.1% of episodes (*n* = 1,325).

For post-procedural prescribing where prophylaxis was recommended by guidelines, 40.0% were deemed inappropriate (*n* = 1,214). The most common reasons for inappropriate post-procedural prophylaxis were incorrect duration (75.0%) and incorrect dose or frequency (20.7%).

Antimicrobials prescribed post-procedurally for prophylaxis were continued for longer than 24 hours for 68.9% (3,161/4,585) of prescriptions, and 42.4% (1,944/4,585) of prescriptions continued for longer than 48 hours.

Three procedure groups accounted for more than half (53.7%) of all prescriptions for 48 hours or longer: ophthalmology, plastic and reconstructive surgery, and orthopaedic surgery. It should be noted that in ophthalmic surgery the use of chloramphenicol may be considered for up to a week post procedurally as per recommended guidelines.

In 2021, just under one-quarter of all post-procedural prophylaxis was inappropriate for surgical episodes. Breast surgery, dentoalveolar surgery and orthopaedic surgery were the procedure groups with the most inappropriate post-procedural prescribing.

3.3 Antimicrobial use in the community

Data on the volume of AU in the community (primary care and aged care) include dispensing data that are sourced from the PBS and the RPBS.

Data on appropriateness of AU in primary care are provided by participating MedicineInsight practices.[14]

Data on appropriateness of AU in aged care homes are sourced from the Aged Care National Antimicrobial Prescribing Survey (Aged Care NAPS).[15] Note that the data within each Aged Care NAPS reflect antimicrobials used on the day of the survey.

Information about all these data sources is included in Appendix 1.

Antimicrobial dispensing: Pharmaceutical Benefits Scheme and Repatriation Pharmaceutical Benefits Scheme

The principal sources of Australian prescribing data in the community are the PBS and RPBS. Data on all antimicrobial prescriptions dispensed under the PBS and RPBS are recorded in a national database. PBS and RPBS data are estimated to capture more than 90% of all antimicrobial prescriptions dispensed in the community.[16] Other prescriptions may be dispensed privately or are non-PBS and non-RPBS prescriptions. This means that the PBS and RPBS do not subsidise the cost of the medicine.

Table 3.7: Antimicrobials included in the analyses of PBS and RPBS data

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)
P01AB01	Metronidazole
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

An indication of the proportion of private prescriptions dispensed in Australia is provided in the MedicineInsight section in this chapter.

For AURA 2023, eight years of PBS and RPBS data from 1 January 2015 to 31 December 2022 were analysed to assess trends, including the standard collection of data for the Anatomical Therapeutic Chemical (ATC) Classes (see Appendix 1).

In 2022, 36.6% (*n* = 9,502,834) of the Australian population had at least one antimicrobial supplied under the PBS or RPBS, slightly higher than 2021 figures (32.9%; *n* = 8,468,093).

A total of 21,848,005 antimicrobial prescriptions were dispensed, which was a 9.6% increase from 2021 (*n* = 19,931,271); however, this was still well below the use of antimicrobials prior to the COVID-19 pandemic (Table 3.8).

A slight increase in antimicrobial use was observed when examining the use by volume of antimicrobial. The DDD per 1,000 people per day was 16.8 in 2022 compared to 15.9 in 2021.

Table 3.8: Number of PBS and RPBS antimicrobial prescriptions dispensed, 2015–2022

Year	All antimicrobials (*n*)	J01 antibacterials (*n*)	Non-J01 antimicrobials (*n*)	Non-J01 antimicrobials (%)
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
2020	20,095,926	19,425,518	670,408	3.3
2021	19,931,271	19,208,986	722,285	3.6
2022	21,848,005	21,059,515	788,490	3.6

J01 = antibacterials for systemic use; PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Source: Gadzhanova, Roughead[17]

From 1 April 2020, policy changes for the PBS and RPBS came into effect to encourage prescribers to issue repeat prescriptions for antimicrobials only when indicated.[14] Restrictions were introduced for the five most commonly dispensed antimicrobials (amoxicillin, amoxicillin–clavulanic acid, cefalexin, doxycycline and roxithromycin) as follows:

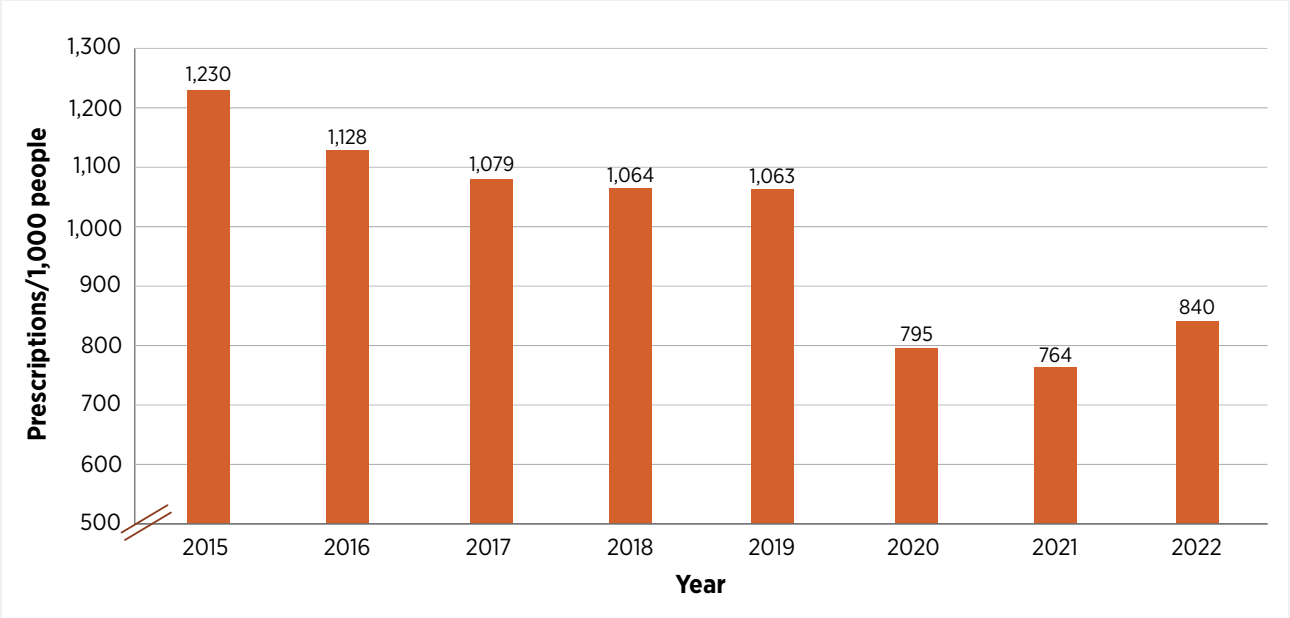
- Maximum quantities and numbers of repeats were changed (typically from one to zero) to reduce inadvertent and unnecessary repeat prescribing when initiating treatment
- New PBS and RPBS listings were added for amoxicillin, amoxicillin–clavulanic acid and cefalexin under authority listings for people who required longer courses of treatment.

Prescribers were able to request a PBS or RPBS authority to prescribe repeats for antimicrobials that otherwise had restricted repeats, and no changes to the maximum quantities for unrestricted antimicrobials were made.

The impact of COVID-19 during 2020 and 2021 was examined in detail in AURA 2021[11] and *Antimicrobial use and appropriateness in the community: 2020–2021*.[14] The impact of COVID-19 remains evident in the 2021 and 2022 data.

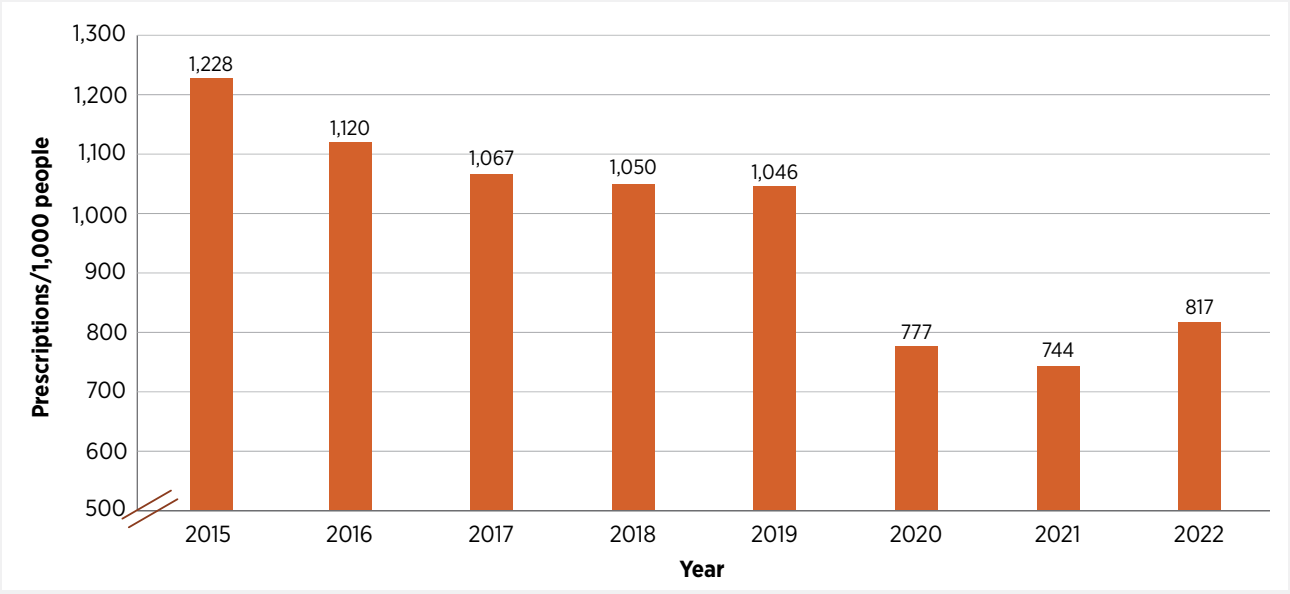
The rate of antimicrobial prescriptions dispensed per 1,000 people in Australia was relatively stable between 2017 and 2019 but declined in 2020 and 2021 (Figure 3.21 and Figure 3.22), most likely due to the change in availability of repeats as well as the COVID-19 pandemic and physical distancing restrictions. However, in 2022 the age-standardised rate increased to 817 prescriptions per 1,000 people (Figure 3.22).

Figure 3.21: Number of PBS and RPBS antimicrobial prescriptions dispensed per 1,000 people, crude rate, 2015–2022



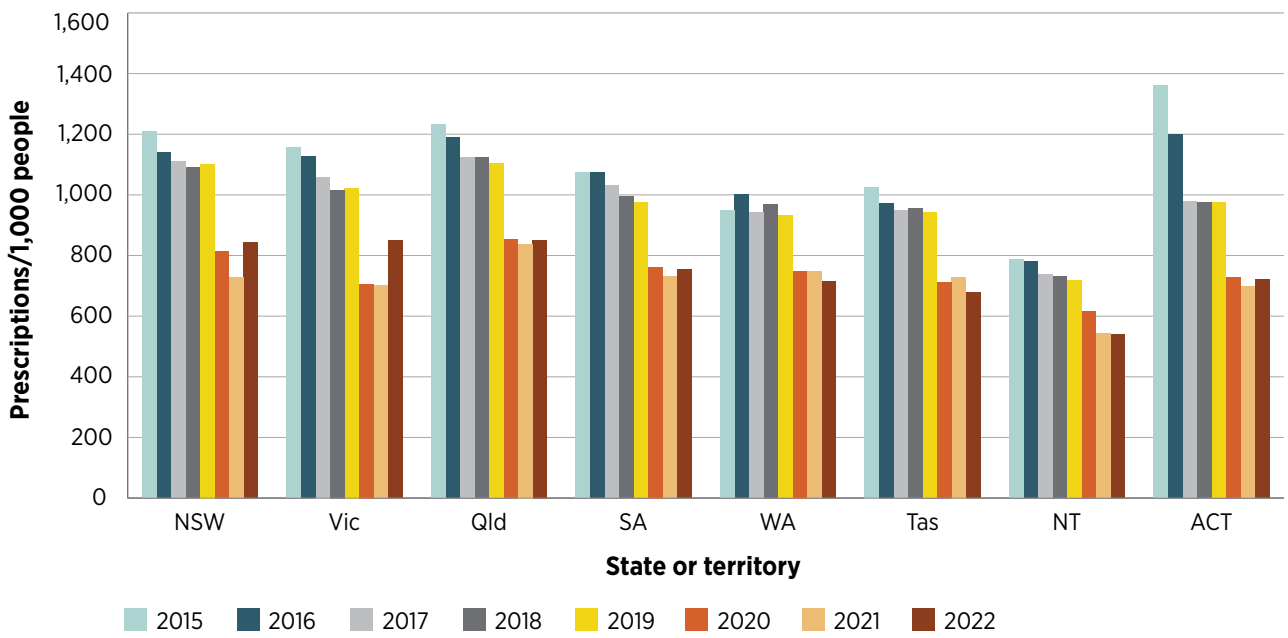
PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Source: Gadzhanova, Roughead[17]

Figure 3.22: Number of PBS and RPBS antimicrobial prescriptions dispensed per 1,000 people, age-standardised rate, 2015–2022



PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Note: Rates are age-standardised based on the age structure of the Australian national population in 2013 (for consistency with previous reports[11,18–20]); national rates are based on the total number of prescriptions dispensed and people in Australia in the given year.
Source: Gadzhanova, Roughead[17]

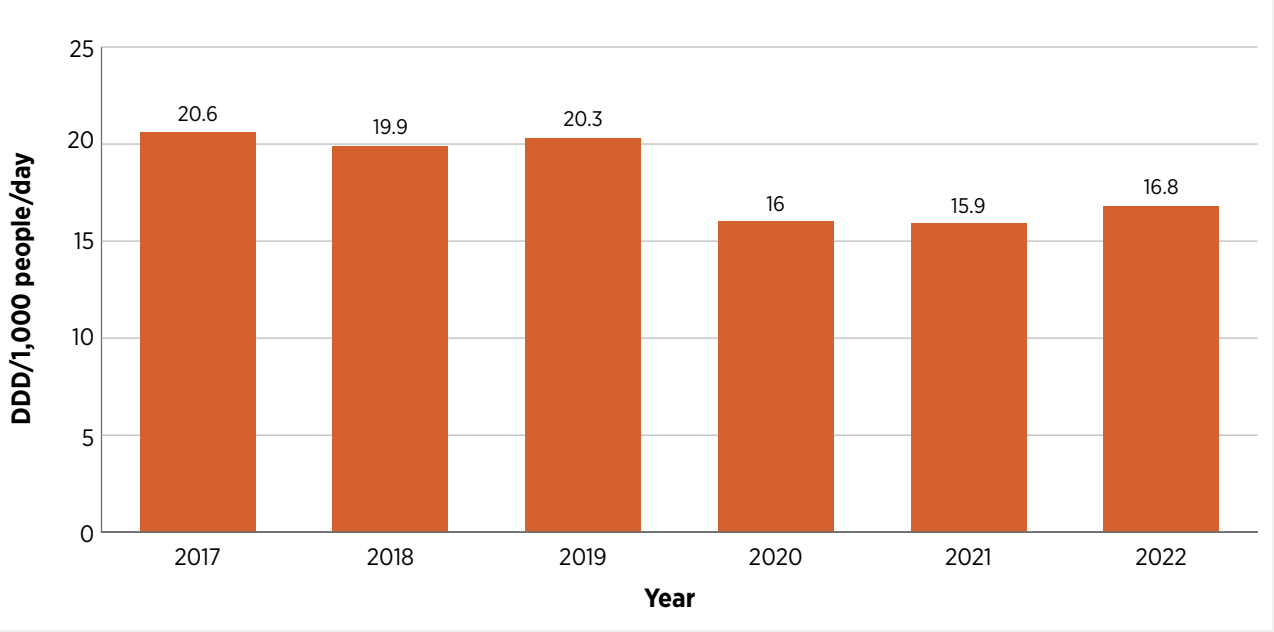
Figure 3.23: Number of PBS and RPBS antimicrobial prescriptions dispensed per 1,000 people, age-standardised rate, by state and territory, 2015–2022



PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Note: Rates are age-standardised to the age structure of the Australian national population in 2013; rates are based on the total number of prescriptions and people in the given state/territory.
Source: Gadzhanova, Roughead[17]

Lower rates of antimicrobial use in 2020 and 2021 compared with previous years were observed in all states and territories (Figure 3.23). In 2022, rates were mostly sustained at a lower level than in 2019, and antimicrobial use was highest in Queensland, NSW and Victoria, and lowest in the NT.

Figure 3.24: Quantity of antimicrobials dispensed under the PBS and RPBS (DDD/1,000 people/day), 2017–2022



DDD = defined daily dose; PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Note: DDD for oral amoxicillin was changed from 1g to 1.5g by the World Health Organization Collaborating Centre for Drug Statistics Methodology in 2019.[21] The current amoxicillin DDD value has been applied in this report, causing slight variance to results presented in previous reports.
Source: Gadzhanova, Roughead[17]

The volume of all antimicrobials supplied in Australia increased slightly from 15.9 DDD/1,000 people/day in 2021 to 16.8 DDD/1,000 people/day in 2022 (Figure 3.24).

Table 3.9 shows the ten Australian Bureau of Statistics Statistical Areas Level 3 (SA3) with the highest percentage increase in antimicrobial use in 2022 compared with 2021. Table 3.10 shows the ten SA3 areas with the greatest percentage decrease in antimicrobial use in 2022 compared with 2021.

Table 3.9: Top 10 SA3 areas with greatest percentage increase in rate of PBS and RPBS antimicrobial prescriptions dispensed per 1,000 people, 2015–2022

SA3 code	SA3 name	State	2015	2016	2017	2018	2019	2020	2021	2022	% change (2016 to 2015)	% change (2017 to 2016)	% change (2018 to 2017)	% change (2019 to 2018)	% change (2020 to 2019)	% change (2021 to 2020)	% change (2022 to 2021)
20604	Melbourne City	Vic	1,152	967	913	555	552	378	375	530	-19.1	-5.9	-64.5	-0.5	-46	-0.8	29.2
11603	Mount Druitt	NSW	1,601	1,533	1,477	665	726	548	561	749	-4.4	-3.8	-122.1	8.4	-32.5	2.3	25.1
20606	Stonnington - West	Vic	1,083	1,033	978	892	909	633	596	796	-4.8	-5.6	-9.6	1.9	-43.6	-6.2	25.1
20804	Stonnington - East	Vic	892	867	787	732	748	505	489	647	-2.9	-10.2	-7.5	2.1	-48.1	-3.3	24.4
12501	Auburn	NSW	1,172	1,049	1,022	936	952	713	594	778	-11.7	-2.6	-9.2	1.7	-33.5	-20	23.7
20602	Darebin - South	Vic	1,026	982	917	661	668	481	433	567	-4.5	-7.1	-38.7	1	-38.9	-11.1	23.6
20605	Port Phillip	Vic	1,019	975	936	849	870	617	573	748	-4.5	-4.2	-10.2	2.4	-41	-7.7	23.4
21204	Dandenong	Vic	1,132	1,052	1,004	925	955	679	604	788	-7.6	-4.8	-8.5	3.1	-40.6	-12.4	23.4
20607	Yarra	Vic	919	868	814	768	775	549	507	659	-5.9	-6.6	-6	0.9	-41.2	-8.3	23.1
20701	Boroondara	Vic	1,043	1,016	932	871	884	607	583	756	-2.7	-9	-7	1.5	-45.6	-4.1	22.9

PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme; SA3 = Australian Bureau of Statistics Statistical Areas Level 3[22]
Source: Gadzhanova, Roughead[17]

Table 3.10: Top 10 SA3 areas with greatest percentage decrease in rate of PBS and RPBS antimicrobial prescriptions dispensed per 1,000 people, 2015–2022

SA3 code	SA3 name	State	2015	2016	2017	2018	2019	2020	2021	2022	% change (2016 to 2015)	% change (2017 to 2016)	% change (2018 to 2017)	% change (2019 to 2018)	% change (2020 to 2019)	% change (2021 to 2020)	% change (2022 to 2021)
51001	Kimberley	WA	377	425	407	415	433	415	337	280	11.3	-4.4	1.9	4.2	-4.3	-23.1	-20.4
60303	South East Coast	Tas	886	890	884	867	809	619	669	569	0.4	-0.7	-2	-7.2	-30.7	7.5	-17.6
51104	Mid West	WA	1,034	1,096	1,001	934	895	785	733	645	5.7	-9.5	-7.2	-4.4	-14	-7.1	-13.6
60301	Central Highlands (Tas.)	Tas	372	341	317	471	450	308	377	332	-9.1	-7.6	32.7	-4.7	-46.1	18.3	-13.6
60103	Hobart - North West	Tas	1,252	1,149	1,146	1,109	1,084	812	777	688	-9	-0.3	-3.3	-2.3	-33.5	-4.5	-12.9
50102	Bunbury	WA	1,154	1,189	1,115	917	876	707	734	653	2.9	-6.6	-21.6	-4.7	-23.9	3.7	-12.4
50901	Albany	WA	878	859	821	766	710	610	588	525	-2.2	-4.6	-7.2	-7.9	-16.4	-3.7	-12
51103	Goldfields	WA	1,029	1,069	984	913	858	700	641	576	3.7	-8.6	-7.8	-6.4	-22.6	-9.2	-11.3
31201	Bowen Basin - North	Qld	1,049	1,121	1,100	1,014	1,022	856	797	722	6.4	-1.9	-8.5	0.8	-19.4	-7.4	-10.4
60203	North East	Tas	1,086	978	976	933	958	761	795	725	-11	-0.2	-4.6	2.6	-25.9	4.3	-9.7

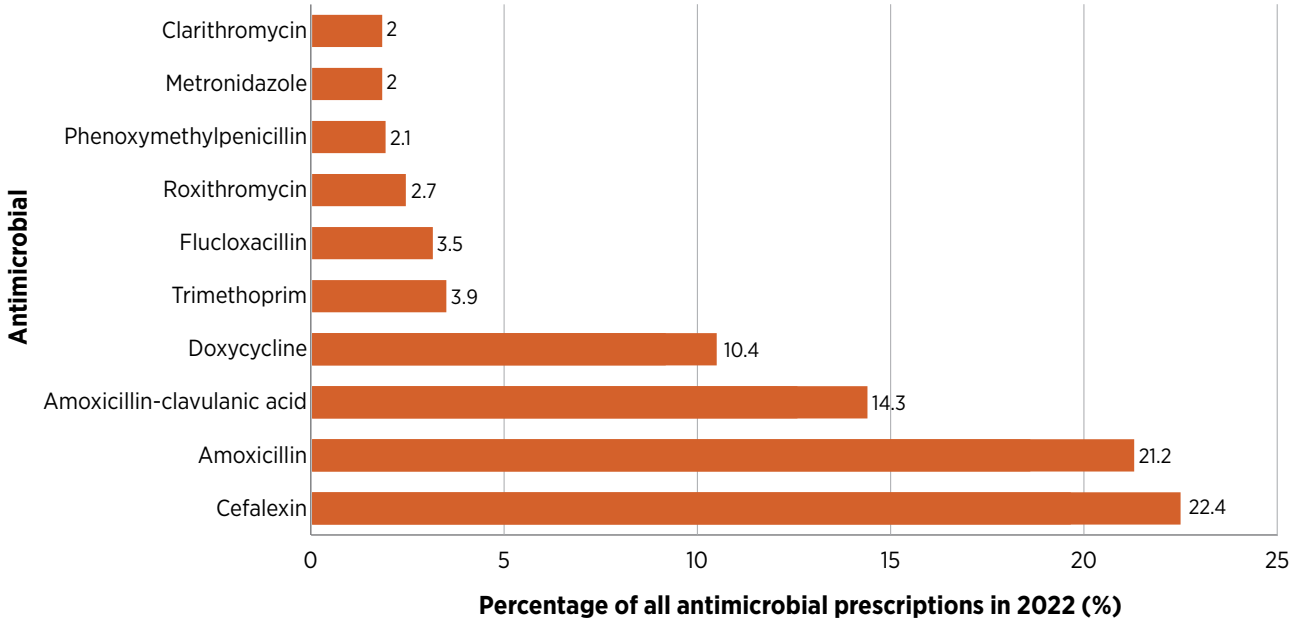
PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme; SA3 = Australian Bureau of Statistics Statistical Areas Level 3[22]

Source: Gadzhanova, Roughead[17]

In 2022, the top ten antimicrobials supplied under the PBS and RPBS accounted for 84.5% of all antimicrobials dispensed (Figure 3.25). Cefalexin, amoxicillin and amoxicillin–clavulanic acid were the three most commonly dispensed antimicrobials in 2022, together accounting for 57.9% of all PBS and RPBS antimicrobials.

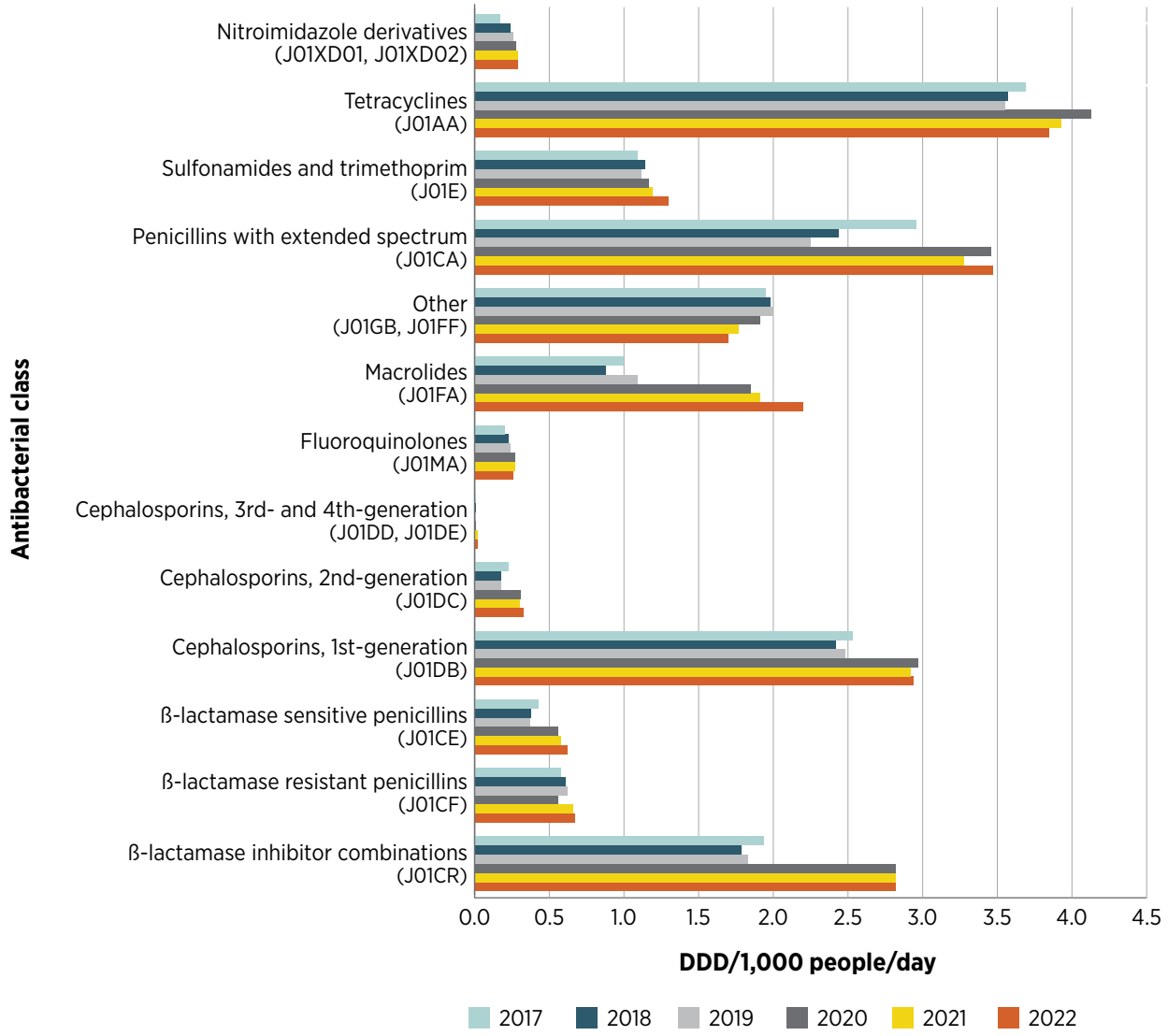
The most commonly dispensed systemic antibacterials by class were tetracyclines, penicillins with extended-spectrum and first-generation cephalosporins, which is consistent with previous years (Figure 3.26).

Figure 3.25: The 10 most commonly dispensed antimicrobials under the PBS and RPBS, 2022



PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Source: Gadzhanova, Roughead[17]

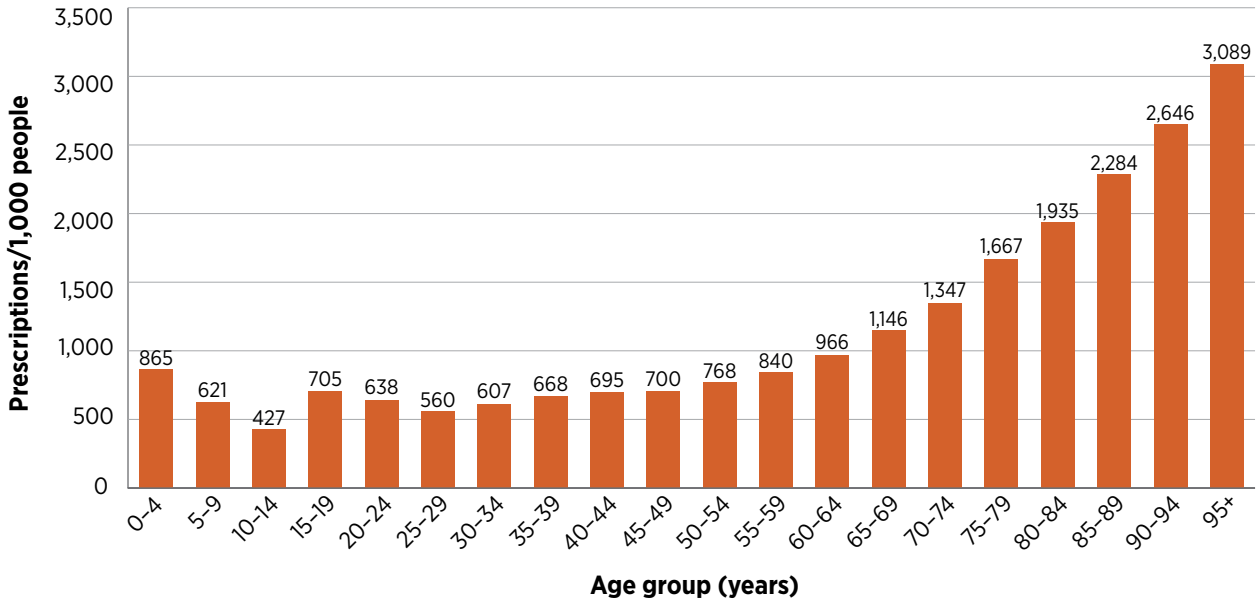
Figure 3.26: Antibacterials dispensed under the PBS and RPBS (DDD/1,000 people/day), by class of systemic antibacterials (J01), 2017–2022



DDD = defined daily dose; PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Source: Gadzhanova, Roughead[17]

In 2022, the usage rates of antimicrobials differed substantially across age groups (Figure 3.27). Data showed that Australians aged 65 years and over received the highest number of antimicrobial prescriptions, with an average of 1–2 antimicrobial prescriptions per person.

Figure 3.27: Number of PBS and RPBS antimicrobial prescriptions dispensed per 1,000 people, by age group, 2022



PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Source: Gadzhanova, Roughead[17]

Original prescriptions accounted for 86.5% of all prescriptions supplied in 2022 for the top 10 antimicrobials supplied. Since PBS and RPBS policy changes were implemented from April 2020, the vast majority of original prescriptions for amoxicillin, amoxicillin–clavulanic acid, cefalexin, doxycycline and roxithromycin were ordered without repeats. There was a substantial reduction in the number of repeats that were dispensed for these agents in 2021–2022, compared to 2019 (Table 3.11).

Except for roxithromycin, there was little difference between the proportion of repeat prescriptions dispensed in 2019 and 2021–2022. Repeat prescriptions filled within 10 days usually indicate a continuation of the original course of treatment. Repeat prescriptions dispensed after 10 days may indicate an interruption of the original duration of treatment and increased potential for inappropriate use.

Table 3.11: Number and percentage of PBS and RPBS repeat antimicrobial prescriptions dispensed within 10 days of the original prescription being dispensed, 2019, 2021 and 2022

Antimicrobial	2019 (*n*)	2019 (%)	2021 (*n*)	2021 (%)	2022 (*n*)	2022 (%)
Cefalexin	398,222	51.3%	33,495	36.5%	37,447	37.6%
Amoxicillin	193,492	50.3%	39,902	50.4%	46,809	52.8%
Amoxicillin–clavulanic acid	510,847	61.1%	25,934	60%	28,631	59.9%
Doxycycline	102,562	32.8%	66,969	24.1%	76,934	26.8%
Roxithromycin	142,145	69.9%	144	6.4%	123	5.9%
Trimethoprim	35,494	40.8%	30,485	39.3%	27,600	37.9%
Flucloxacillin	7,466	56.1%	5,370	47.9%	5,055	47.2%
Clarithromycin	54,748	55.8%	28,456	49.5%	31,705	49.4%
Metronidazole	14,613	44.8%	12,381	40.3%	7,879	41.8%
Phenoxymethylpenicillin	2,582	32.5%	1,709	27.3%	2,264	34.3%
Trimethoprim–sulfamethoxazole	28,948	34%	20,228	26.3%	18,592	25.5%

PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Notes:
1. From 1 April 2020, PBS and RPBS repeats were not allowed for amoxicillin, amoxicillin–clavulanic acid, cefalexin, doxycycline and roxithromycin (shaded) so 2020 data have been excluded from Table 3.11 to enable full year-to-year comparison.
2. Repeats were not allowed for flucloxacillin capsules, but repeats were allowed for flucloxacillin powder for oral liquid.
3. Less than 10 days was chosen for analysis as most pack sizes provide treatment for 5 to 10 days.
Source: Gadzhanova, Roughead[17]

Prescribing patterns in general practice: MedicineInsight program

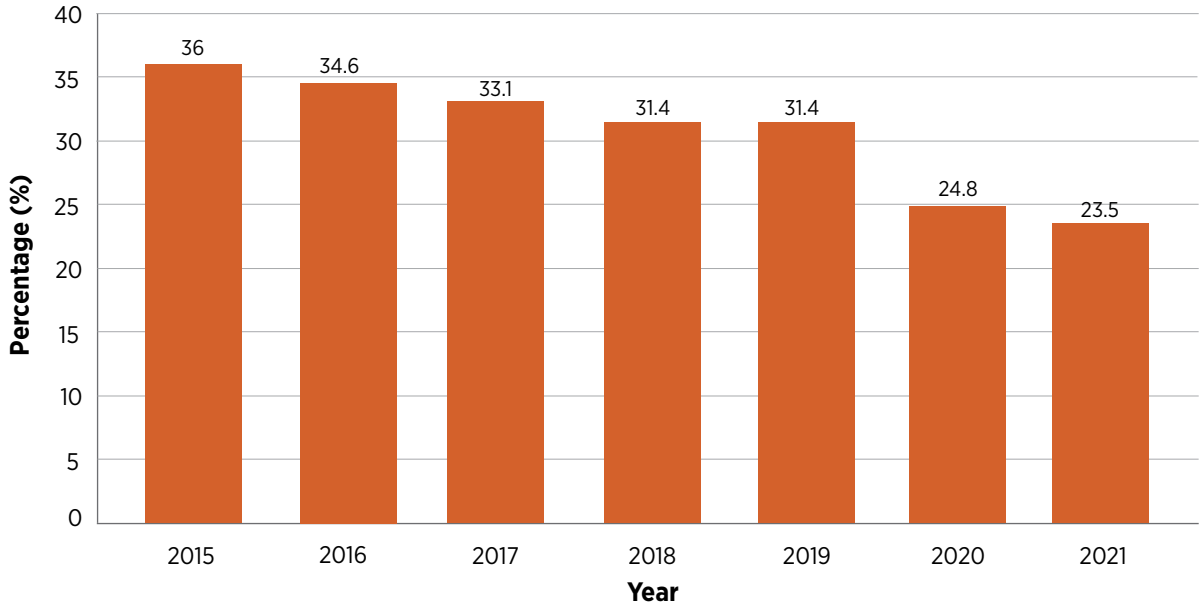
MedicineInsight is a large general practice dataset that collects longitudinal de-identified clinical data from participating general practices across Australia. The data include information on patterns of prescribing, as well as the demographic characteristics, diagnoses and risk factors of the patients prescribed systemic antibacterials (ATC Class J01).

AURA 2023 includes MedicineInsight data for 2015–2021. In 2021, data were contributed by 504 general practice sites for 2,778,848 patients.

In 2020, 24.8% (639,306/2,581,255) of MedicineInsight patients who attended a general practice were prescribed antibacterials at least once during the year – a reduction of 6.6% compared with 2019 figures (Figure 3.28). Although this decline is lower than that observed for PBS and RPBS antimicrobials, it may reflect a number of differences in the data between MedicineInsight and the PBS and RPBS, and the services that they capture.

The drop was sustained in 2021 when 23.5% (654,385/2,778,848) of patients were issued with at least one antibacterial prescription.

Figure 3.28: Percentage of patients prescribed one or more systemic antibacterials across MedicineInsight practices, 2015–2021



Note: Number of practices was 480 in 2015, 493 in 2016, 498 in 2017, 502 in 2018, 502 in 2019, 503 in 2020 and 504 in 2021. The number of patients in the denominator may vary each year (see Appendix 1 for data source description).
Source: MedicineInsight[14]

In 2021, 23.5% of patients at MedicineInsight practices received at least one antibacterial prescription – a reduction compared with 2019 and 2020.

Age group prescribing patterns

In 2021, rates of antibacterial prescribing among MedicineInsight practices varied across age groups. The lowest rate was among those aged 10–14 years, while the highest rate was for those aged 75 years and over (Figure 3.29).

Socioeconomic group prescribing patterns

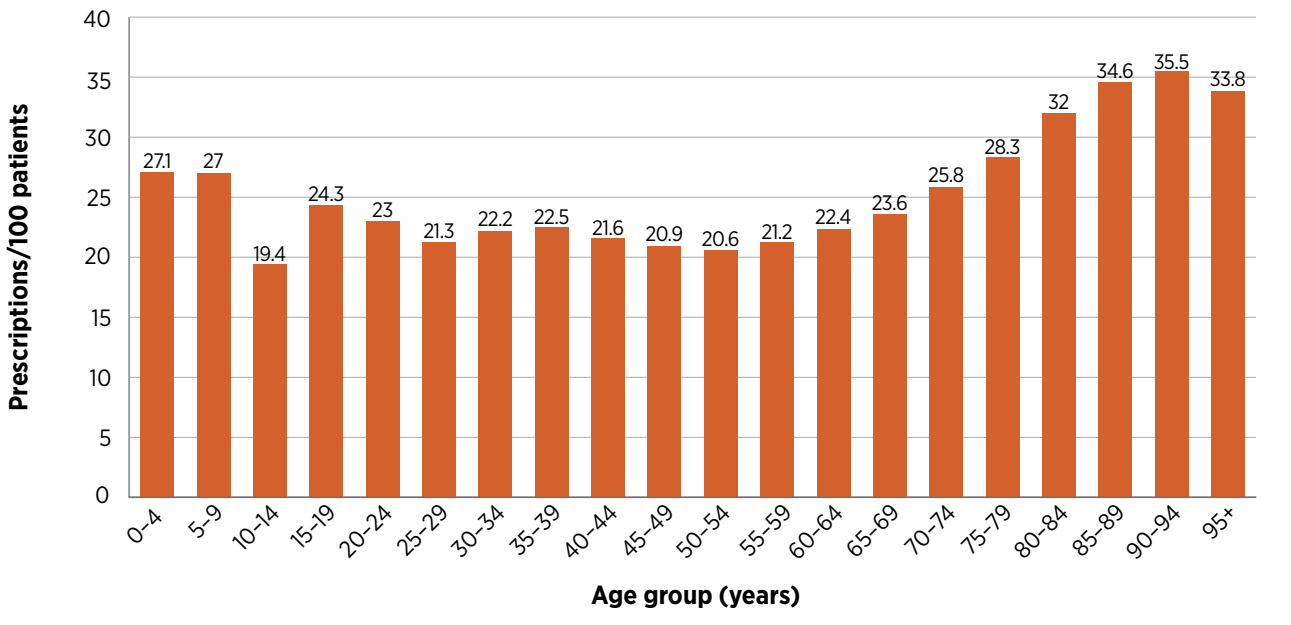
Socioeconomic differences are measured using the Socio-Economic Indexes for Areas (SEIFA).[23] Table 3.12 summarises the demographics of patients prescribed antibacterials in MedicineInsight practices between 2019 and 2021 by their SEIFA deciles.

The rate of prescribing per 100 patients was 25.9% (2020) and 24.6% (2021) among people living within the most disadvantaged SEIFA decile.

The rate of prescribing per 100 patients was 23.3% (2020) and 21.3% (2021) among people living within the least disadvantaged SEIFA decile.

There was consistency across states and territories in relation to SEIFA decile and the rate of antibacterial prescriptions per 100 patients.

Figure 3.29: Number of patients prescribed one or more systemic antibacterials per year, per 100 patients, by age group, MedicineInsight practices, 2021



Note: Number of practices was 502 in 2019, 503 in 2020, and 504 in 2021. The number of patients in the denominator may vary each year (see Appendix 1 for data source description).
Source: MedicineInsight[14]

Differences were observed in antibacterial prescribing between people living in major cities and those living in more remote areas (Table 3.12). People living in very remote areas were the only group by remoteness for which prescribing rates increased in 2021 compared with 2020. It is noteworthy that remote areas of Australia are underrepresented 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.[24]

Overall, minimal variation was observed in antibacterial prescribing rates between states and territories. The highest rates were observed in the NT in 2020 (28.8 per 100 patients) and the ACT in 2021 (26 per 100 patients). The lowest rates were observed in Tasmania (23.9 per 100 patients) in 2020 and in NSW (22.3 prescriptions per 100 patients) in 2021. Tasmania was the only jurisdiction in which prescribing rates increased from 2020 to 2021.

Table 3.12: Region of residence and socioeconomic status for patients prescribed systemic antibacterials, MedicineInsight practices, 2019–2021

		Percentage of patients prescribed one or more antibacterials (%)		
Measure	**Category**	**2019**	**2020**	**2021**
State or territory	NSW	31.7	24.4	22.3
	Vic	31.8	24	22.9
	Qld	31.6	25.5	24.5
	SA	31.4	26.4	24.8
	WA	29.4	25.3	25.2
	Tas	30.2	23.9	24.8
	NT	33.5	28.8	25.2
	ACT	34.3	27.2	26
Remoteness	Major cities	32.1	25	23.5
	Inner regional	30	24.1	23.5
	Outer regional	31.1	25	24.2
	Remote	24.6	20.8	19.3
	Very remote	28.3	26.9	28.1
	Unknown/other	22.7	22.8	16.8
SEIFA decile	1 (most disadvantaged)	31.6	25.9	24.6
	2	30.8	25.1	24.1
	3	30.8	24.7	24.7
	4	30.7	24.9	23.8
	5	31.5	25	23.6
	6	31.9	25.2	24.2
	7	32	25.2	23.8
	8	31.8	25.2	24
	9	31.1	23.8	22.6
	10 (least disadvantaged)	31.6	23.3	21.3
	Unknown/other	22.7	22.8	16.8

SEIFA = Socio-Economic Indexes for Areas[23]
Notes:
1. The number of MedicineInsight practices was 498 in 2017, 502 in 2018, 502 in 2019, 503 in 2020 and 504 in 2021.
2. The number of patients in the denominator may vary each year (see Appendix 1 for data source description).
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: MedicineInsight[14]

Seasonal prescribing patterns

Between January 2015 and December 2021, the number of antibacterial prescriptions (originals and repeats) per 100 GP consultations in participating MedicineInsight practices steadily declined from a peak of 22.9 in August 2015 to a trough of 11.1 in June 2021.

Monthly and seasonal variations were observed throughout this period. The overall variation observed across 2020 and 2021 was much smaller than in previous years (Figures 3.30 and 3.31). During the COVID-19 pandemic, antibacterial prescribing decreased from an average of 16 prescriptions per 100 GP visits in 2019 to an average of 7 prescriptions per 100 GP visits in both 2020 and 2021.

Seasonal prescribing variation, with peaks in winter months, was observed for all antibacterials except cefalexin. This may be because cefalexin is less commonly prescribed when an antibacterial is indicated for a respiratory tract infection. There were more prescriptions for cefalexin during the summer period, and it was also the most frequently prescribed antibacterial in 2020 and 2021. However, cefalexin prescribing rates declined by 36.4% from 3.3 prescriptions per 100 GP visits in March 2020 to 2.1 prescriptions per 100 GP visits in May 2020.

The rate of amoxicillin prescribing also decreased dramatically at this time, following an ongoing decline since 2016. Figures 3.31 and 3.32 show the rate of original and repeat prescribing respectively; both demonstrate a decreasing pattern for amoxicillin, which is consistent with the trends observed for original and repeats combined (Figure 3.30).

Smaller decreases in prescribing rates were observed for other antibacterials commonly used for respiratory tract infections (amoxicillin–clavulanic acid, doxycycline, azithromycin and roxithromycin), but not for cefalexin, which is more frequently used for the treatment of skin and soft tissue infections and UTIs. This may have also been affected by PBS and RPBS repeat changes. Of note, there was only a marginal decrease in the rate of doxycycline repeat prescriptions following the introduction of PBS and RPBS restrictions, compared with other high-use (most frequently prescribed) antibacterials (Figure 3.32). This may be because doxycycline has a broader range of indications.

High-use antibacterial prescribing patterns

In the context of *Therapeutic Guidelines: Antibiotic*[12] recommendations, antibacterials continue to be overprescribed in Australia. Figures 3.30 and 3.31 show data on the seven most frequently prescribed antibacterials (amoxicillin, amoxicillin–clavulanic acid, azithromycin, cefalexin, ciprofloxacin, doxycycline and roxithromycin) recorded in the MedicineInsight program – referred to as high-use antibacterials.

In 2021, of these high-use antibacterials prescribed, cefalexin was the most frequently prescribed, followed by amoxicillin, amoxicillin–clavulanic acid, doxycycline, roxithromycin, azithromycin and ciprofloxacin (Table 3.13). This order has remained the same since 2015; however, the proportion of cefalexin prescribed relative to the other high-use antibacterials increased during 2020 and 2021.

Table 3.13: Patterns of GP prescribing for high-use antibacterials, MedicineInsight practices, 2021

Antibacterial	Patients issued a prescription (PBS and RPBS or private) (%)*	Most common indication (%)†	Patient age group with highest rate§ of prescribing (years)	Prescriptions (PBS and RPBS or private) ordered with repeats (%)	Prescriptions ordered as private (%)
Cefalexin	7.7	Skin/wound infection (20.7)	90–94	7.2	0.9
		UTI (16.7)			
		Other infection (8.4)			
		Respiratory-related infection (5.2)			
Amoxicillin	6.5	URTI (acute) (16.3)	0–4	9.1	0.9
		Pneumonia (10.6)			
		Otitis media (10.3)			
		Sinusitis (acute/chronic) (8.5)			
Amoxicillin–clavulanic acid	4.1	Other infection (13.2)	80–84	5.4	2.9
		Sinusitis (acute/chronic) (8.1)			
		Skin/wound infection (6.2)			
		Pneumonia (5.8)			
Doxycycline	3.9	Acne (16.4)	15–19	60.9	6.8
		Pneumonia (10.2)			
		Skin/wound infection (6.2)			
		Sinusitis (6)			
Roxithromycin	1.7	URTI (acute) (17.2)	80–84	2.7	1.6
		Pneumonia (12.1)			
		Sinusitis (acute/chronic) (7.6)			
		Other infection (6.8)			
		Bronchitis (acute) (5.4)			

continues

Table 13: *continued*

Antibacterial	Patients issued a prescription (PBS and RPBS or private) (%)*	Most common indication (%)†	Patient age group with highest rate§ of prescribing (years)	Prescriptions (PBS and RPBS or private) ordered with repeats (%)	Prescriptions ordered as private (%)
Azithromycin	0.6	*Chlamydia* infection (12.2)	20–24	16.8	44.6
		Unclassified reason for prescription# (9.6)			
		Pneumonia (6.8)			
		Other infection (6.6)			
Ciprofloxacin	0.3	Other infection (31.6)	95+	24.5	37.4
		Unclassified reason for prescription# (10.8)			
		UTI (9.7)			
		Skin/wound infection (8.3)			

GP = general practitioner; PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme; URTI = upper respiratory tract infection; UTI = urinary tract infection

* Percentage of patients who visited a MedicineInsight practice GP at least once between 1 January and 31 December 2021 and had one or more prescriptions for the specified antibacterial issued on the day of the visit

† If an explicit recorded reason for the prescription was incomplete, an association was assumed between the antibacterial prescribed and a reason for the encounter and/or a diagnosis that was recorded on the same day as the prescription

§ Number of MedicineInsight patients prescribed one or more antibacterial prescriptions per 100 patients

\# Prescriptions with a recorded entry in the reason for prescription, or a reason for encounter or diagnosis on the same day that did not match an antibacterial-related indication

Note: The denominator reflects number of patients, and therefore ranking and values will be different to denominator using GP visits.

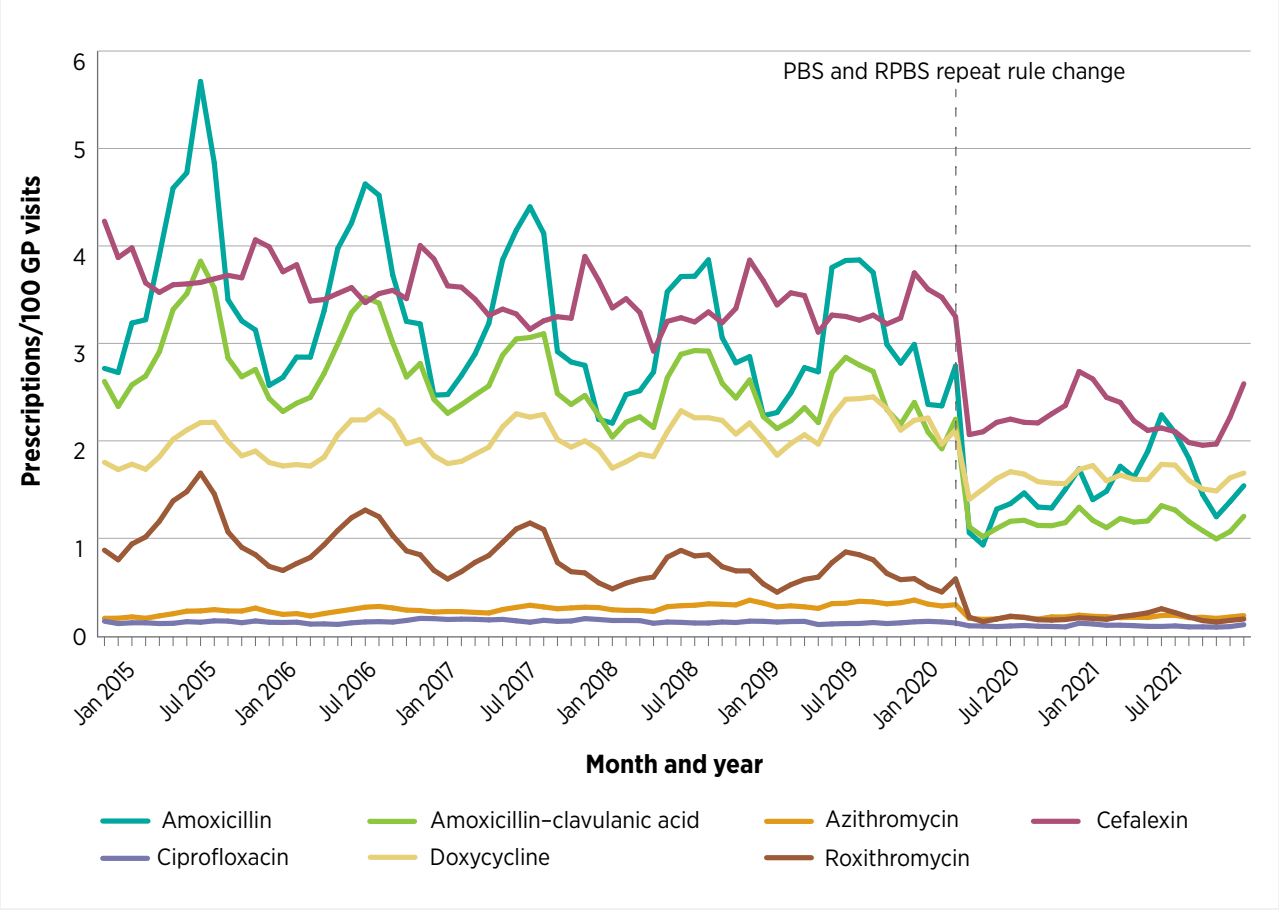
Source: MedicineInsight[14]

Of antibacterial prescriptions issued by MedicineInsight practices between 2015 and 2021, a little over one-third contained an explicit 'Reason for Prescription'. Of the remaining prescriptions, where no data was provided for the 'Reason for Prescription' but it matched one of the identifiable conditions, then the analysis included the 'Reason for Encounter and Diagnosis' recorded on the same day as the prescription to identify the indication. As a result, the likely indication for the prescription was determined in more than 65% of cases.

The most commonly recorded indications for cefalexin prescriptions were skin infections in 2020 (22.3%) and 2021 (20.7%) and UTIs in 2020 (17.2%) and 2021 (16.7%). On average, 4.9% of cefalexin prescriptions were indicated for respiratory-related conditions in 2020 and 2021 – acute upper respiratory tract infection (URTI), acute tonsillitis, pneumonia, sinusitis, acute bronchitis and influenza/influenza-like illness.

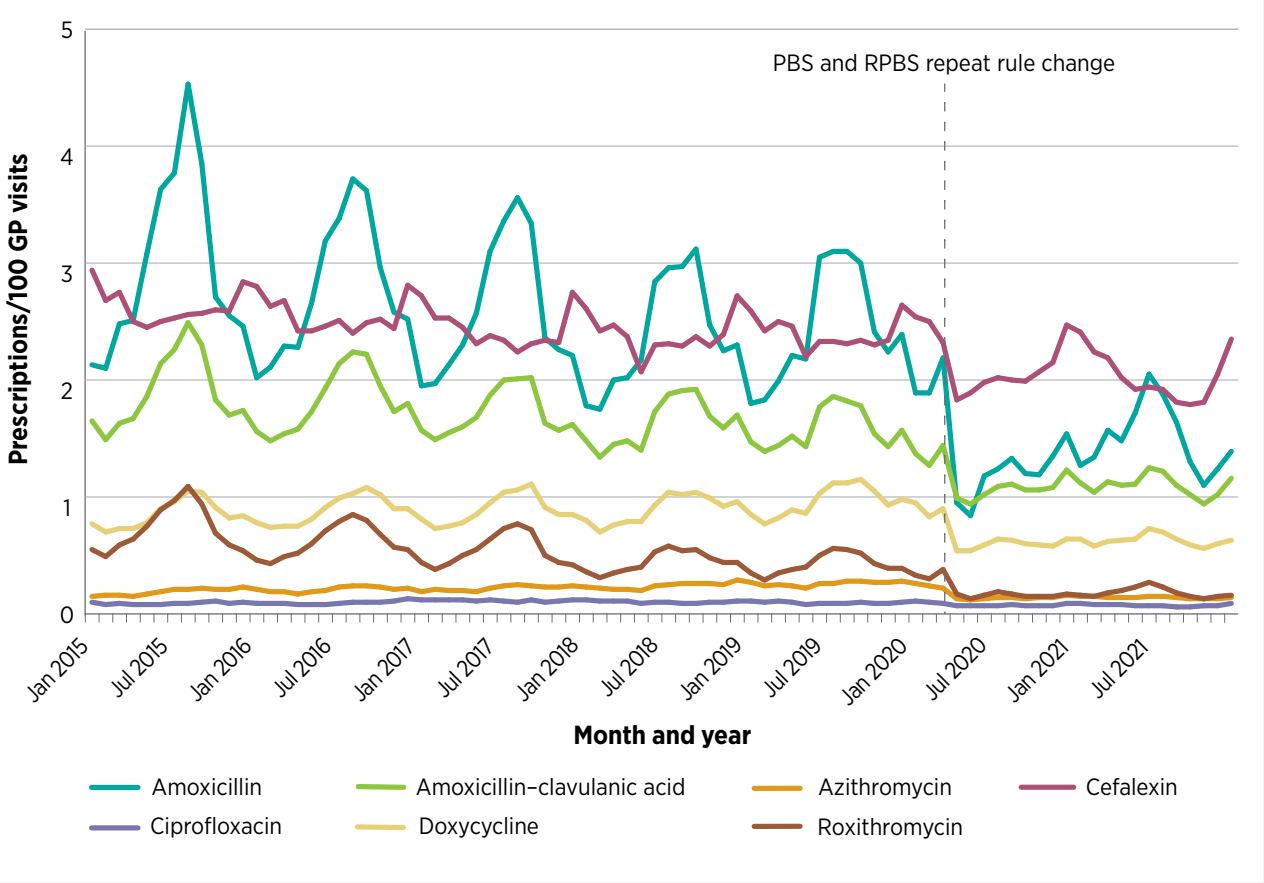
Continuing the trend from 2019, around one-fifth of ciprofloxacin prescriptions did not have a clear indication, with 'other infection' being the most common indication for 23.5% (2020) and 31.6% (2021). The most commonly recorded reason for ciprofloxacin prescribing in MedicineInsight practices was 'unclassified reason for prescription' in 2020 (12.2%) and in 2021 (10.8%). As ciprofloxacin has a broad spectrum of activity, recording its indication is important in understanding its appropriateness of prescribing, identifying focus areas for AMS interventions, and limiting the impact on AMR. This is also important for azithromycin, as PBS and RPBS benefits for both antibacterials are restricted. In 2021, 'unclassified reason for prescription' was commonly recorded for azithromycin (9.6%).

Figure 3.30: Rate of high-use antibacterials prescribed (total prescriptions including originals and repeats) per 100 GP visits, MedicineInsight practices, 2015–2021



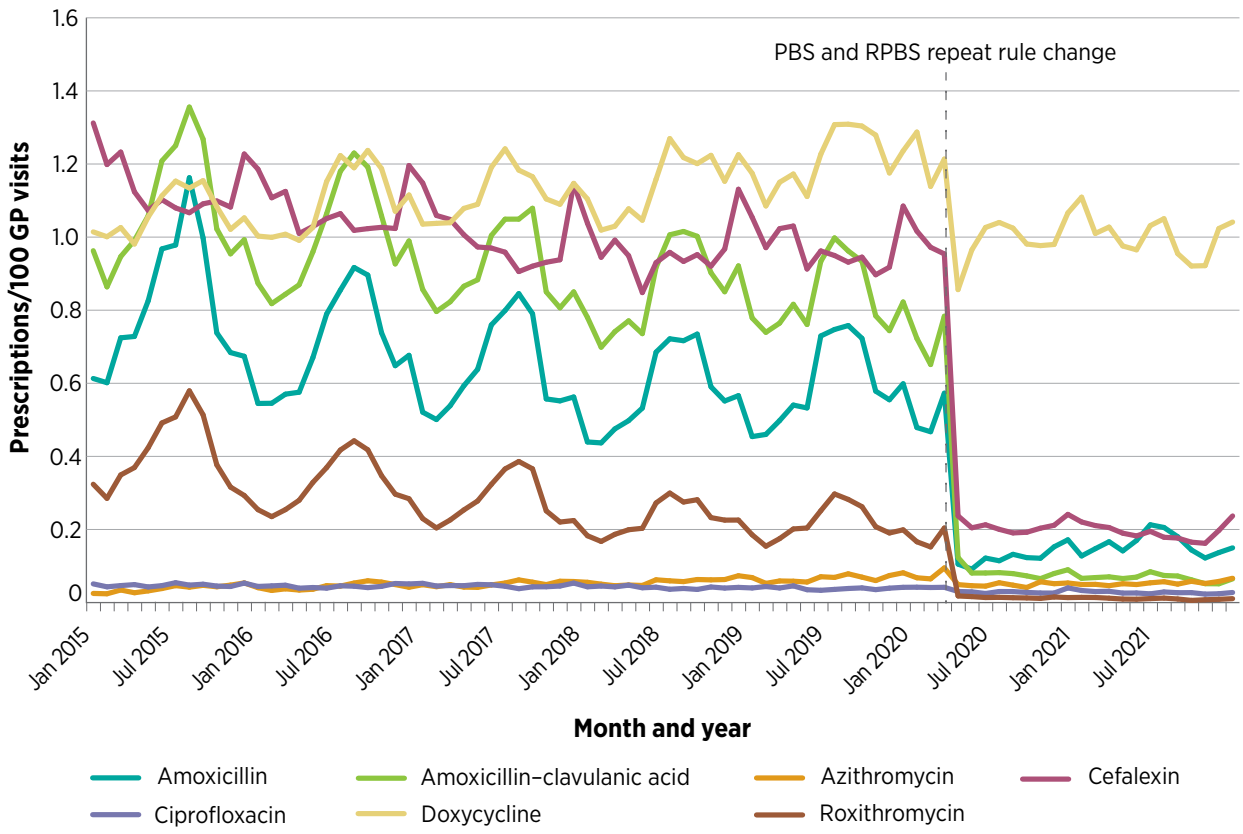
GP = general practitioner; PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Note: From 1 April 2020, PBS and RPBS repeats were not allowed for amoxicillin, amoxicillin–clavulanic acid, cefalexin, doxycycline and roxithromycin, which coincided with the full implementation of COVID-19 pandemic restrictions across Australia.
Source: MedicineInsight[14]

Figure 3.31: Rate of original high-use antibacterial prescriptions issued per 100 GP visits, MedicineInsight practices, 2015–2021



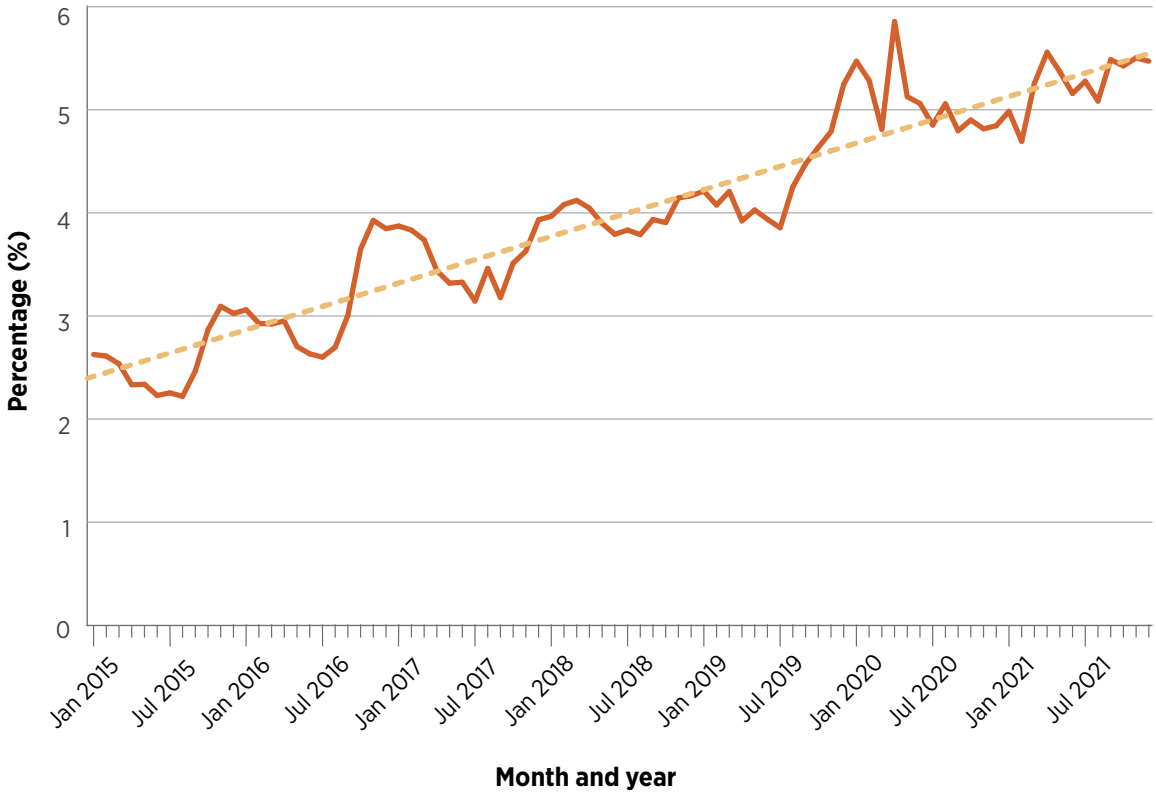
GP = general practitioner; PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Note: From 1 April 2020, PBS and RPBS repeats were not allowed for amoxicillin, amoxicillin–clavulanic acid, cefalexin, doxycycline and roxithromycin, which coincided with the full implementation of COVID-19 pandemic restrictions across Australia.
Source: MedicineInsight[14]

Figure 3.32: Rate of repeat high-use antibacterial prescriptions issued per 100 GP visits, MedicineInsight practices, 2015–2021



GP = general practitioner; PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Note: From 1 April 2020, PBS and RPBS repeats were not allowed for amoxicillin, amoxicillin–clavulanic acid, cefalexin, doxycycline and roxithromycin, which coincided with the full implementation of COVID-19 pandemic restrictions across Australia.
Source: MedicineInsight[14]

Figure 3.33: Percentage of private systemic antibacterial prescriptions (originals plus repeats) of total systemic antibacterial prescriptions (originals plus repeats), MedicineInsight practices, 2015–2021



PBS = Pharmaceutical Benefits Scheme; RPBS = Repatriation Pharmaceutical Benefits Scheme
Notes:
1. Figure 3.33 represents the proportion of prescriptions that are written with repeats, compared with prescriptions that are written as originals (repeat not stated). It is noted that changes in number of GP visits, practices and patients occur over time.
2. Number of practices was 480 in 2015, 493 in 2016, 498 in 2017, 502 in 2018, 502 in 2019, 503 in 2020, and 504 in 2021.
Source: MedicineInsight[14]

Private prescriptions more than doubled from 2.5% in 2015 to 5.3% in 2021 (Figure 3.33). Over this period, there was a high proportion of private azithromycin prescriptions.[14]

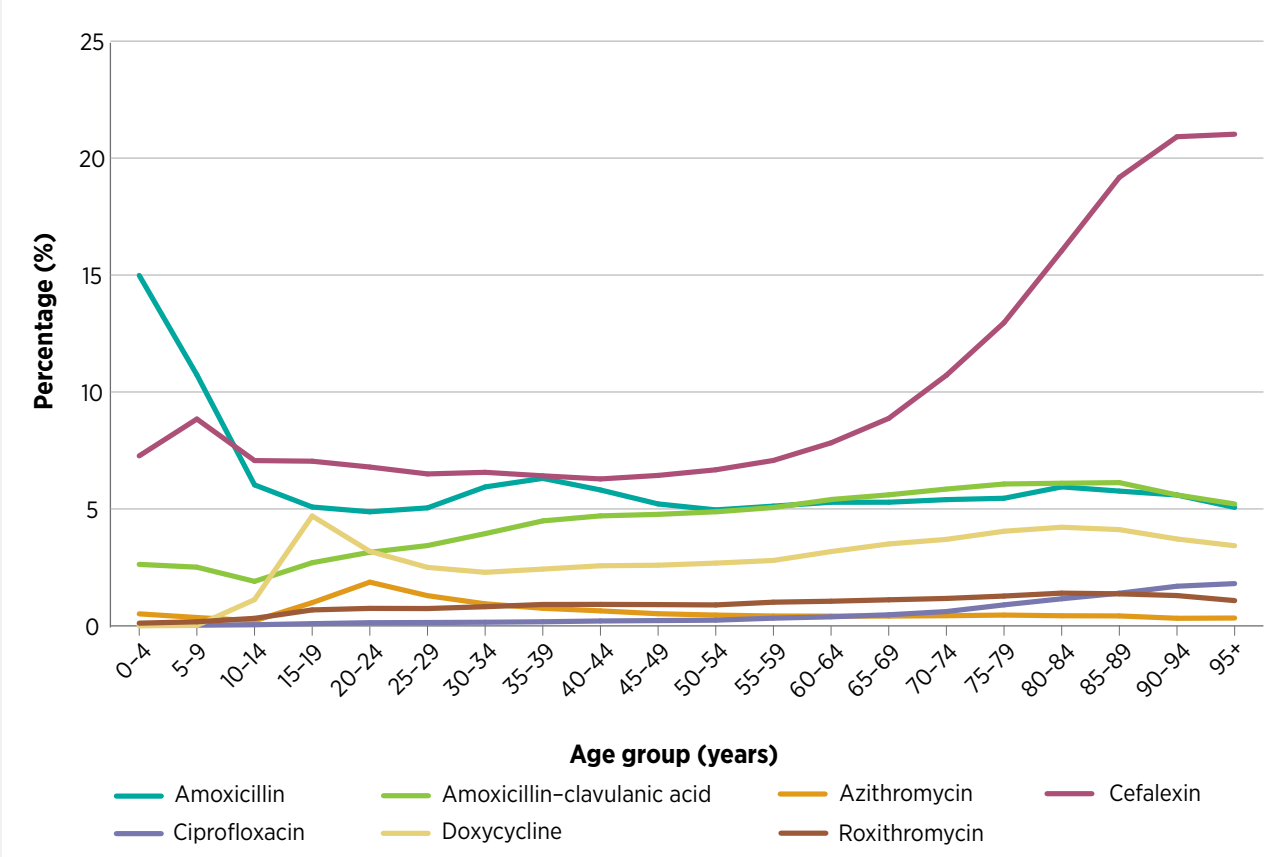
There was a similar steady rise in the proportion of private prescriptions for ciprofloxacin.[14] This may be partly attributed to the ciprofloxacin PBS and RPBS restriction category, which has been in operation since 1988.[25] Understanding the total use of ciprofloxacin as a broad-spectrum antibacterial is important as Australia has historically had low rates of ciprofloxacin use compared with other countries, and limiting its use is a key aspect of AMS programs.

Differences in prescribing patterns for high-use antibacterials were observed across age groups (Figure 3.34). Amoxicillin was commonly prescribed for children aged 0–4 years (15% of children aged 0–4 years who visited a GP received a prescription for amoxicillin). For adults aged 85 years or over, cefalexin was commonly prescribed (19.2–21 per 100 patients). Doxycycline was

commonly prescribed for the 15–19-year age group (4.7 per 100 patients) and azithromycin for the 20–24-year age group (1.9 per 100 patients).

This pattern of prescribing likely reflects the most common indications for which antibacterials were prescribed in these age groups (Tables 3.13 and 3.14).

Figure 3.34: Percentage of patients prescribed one or more high-use antibacterials, by age group, MedicineInsight practices, 2020–2021



Notes:
1. Patients prescribed the selected antibacterial at least once in 2020–2021 (combined) as a percentage of all patients in that age group with at least one clinical encounter with a GP in 2020–2021.
2. The number of practices in 2020 was 503, and 504 in 2021.

Source: MedicineInsight[14]

Prescribing patterns for the most common primary care conditions

In the context of *Therapeutic Guidelines: Antibiotic*[12] recommendations, antimicrobials continue to be overprescribed in Australia. The proportion of patients prescribed antibacterials for the nine conditions seen most frequently in primary care settings is outlined in Table 3.14. Antimicrobial prescribing is generally not recommended for these conditions, with some exceptions.

Although direct comparisons should be made with caution, Table 3.14 suggests that antimicrobials are overprescribed for these conditions compared with the recommendations in *Therapeutic Guidelines: Antibiotic*[12] and relevant clinical pathways, for example:

- Antibacterials were prescribed in approximately 80% of acute bronchitis cases for patients aged 18–75 years in 2020 and 2021, despite antimicrobials not being recommended for the management of this condition
- Antibacterials were prescribed at least twice as often as required for acute tonsillitis. In patients aged older than 1 year with acute tonsillitis, approximately 85% were prescribed antibacterials in 2020 and 2021 despite estimates that antimicrobials are required in 19–40% of cases[26]
- Antibacterials were prescribed for acute otitis media in 83.3% of patients (2020) and 85.8% (2021) despite estimates that antimicrobials are required in 20–31% of cases[26]
- Only one-third of patients received guideline-recommended amoxicillin for acute sinusitis.

These data further highlight that antibacterial prescribing was often inconsistent with first-line recommendations in *Therapeutic Guidelines: Antibiotic*.[12]

Prescribing rates for acute bronchitis, acute sinusitis, acute URTI and influenza-like illnesses were not consistent with national guidelines but showed improvement in appropriateness from 2015 to 2021. This is compared with other conditions including UTIs and acute otitis media, for which appropriateness has not improved and prescribing rates remain high (Figure 3.35).

Rates of antibacterial use for specific conditions varied in 2020 and 2021. Antibacterial use for patients presenting with UTIs and tonsillitis has gradually increased since 2015 compared with influenza-like illnesses, for which prescribing has generally decreased. Decreased antibacterial prescribing for acute UTRIs, bronchitis, COPD, acute otitis media, pneumonia and sinusitis coincided with the COVID-19 pandemic in 2020 but increased in 2021 (Figure 3.35).

Despite seasonal variations, antibacterial prescriptions issued by GPs in MedicineInsight practices have decreased since 2015 (Figure 3.36). The observed trend changed dramatically following the implementation of COVID-19 restrictions in April 2020. MedicineInsight data complement findings in the PBS and RPBS datasets that community AU has significantly decreased since 2015 and the COVID-19 pandemic.

Table 3.14: Number and percentage of patients prescribed systemic antibacterials by GPs for selected conditions, MedicineInsight practices, 2020–2021

		2020			2021			Expected new cases to be managed with antimicrobials*
Condition†	**Patients**	***n***	**%**	**95% CI**	***n***	**%**	**95% CI**	**Range (%)**
Acute bronchitis	Aged 18–75 years prescribed antibacterials	11,007	78.5	76.0–81.1	12,403	80.9	78.9–82.9	0
COPD	Aged 18–75 years prescribed antibacterials	7,326	31	29.9–32.2	6,981	32	30.7–33.3	nd
Influenza-like illness	Older than 1 year prescribed antibacterials	650	8.6	7.4–9.5	287	6.3	3.8–8.7	0
Acute otitis media	Older than 2 years prescribed antibacterials	20,809	83.3	81.6–85	26,137	85.8	84.5–87.0	20–31
	And prescribed TG-recommended amoxicillin	13,818	55.3	53.5–57.1	18,284	60	58.1–61.9	20–31
Pneumonia	Aged 18–65 years prescribed antibacterials	26,978	78.4	76.4–80.5	30,804	83.8	82.6–85.1	nd
	And prescribed TG-recommended antibacterial (for mild CAP – amoxicillin or doxycycline)	15,814	46	44.1–47.8	19,236	52.3	50.2–54.5	100
Sinusitis (acute/ chronic)	Older than 18 years prescribed antibacterials	35,947	75.2	73.5–76.8	38,028	78.2	76.9–79.6	0.5-8
	And prescribed TG-recommended amoxicillin	14,463	30.2	28.8–31.7	16,667	34.3	32.4–36.2	0.5–8 (acute)
Acute tonsillitis	Older than 1 year prescribed antibacterials	26,158	84.5	81–87.9	26,384	86.1	83.8–88.3	19–40
	And prescribed TG-recommended penicillin V	14,835	48	44.5–51.3	15,561	50.8	47.9–53.6	19–40
Acute URTI	Older than 1 year prescribed antibacterials	64,676	27.4	25.3–29.5	70,165	35.1	33.1–37	nd
UTI	Females older than 18 years prescribed antibacterials	65,943	89.5	88.5–90.5	63,436	90.6	89.9–91.3	nd
	And prescribed TG-recommended trimethoprim	30,646	41.6	40.3–42.8	29,516	42.2	40.9–43.4	nd

CAP = community-acquired pneumonia; CI = confidence interval; COPD = chronic obstructive pulmonary disease; GP = general practitioner; nd = not determined; TG = *Therapeutic Guidelines: Antibiotic*; URTI = upper respiratory tract infection; UTI = urinary tract infection

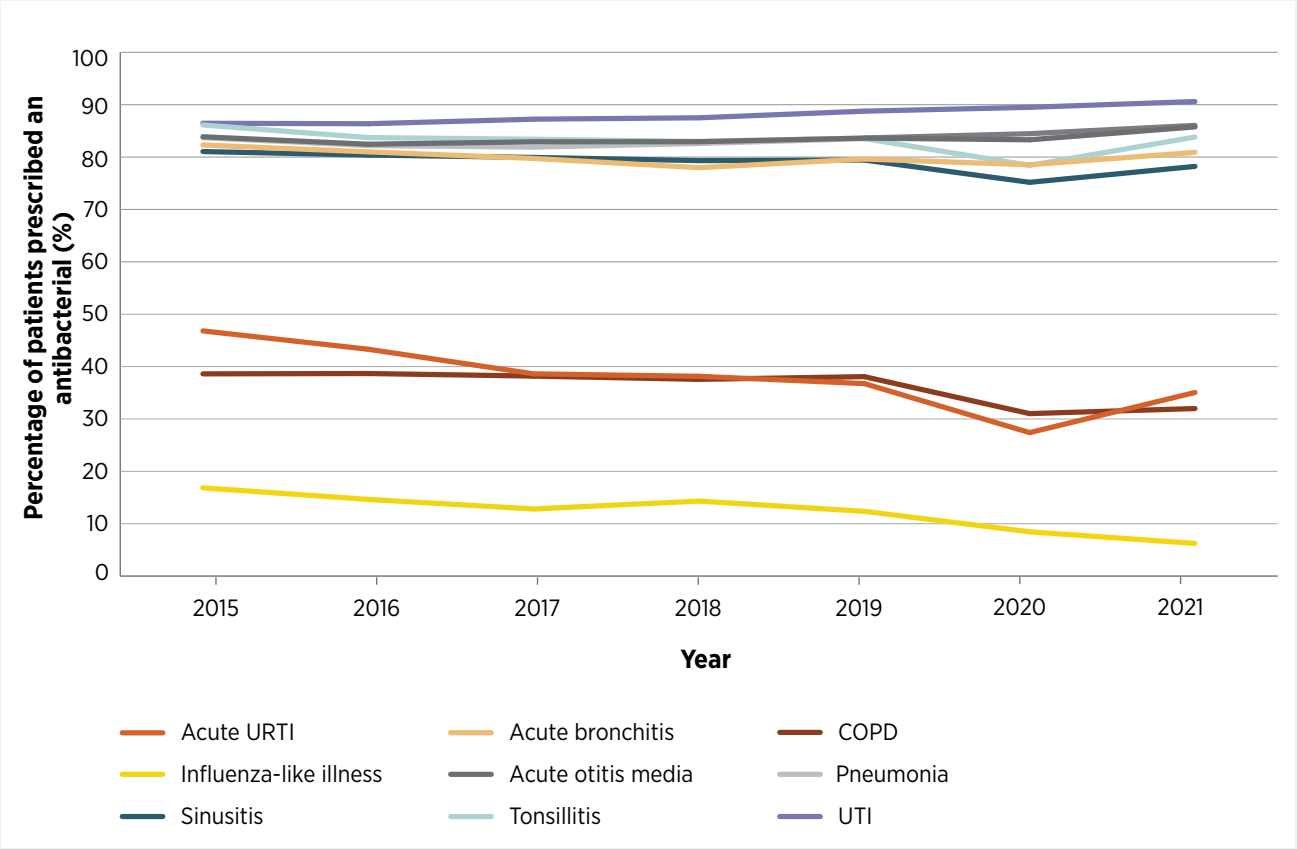
* Mean percentage of new cases to be managed with antimicrobials, based on guideline recommendations, where available

† NPS MedicineWise developed 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.[26]

Note: Number of practices in 2020 was 503, and 504 in 2021.

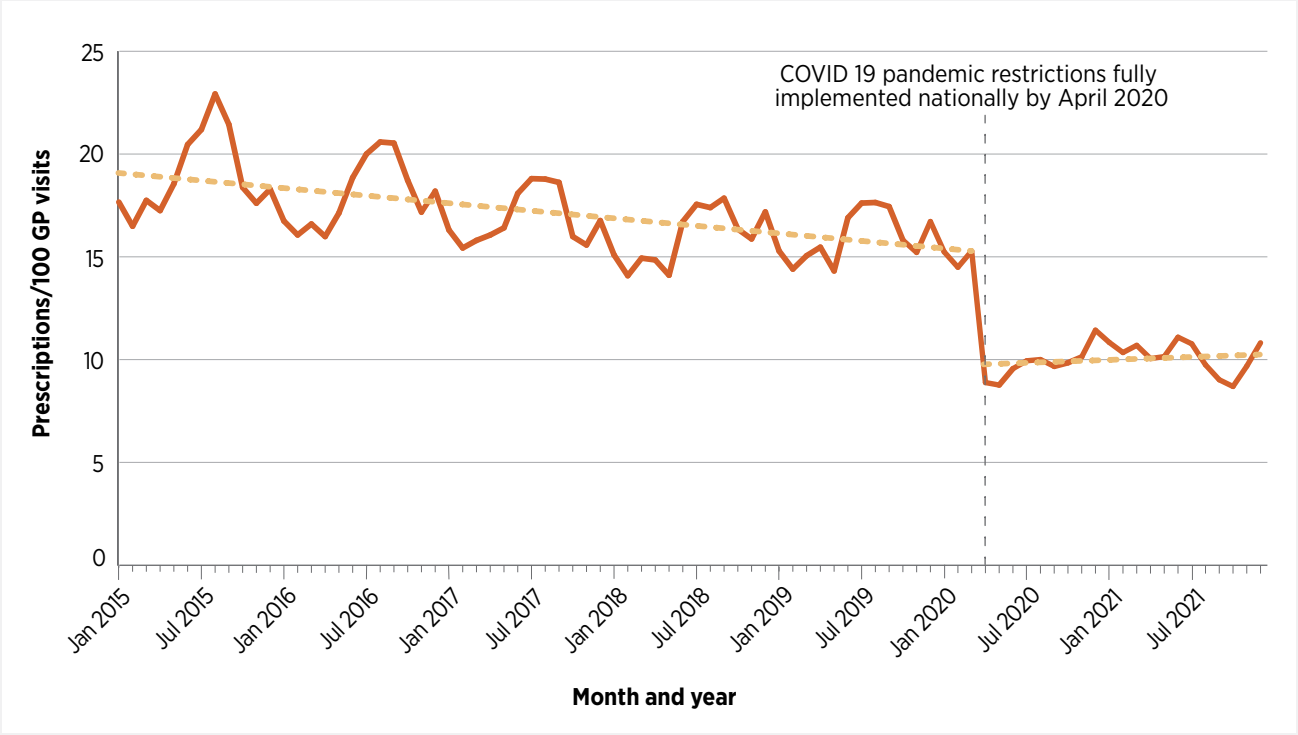
Sources: MedicineInsight[14], McCullough et al.[26]

Figure 3.35: Trends in systemic antibacterial prescribing rates for specific conditions, MedicineInsight practices, 2015–2021



COPD = chronic obstructive pulmonary disorder; URTI = upper respiratory tract infection; UTI = urinary tract infection
Source: MedicineInsight[14]

Figure 3.36: Monthly total antibacterial prescriptions per 100 GP visits, MedicineInsight practices, 2015–2021



GP = general practitioner
Source: MedicineInsight[14]

Antimicrobial use in aged care homes: Aged Care National Antimicrobial Prescribing Survey

In Australia, aged care services are primarily provided through Commonwealth Home Support, home care packages and permanent or respite residential care in aged care facilities. Residential aged care facilities are an important community setting for monitoring AU and AMR because of the significant prevalence of infections and colonisation caused by antimicrobial-resistant organisms in residents.[27] 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. Being residential, these facilities are a close living environment for residents in which they will likely be in frequent contact with potentially colonised or infected surfaces, staff or other residents. Residents may also have multiple or prolonged hospitalisations for the same reasons that make them susceptible to infections.

High levels of inappropriate antimicrobial prescribing and use in aged care homes are well documented.[15] The Aged Care NAPS is a standardised surveillance tool that can be used to monitor the prevalence of infections and AU in residential aged care facilities (specifically aged care homes and multi-purpose services). While Aged Care NAPS does not directly assess appropriateness of antimicrobial prescribing, considerations of elements such as PRN use and indications for prophylaxis have been used to comment on areas for improvement of prescribing in this report. Antimicrobials prescribed for PRN use are inconsistent with guidelines, and

antimicrobials prescribed for prophylaxis are only recommended in limited circumstances.

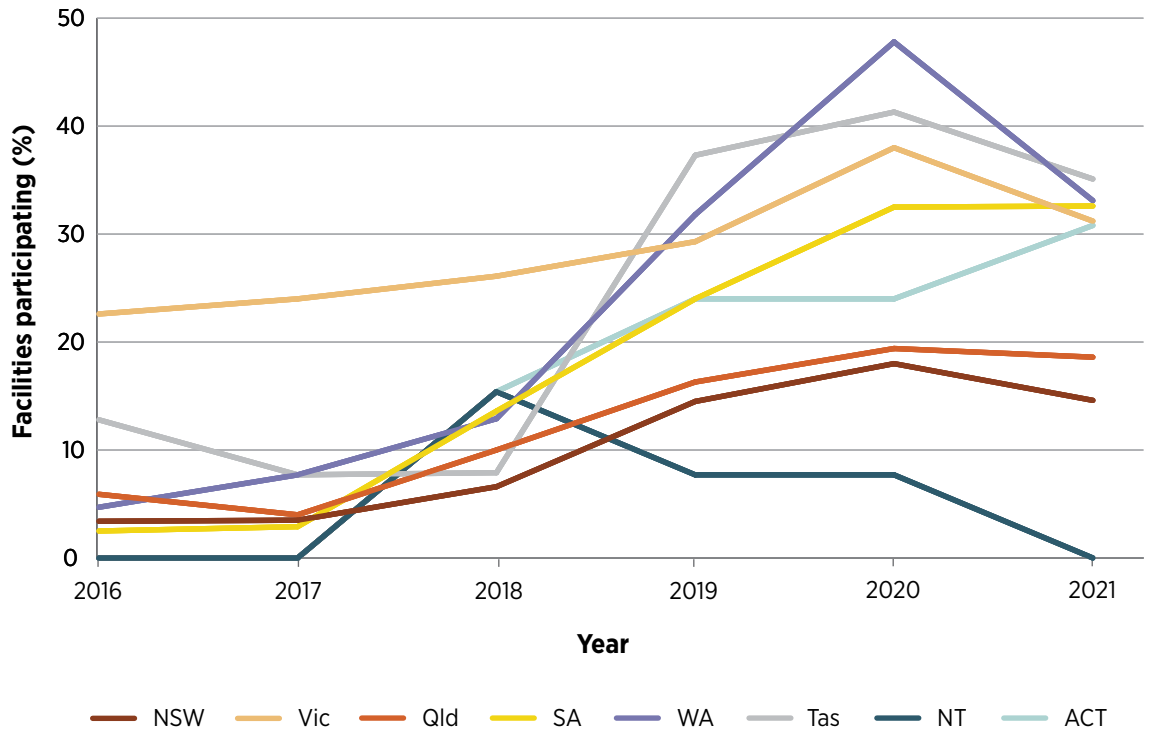
Participation in Aged Care NAPS supports residential facilities to identify areas for AU improvement, prevent infections and reduce AMR. Participation supports facilities to demonstrate compliance with the Aged Care Quality Standards for Clinical Care.[28] More information on Aged Care NAPS is included in Appendix 1.

Participation in Aged Care NAPS continues to increase across states and territories (Figure 3.37). In 2021, 689 aged care facilities (613 aged care homes and 76 multi-purpose services) collected and submitted Aged Care NAPS data at least once, and 18 facilities participated more than once.

The highlights of 2021 Aged Care NAPS data analyses are presented below.

For the facilities that participated from 2017 to 2021, there was a steady annual increase in the prevalence of residents prescribed one or more antimicrobials from 9.2% to 13.7% (Table 3.15). Additionally, only 3.1% of aged care residents exhibited signs and/or symptoms of suspected infections (Table 3.15).

Figure 3.37: Percentage of participating facilities within states and territories, Aged Care NAPS contributors, 2016–2021



NAPS = National Antimicrobial Prescribing Survey
Source: Aged Care NAPS Report 2021[15]

Table 3.15: Prevalence of suspected infections and antimicrobial use on the survey day, Aged Care NAPS contributors, 2017–2021

	2017		2018		2019		2020		2021	
Resident state of health	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
Prescribed at least one antimicrobial	1,047	9.2	1,913	9.8	3,499	9.9	5,601	11.9	5,555	13.7
Prescribed at least one antimicrobial (excluding PRN orders not administered in the last 7 days)	1,047	9.2	1,593	8.2	2,873	8.1	3,999	8.5	3,810	9.4
Prescribed at least one antimicrobial (excluding topical antimicrobials)	692	6.1	1,207	6.2	2,124	6	2,870	6.1	2,577	6.4
With signs and/or symptoms of at least one suspected infection	334	2.9	561	2.9	982	2.8	1,371	2.9	1,248	3.1
With signs and/or symptoms of at least one RACF-associated suspected infection	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1,222	3
Number of residents present	11,418	n/a	19,443	n/a	35,271	n/a	47,144	n/a	40,470	n/a

PRN = pro re nata (when required); n/a = not applicable; NAPS = National Antimicrobial Prescribing Survey; RACF = residential aged care facility
Notes:
1. RACF includes an aged care home or multi-purpose service.
2. RACF-associated suspected infection = infection that developed in resident 48 hours post (re) admission.
Source: Aged Care NAPS Report 2021[15]

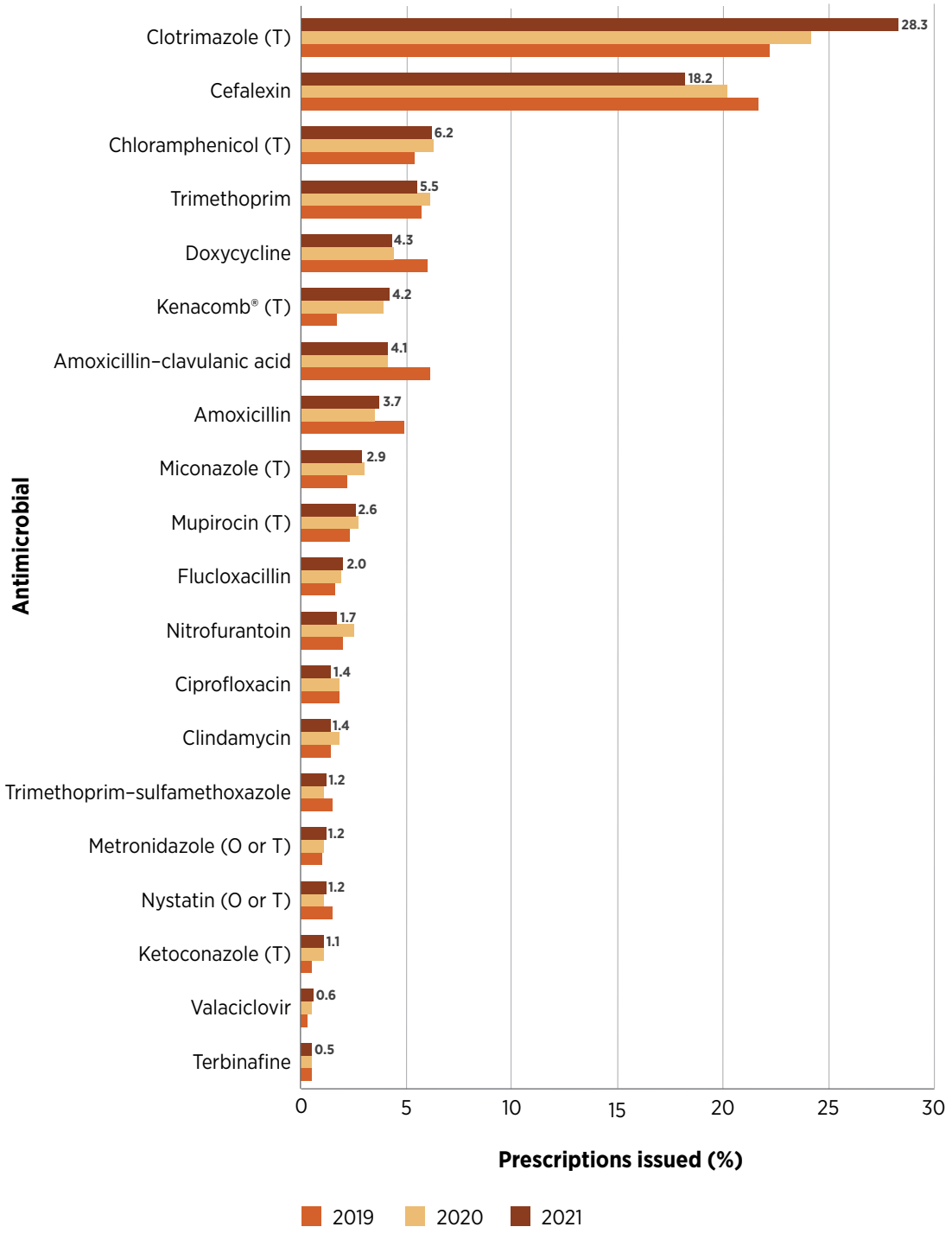
The 2021 Aged Care NAPS showed that 13.7% of aged care residents were prescribed antimicrobials. From 2017 to 2021, there was a steady annual increase in the prevalence of residents prescribed one or more antimicrobials, from 9.2% to 13.7%.

Prescribing patterns for the most common antimicrobials and conditions

In 2021, the three most commonly prescribed antimicrobials in aged care facilities were topical clotrimazole (28.3%), oral cefalexin (18.2%) and topical chloramphenicol (6.2%) (Figure 3.38). This is similar to previous years, although the percentage use of clotrimazole increased and the percentage use of cefalexin decreased between 2019 and 2021.

Just over one-third (35.1%) of antimicrobials still prescribed on the survey day were for pro-re-nata (PRN or as required) administration; the majority of these (92.3%) were for topical antimicrobials, most commonly clotrimazole (65.2%).

Figure 3.38: Most commonly prescribed antimicrobials, Aged Care NAPS contributors, 2019–2021



NAPS = National Antimicrobial Prescribing Survey; O = oral; T = topical
Notes:
1. Denominator used is all antimicrobials prescribed (*n* = 7,633).
2. Only top 20 antimicrobials prescribed listed (excluding methenamine hippurate).
3. Kenacomb® contains triamcinolone, neomycin, nystatin and gramicidin.
Source: Aged Care NAPS Report 2021[15]

The most commonly prescribed antimicrobials were for skin or soft tissue (*n* = 682), urinary tract (*n* = 287) and respiratory tract (*n* = 153) infections (Table 3.16). For Aged Care NAPS, data are collected about patients with infection signs or symptoms that meet internationally accepted surveillance criteria, also known as the McGeer et al. criteria.[29] In 2021, only 32.9% of suspected infections met the McGeer infection surveillance definitions.[15]

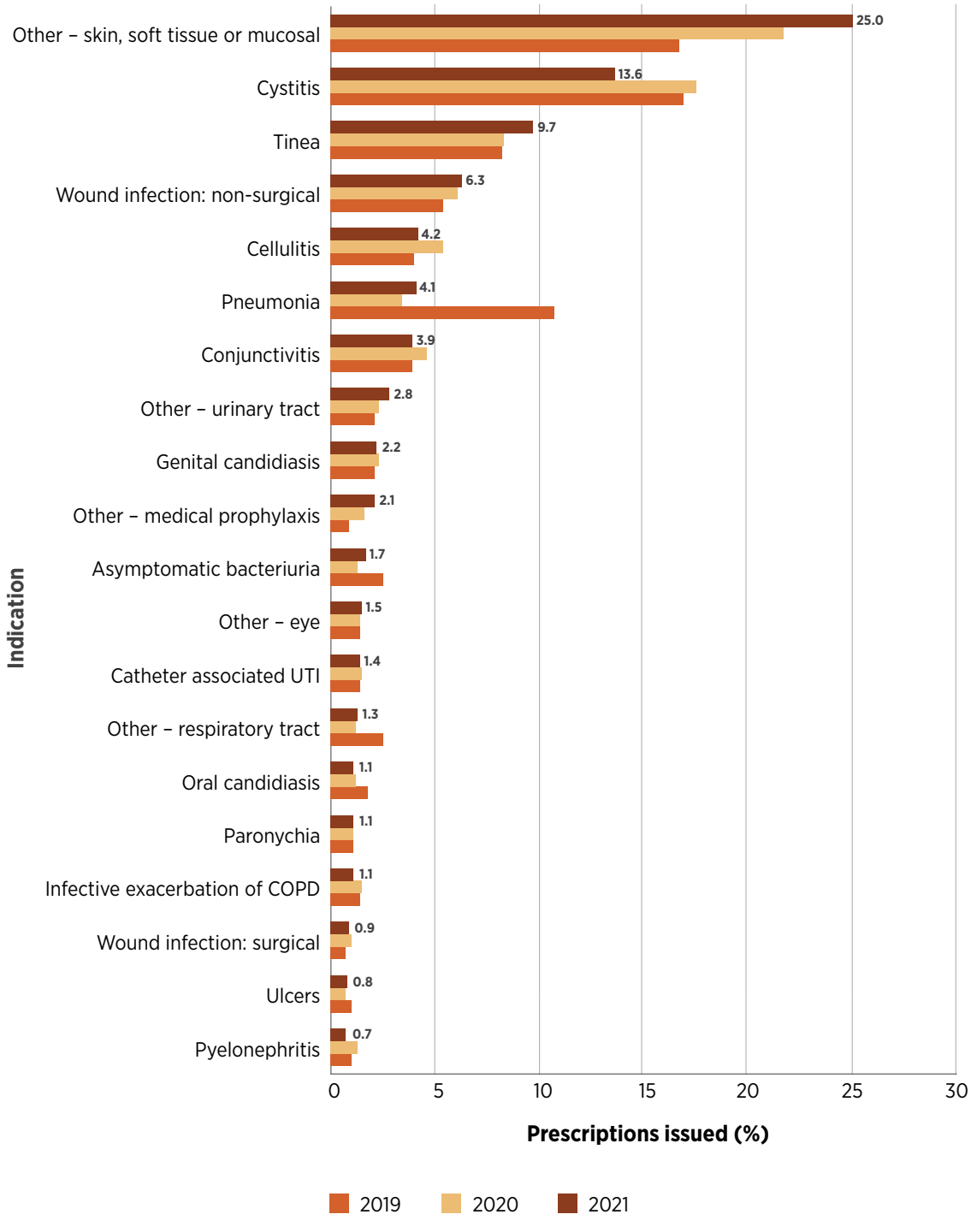
Table 3.16: Number and percentage of suspected infections by body system, Aged Care NAPS contributors, 2021

Body system	Number of suspected infections (*n*)	Number of suspected RACF-associated infections (*n*)	Suspected infections meeting McGeer et al. definition[29]		Suspected RACF-associated infections meeting McGeer et al. definition[29]	
			n	%	*n*	%
Skin or soft tissue	682	668	237	34.8	233	34.2
Respiratory tract	153	149	36	23.5	36	23.5
Urinary tract	287	278	25	8.7	25	8.7
Eye	80	79	66	82.5	66	82.5
Oral	31	31	4	12.9	4	12.9
Other body system/s	63	62	63	100	62	98.4
Total	**1,296**	**1,267**	**431**	**33.3**	**426**	**32.9**

NAPS = National Antimicrobial Prescribing Survey; RACF = residential aged care facility
Note: RACF associated suspected infection = infection that developed in resident 48 hours post (re) admission.
Source: Aged Care NAPS Report 2021[15]

The most common clinical (therapeutic or prophylactic) indications for antimicrobial prescriptions were for unspecified skin, soft tissue or mucosal conditions (25%), cystitis (13.6%) and tinea (9.7%) (Figure 3.39). On the survey day, 3.1% of residents had signs and/or symptoms of a suspected infection. The most commonly reported suspected infections on the survey day were skin or soft tissue (52.6%), urinary tract (22.1%) and respiratory tract (11.8%).

Figure 3.39: Most common indications for antimicrobial prescriptions, Aged Care NAPS contributors, 2019–2021



COPD = chronic obstructive pulmonary disease; NAPS = National Antimicrobial Prescribing Survey; UTI = urinary tract infection
Notes:
1. Only the top 20 indications for antimicrobial prescriptions are listed.
2. Unknown indications for commencing an antimicrobial are excluded.
Source: Aged Care NAPS Report 2021[15]

Duration of antimicrobial prescriptions

Antimicrobials should be used for the shortest possible effective duration of therapy. The prolonged use of antimicrobials can cause gastrointestinal issues for patients and contribute to AMR, which is a concern. Continuous prophylactic therapy, such as cefalexin for UTIs, is generally not appropriate.

Of antimicrobials taken on the survey day, 42.1% (*n* = 2,679) were commenced more than six months prior. Of antimicrobials commenced more than six months prior (*n* = 2,679), 33.2% (*n* = 890) were oral. These oral antimicrobials, such as cefalexin for UTI prophylaxis, have limited evidence for their use and have increased risks of adverse effects and AMR, especially when taken for prolonged periods.

In 2021, 26.5% of prescriptions did not have an indication documented (an increase from 2020) and 55.3% of prescriptions did not have a review or stop date documented (an increase from 2020).

The 2021 Aged Care NAPS report identified minimal improvement in key quality indicators observed for facilities that participated in Aged Care NAPS over time (Table 3.17).

Table 3.17: Key quality indicators for all participating facilities, Aged Care NAPS contributors, 2017–2021

	2017		2018		2019		2020		2021	
Indicator	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
Indication for prescribing an antimicrobial										
Documented	1,153	79.1	1,895	76.8	3,378	73.1	5,783	76.4	5,613	73.5
Not documented	304	20.9	574	23.2	1,242	26.9	1,790	23.6	2,023	26.5
Review or stop date										
Documented	776	53.3	1,157	46.9	2,506	54.2	3,458	45.7	3,414	44.7
Not documented	681	46.7	1,312	53.1	2,114	45.8	4,115	54.3	4,222	55.3
Total	**1,457**	**–**	**2,469**	**–**	**4,620**	**–**	**7,573**	**–**	**7,636**	**–**

NAPS = National Antimicrobial Prescribing Survey
Source: Aged Care NAPS Report 2021[15]

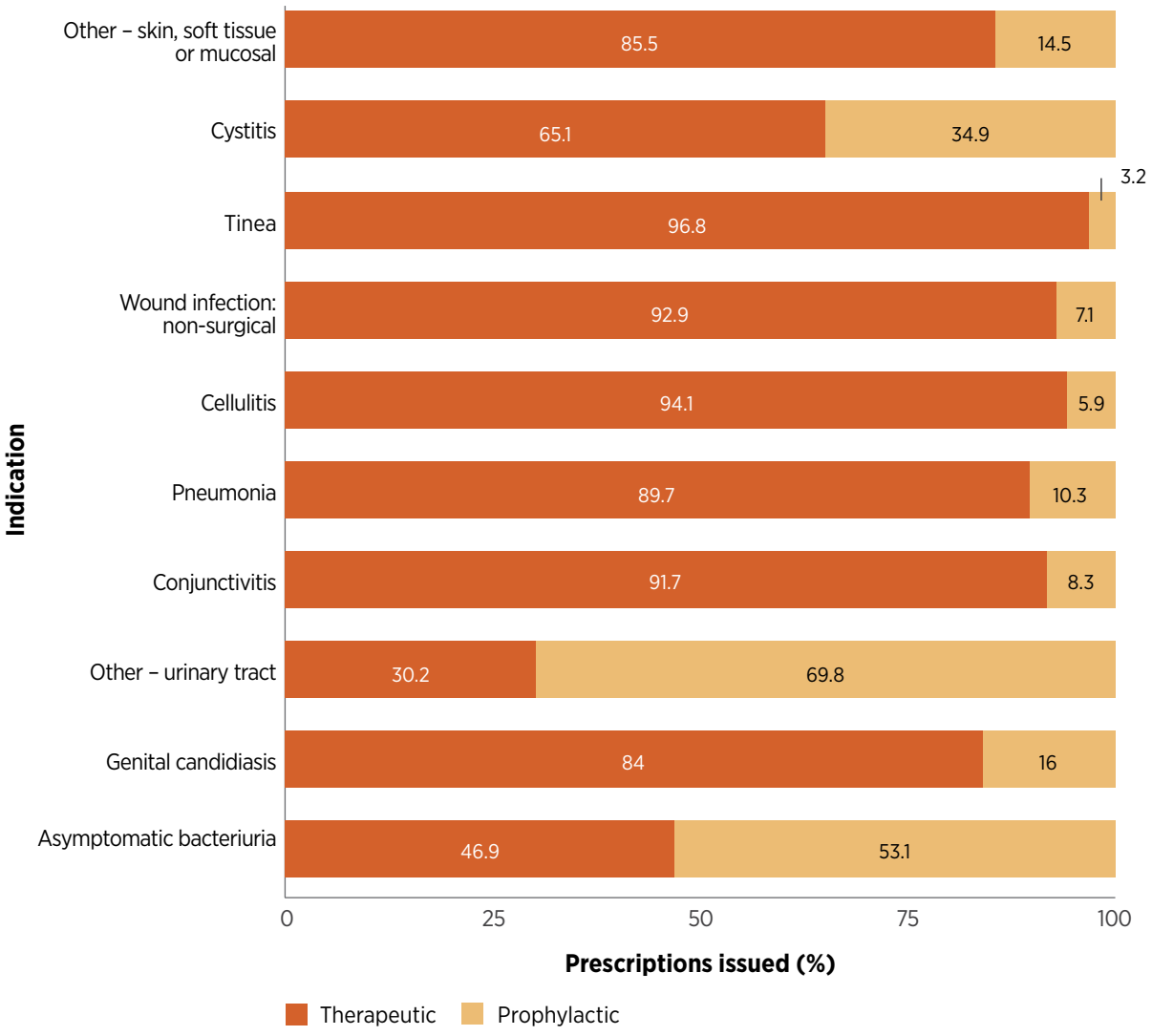
Patterns of prophylaxis prescribing

In 2021, just over one-fifth of antimicrobial prescriptions in aged care facilities were for prophylactic use (1,701/5,611, 22.3%) (Figure 3.40). The most common prophylactic indications were cystitis (21.3%), unspecified skin, soft tissue or mucosal conditions (16.3%) and unspecified medical prophylaxis conditions (8.8%).[15]

Of all antimicrobials prescribed for cystitis in aged care facilities in 2021 (*n* = 1,039), just under two-thirds (65.1%) were for therapeutic indications (*n* = 676) (Figure 3.40).

In 2021, 22.3% of antimicrobial prescriptions in aged care facilities were for prophylactic use, the most common being for cystitis. Of all antimicrobials prescribed for cystitis, just under two-thirds (65.1%) were for therapeutic indications; the remaining were for prophylaxis.

Figure 3.40: Comparison of therapeutic and prophylactic antimicrobial prescriptions or common indications, Aged Care NAPS contributors, 2021



NAPS: National Antimicrobial Prescribing Survey
Notes:
1. Only top 10 indications for prophylactic antimicrobial prescriptions are listed.
2. Medical Prophylaxis and Unknown indications for commencing an antimicrobial are excluded.
Source: Aged Care NAPS Report 2021[15]

An update on *Clostridioides difficile* infection in Australia

Clostridioides difficile infection (CDI), also known as *Clostridium difficile* infection, is a significant but preventable healthcare-associated infection (HAI) that is associated with AU and healthcare exposure.[30] *C. difficile* is a gram-positive, spore-forming bacterium, commonly found in the environment and in animals as well as asymptomatic infected people.[31,32] Asymptomatic colonisation with *C. difficile* spores in humans is common and can develop into symptomatic infection if spores proliferate. Symptomatic CDI results in fever, abdominal pain, nausea, vomiting and diarrhoea. Infections range from mild to severe and can cause colitis, toxic megacolon, pseudomembranous colitis and death.[32,33]

The risk factors for CDI infection include AU, age over 65 years, recent hospitalisation and underlying chronic medical conditions. AU is the most important and modifiable risk factor.[32,34] The onset of CDI can occur between 4 and 12 weeks after exposure to antimicrobial treatments[32,35] that alter gut flora and gastric pH and can trigger spore proliferation and the resulting development of symptomatic disease.[33] Almost all antimicrobial classes have been associated with the development of CDI, especially those that disrupt normal gut flora.[32,36,37] The risk of developing CDI within four weeks of AU is up to 10 times greater than for someone who has not previously received antimicrobials.[32] This risk increases further if the duration of AU is prolonged, and if multiple antimicrobial classes are used.[38]

C. difficile is recognised as a global health concern and the United States Centers for Disease Control and Prevention (CDC) has listed CDI as an urgent antimicrobial resistance (AMR) threat in the United States.[39] Resistance patterns for *C. difficile* in Australia have been monitored through the *Clostridioides difficile* Antimicrobial Resistance Surveillance (CDARS) study since 2015.[40,41] CDARS data show that most *C. difficile* strains detected in Australia have not developed resistance to the recommended antimicrobial treatments for CDI. However, CDI is a significant burden on the Australian health system. Hospitalisation with a CDI diagnosis in an Australian public hospital is estimated to cost $12,704[42], with an average length of stay of 7–15 days.[43]

In Australia, CDI is not notifiable. The Commission has monitored CDI in Australian public hospitals since 2016, using data from the Admitted Patient Care National Minimum Data Set (APC NMDS).[43]

In the APC NMDS, CDI diagnoses are categorised as either a principal diagnosis or a non-principal diagnosis. A non-principal diagnosis is further classified by condition onset flags (COFs). These terms are defined as follows:

- A **principal CDI diagnosis** describes the primary condition resulting in a hospital admission. This may include cases of CDI that develop in the community or may be attributed to a previous hospital admission.[44,45]
- A **non-principal CDI diagnosis** describes a condition that may have contributed to the admission to hospital but is not the main reason for admission. This includes cases of CDI that develop during an inpatient admission.[44,46,45]
- A **non-principal CDI diagnosis with a COF1** refers to a condition that has arisen during the episode of admitted care that would not have been present or suspected on hospital admission.[45] Separations coded as a non-principal CDI diagnosis with a COF1 may be described as healthcare-associated inpatient-onset CDI.
- A **non-principal CDI diagnosis with a COF2** refers to a condition that was previously existing or suspected on admission, such as the presenting problem, a comorbidity or chronic disease.[47] Separations coded as non-principal CDI diagnoses with a COF2 may describe either a healthcare-associated community-onset CDI or a community-associated CDI.
- The term **separation** describes the completion of a patient's care from hospital by discharge, death or transfer.[47]

CDI burden in Australian public hospitals, 2019–2021

Between 2019 and 2021, the number of separations with a CDI diagnosis fluctuated, as did total hospital separations for all diagnoses.[48] Separations declined in 2020 compared with 2019, which may have been influenced by the introduction of COVID-19 restrictions. In comparison, the number of separations for all categories of CDI diagnoses increased in 2021 and was greater than the number observed in 2019 (Table A).

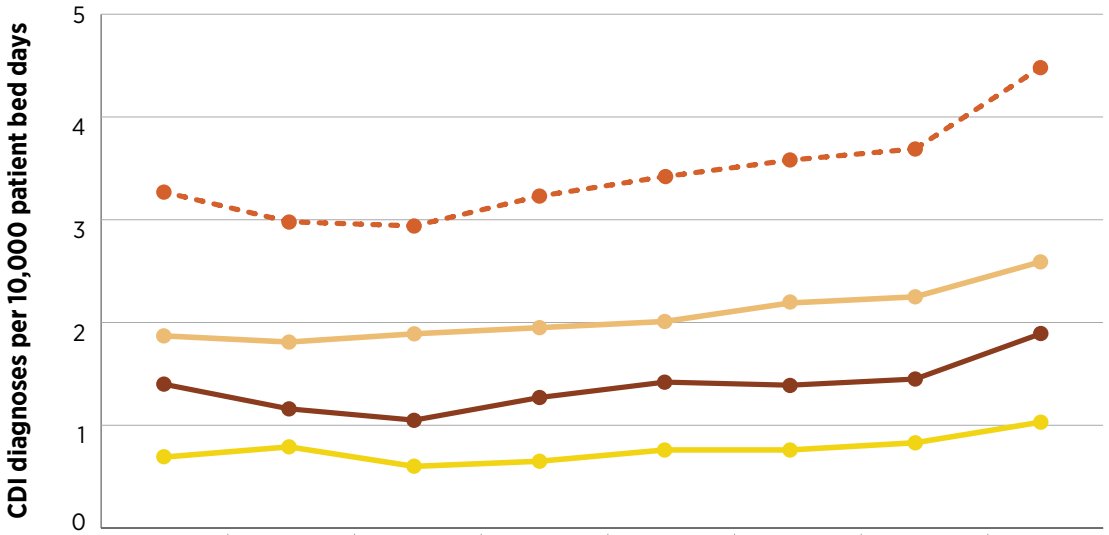
Approximately 80% of separations coded with a CDI diagnosis in 2020 and 2021 were for patients with pre-existing CDI symptoms on admission to hospital. In 2020, there were 6,630 separations with pre-existing CDI, and this increased to 8,499 separations in 2021. The rate of community-onset CDI increased from 2020 to 2021 (Figure A), which suggests that CDI is a more significant health issue in the community than previously understood.[31,43,50]

Table A: Total number of hospital separations and CDI-related separations in Australian public hospitals*, 2019–2021

Number of separations	2019	2020	2021
Australian public hospitals (all diagnoses)	7,504,330	7,242,690	7,580,271
All CDI diagnoses	8,607	8,127	10,512
Principal CDI diagnoses	2,708	2,644	3,551
Non-principal CDI diagnoses	5,899	5,483	6,961
Non-principal CDI diagnosis, with COF1*	1,699	1,371	1,835
Non-principal CDI diagnosis, with COF2*	4,010	3,986	4,948
Pre-existing CDI symptoms (Principal CDI + non-principal CDI with COF2*)	6,664	6,630	8,499

CDI = *Clostridioides difficile* infection; COF = condition onset flag
*Australian public hospitals with highly reliable COF coding only (*n* = 547 in 2019; *n* = 502 in 2020; *n* = 519 in 2021)
Sources: *Clostridioides difficile* infection 2019 Data Snapshot Report, *Clostridioides difficile* infection: Data snapshot report 2020–2021[48, 49]

Figure A: Estimated rates of pre-existing *Clostridioides difficile* infection in Australian public hospital patients*, by diagnostic category, by quarter, 2020–2021



	2020 Q1	2020 Q2	2020 Q3	2020 Q4	2021 Q1	2021 Q2	2021 Q3	2021 Q4
Estimated rate of separations with pre-existing CDI	3.27	2.98	2.94	3.23	3.42	3.58	3.69	4.48
Non-principal CDI diagnoses with COF2	1.87	1.81	1.89	1.95	2.01	2.19	2.25	2.59
Principal CDI diagnoses	1.4	1.16	1.05	1.27	1.42	1.39	1.45	1.89
Non-principal CDI diagnoses with COF1	0.69	0.79	0.6	0.65	0.76	0.76	0.83	1.03

CDI = *Clostridioides difficile* infection; COF = condition onset flag; Q1–4 = quarter of the year (Q1 January to March, Q2 April to June, Q3 July to September, Q4 October to December)
* Australian public hospitals with highly reliable COF coding only (*n* = 502 in 2020; *n* = 519 in 2021)
Source: *Clostridioides difficile* infection: Data snapshot report 2020–2021[48]

Impact of the COVID-19 pandemic on CDI rates in Australian public hospitals

It is not clear to what extent the COVID-19 pandemic and its impact on health service provision in Australia directly affected rates of CDI in 2020 and 2021, particularly the increase observed from 2020 to 2021.

In the community, there were fewer face-to-face GP and medical specialist consultations, and the use of telehealth increased in association with the introduction by the Australian Government of Medicare Benefits Schedule items for telehealth and video consultations to improve access to healthcare services and reduce opportunities for infection transmission.[14] In acute health service organisations, elective surgery was suspended.[51] These changes to health service provision during 2020, and the reintroduction of health services such as elective surgery in 2021, likely impacted the total number of separations for all diagnoses during those years.

During the pandemic response period, AU in the community decreased by 25.3% between 2019 and 2021, and prescriptions for antimicrobials were issued at a lower rate compared with before the pandemic.[14] A greater awareness and enhancement of infection prevention and control practices in health service organisations may have reduced the risk of hospital-onset CDI in 2020.[14,33]

Key messages:

- Community-onset CDI is a larger health concern in Australia than previously recognised.
- Simple, organisation-wide antimicrobial stewardship and infection prevention and control interventions are effective in reducing the development and transmission of CDI in hospitals.

What can be done to reduce the risk of CDI in the community?

Community and primary health pathways are important tools for providing clinical management information for primary and community care providers during patient consultations. Ensuring that these health pathways include information on the diagnosis and management of CDI will support GPs and other primary healthcare clinicians to contribute to reducing the burden of community-onset CDI. In addition, promoting appropriate antimicrobial prescribing in primary care will reduce the risk of community-onset CDI in the future.[50,52,53]

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Chapter 4

Antimicrobial resistance

Antimicrobial resistance

Key findings

- National rates of antimicrobial resistance (AMR) for many priority organisms have not changed substantially from those reported in AURA 2021. However, several changes in resistance are important to consider for infection prevention and control, and antimicrobial prescribing.
- In *Escherichia coli*, resistance to ciprofloxacin declined in all states and territories except Tasmania. The rate of resistance began to stabilise, except in remote and very remote areas, where resistance continued to increase. Meropenem resistance has remained low. In blood culture isolates, ciprofloxacin resistance decreased nationally by just under a quarter from 2020 to 2021.
- In *Enterobacterales*, rates of resistance were lower in the community than in hospitals for most antimicrobial agents. The rates were similar for public and private hospitals, except for resistance to cefazolin, which was higher in private hospitals. The rates in aged care homes were as high as, or higher than, rates in hospitals. Carbapenem resistance remains uncommon and is found more often in the *Enterobacter cloacae* complex than in *E. coli* or *Klebsiella pneumoniae*.
- In *Neisseria gonorrhoeae*, the rates of azithromycin resistance have declined since 2017, with resistance at 4.7% in 2021. The total number of notified cases also declined in 2021.
- In *N. meningitidis*, the lowest number of notified cases was reported in 2021 since 1991 when records began. Reduced susceptibility to benzylpenicillin has declined from 44.9% in 2017 to 13.0% in 2021. Full resistance to benzylpenicillin was not observed in 2021.
- In *Salmonella*, ciprofloxacin resistance in typhoidal species (*Salmonella* Typhi and *Salmonella* Paratyphi) exceeded 74% in 2020, 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* (MRSA) has become prominent across all states and territories. This demonstrates the need for a renewed focus on infection prevention and control in both community and acute settings. As a percentage of all MRSA strains, community-acquired MRSA clones increased to 85% in 2020–2021, compared with 77% in 2018.

continues

- In *Streptococcus agalactiae*, resistance to erythromycin and clindamycin has steadily increased to around 35% in 2021. In *S. pyogenes*, macrolide resistance has more than doubled since 2017 to 9% in 2021, reducing the utility of these second-line agents.
- In *Shigella sonnei*, resistance to ceftriaxone, ciprofloxacin and ampicillin has reduced since 2020. Rates in 2021 were similar to those of 2017, after rapid increases in 2018 and 2019.

4.1 Introduction

Antimicrobial-resistant bacteria and their resistance genes can spread readily between people in the community, primary care services, hospitals and aged care homes. It can happen rapidly and often goes 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 are communicated about and managed appropriately.

This chapter provides analyses of data from:

- Australian Group on Antimicrobial Resistance (AGAR)
- Australian Passive AMR Surveillance (APAS)
- HOTspots program
- National Neisseria Network (NNN) on *N. gonorrhoeae* and *N. meningitidis*
- National Notifiable Diseases Surveillance System (NNDSS) on *Mycobacterium tuberculosis*
- Sullivan Nicolaides Pathology (SNP).

These data are sourced from hospitals, aged care homes and the community. The results have been compiled for each of the 13 human health priority organisms determined for the Antimicrobial Use and Resistance in Australia Surveillance System (AURA). All data are analysed in such a way as to avoid any possible duplication where more than one source may be available.

Information on the methods used by each of the sources for data on AMR in this report, including information on processes and limitations, is included in Appendix 1. The priority organisms for surveillance of antimicrobial resistance in human health are described in Appendix 2.

The resistance rates to all antimicrobials tested, as well as tables with more detailed information, can be found in *AURA 2023: Supplementary data*.

Data on priority organisms

Table 4.1 provides a list of the priority organisms and a summary of the data sources for each. A summary of the AMR prevalence for the priority organisms is provided in *AURA 2023: Supplementary data.*

Table 4.1: Priority organisms and respective data sources included in this report, 2020–2021

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

AGAR = Australian Group on Antimicrobial Resistance (national public and private hospitals); APAS = Australian Passive AMR Surveillance (national public hospitals and health services [except the NT], private pathology service Queensland, private hospitals in SA; HOTspots (public hospitals and community health services in the NT); 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 (Queensland and northern NSW communities, private hospitals and aged care homes)

In 2020–2021, physical distancing and travel restrictions imposed as public health measures in response to the COVID-19 pandemic had a substantial impact on many communicable diseases in Australia, including the priority organisms outlined in this chapter.

4.2 *Acinetobacter baumannii* complex

This section describes the health impact and treatment of the *Acinetobacter 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

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

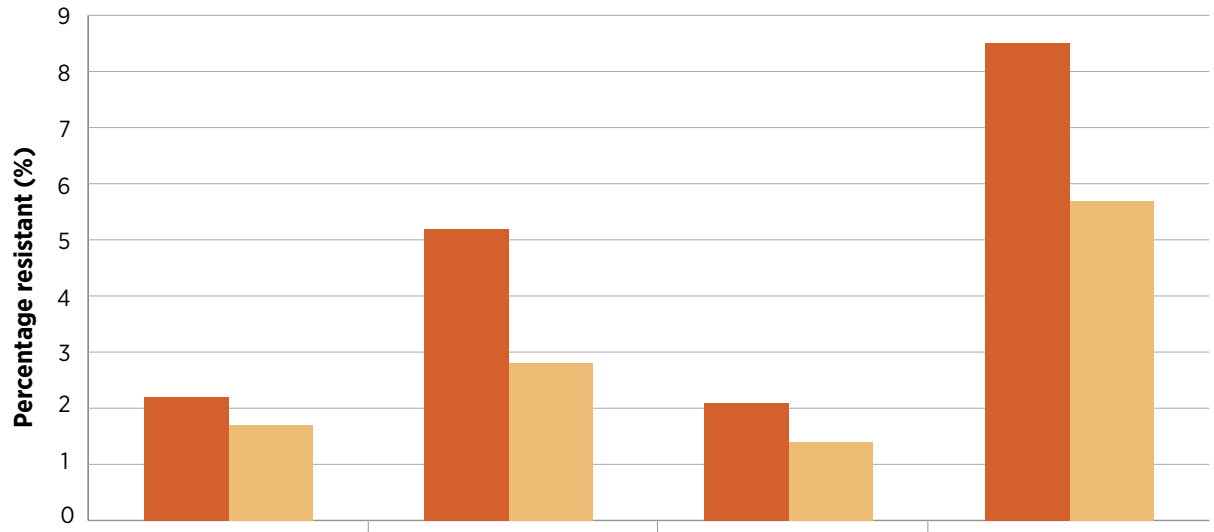
Types and impact of resistance

The members of the *A. baumannii* complex have a high propensity for developing resistance to multiple antimicrobials, including broad-spectrum agents such as carbapenems. They may be only susceptible to potentially toxic antimicrobials, such as colistin. Even this agent can be problematic because of hetero-resistance (strains that naturally harbour resistant sub-populations), which requires combination treatment with other antimicrobials.

Key findings: national

Rates of resistance to key antimicrobial agents remained low in 2020 and 2021 (Figure 4.1) – often less than 5%. Resistance rates varied between hospitals and community settings (Figure 4.2).

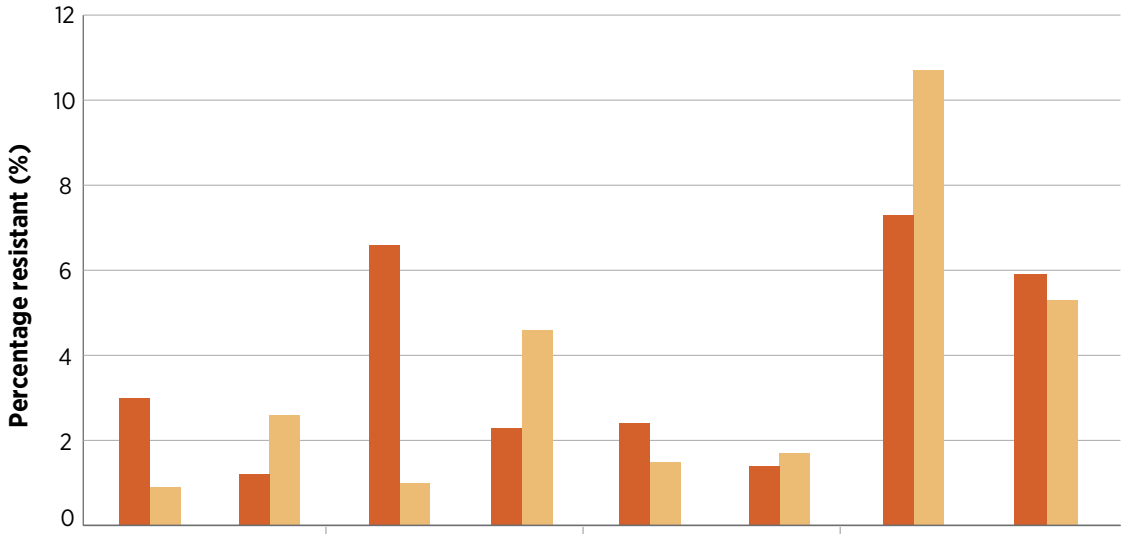
Figure 4.1: *Acinetobacter baumannii* complex resistance, 2020–2021



	Gentamicin	Ciprofloxacin/ norfloxacin	Meropenem	Trimethoprim–sulfamethoxazole
2020, %	2.2	5.2	2.1	8.5
2021, %	1.7	2.8	1.4	5.7
2020, *n*	2,025	871	1,872	1,821
2021, *n*	2,242	1,011	2,090	2,070

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

Figure 4.2: *Acinetobacter baumannii* complex resistance, by clinical setting, 2020–2021



	Gentamicin 2020	Gentamicin 2021	Ciprofloxacin/ norfloxacin 2020	Ciprofloxacin/ norfloxacin 2021	Meropenem 2020	Meropenem 2021	Trimethoprim–sulfamethoxazole 2020	Trimethoprim–sulfamethoxazole 2021
Hospitals (public and private), %	3.0	1.2	6.6	2.3	2.4	1.4	7.3	5.9
Community, %	0.9	2.6	1.0	4.6	1.5	1.7	10.7	5.3
Hospitals, *n*	1,282	1,375	648	735	1,221	1,327	1,191	1,313
Community, *n*	673	801	190	224	585	702	563	698

Sources: AGAR, APAS and HOTspots (public hospitals); APAS (Qld, SA) and SNP (private hospitals); APAS, HOTspots 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, *E. coli* and *K. pneumoniae* complex are the most common and important species and cause both community- and hospital-associated infections. The *E. cloacae* complex is a common pathogen group in hospital care. *Enterobacterales* also includes *Salmonella* and *Shigella* species, which are reported on separately in Sections 4.9 and 4.10, respectively.

E. coli, *K. pneumoniae* complex and *E. cloacae* complex are associated with a variety of infections, including urinary tract infections (UTIs), biliary tract infections, other intra-abdominal infections (including those following surgery, and often mixed with other pathogens) and bacteraemia. *E. coli* is the

most common cause of UTI and bacteraemia in the community and in otherwise healthy people. These three species can also cause meningitis, and bacteraemia from intravascular lines.

Treatment

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

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 the community in Australia, making these strains resistant to ampicillin and amoxicillin. Both *K. pneumoniae* and *E. cloacae* complexes contain intrinsic β-lactamases that make them naturally resistant to ampicillin and amoxicillin. In addition, the intrinsic β-lactamase of the *E. cloacae* complex makes this species resistant to first-generation cephalosporins, such as cefazolin and cefalexin, and the enzyme can be easily upregulated 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 (MDR).

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

E. coli, *K. pneumoniae* and *E. cloacae* complexes have the 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 for capturing and accumulating resistance genes (integrons), giving them the capacity to become multidrug-resistant. Few antimicrobial agents are available for the treatment of highly MDR strains, and all are more toxic than β-lactams.

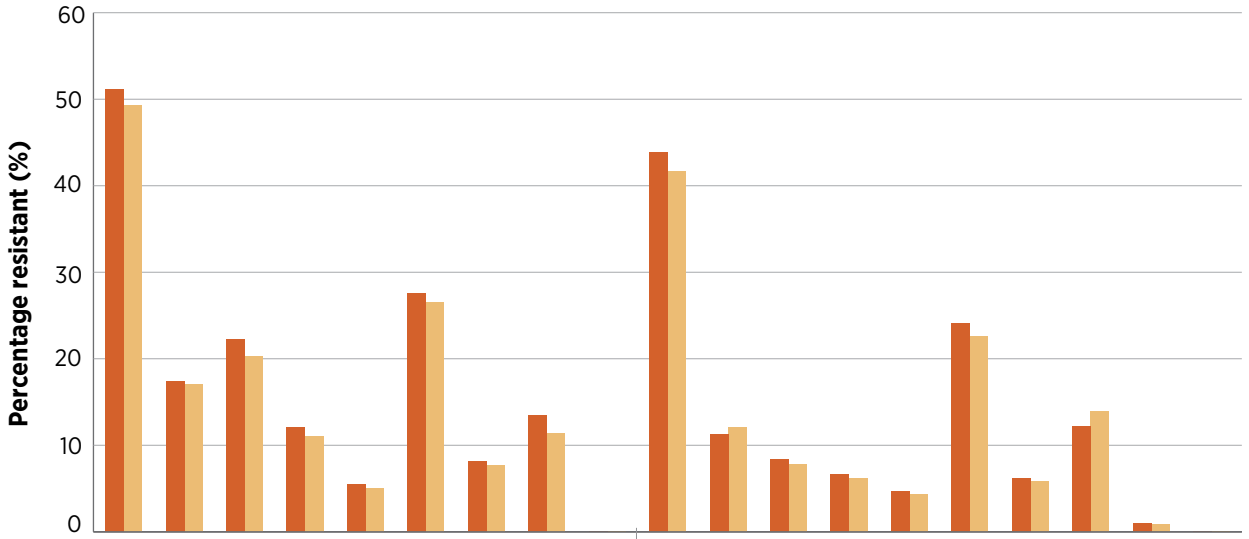
Key findings: national

As observed in previous AURA reports, in 2020–2021 there were no substantial differences in resistances between specimen sources (blood and urine) for any of the three reported species. Resistance to ampicillin (and therefore amoxicillin) remains the most common resistance in *E. coli*, and is intrinsic in *K. pneumoniae* and *E. cloacae* complexes. Resistance of *E. coli* to amoxicillin–clavulanic acid was stable in 2020 (11–17%) and 2021 (12–17%) (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 rates of *E. coli* to third-generation cephalosporins (ceftriaxone or cefotaxime) was 7–12% in 2020 and 6–11% in 2021. Resistance rates of *K. pneumoniae* were 3–6% in 2020 and 4–5% in 2021. In the *E. cloacae* complex, ceftriaxone/cefotaxime resistance was found in 28–32% (Figure 4.7), mostly resulting from stably derepressed mutants of its intrinsic cephalosporinase. The resistance rate to cefepime in this species (3% in 2020; 5% in 2021) is an indication of the proportion of this complex that harbours ESBLs. The fluoroquinolone (ciprofloxacin or norfloxacin) resistance rates in *E. coli* were 12–14% in 2020 and 11–14% in 2021. The resistance rates in *K. pneumoniae* were 6–8% in 2020 and 7% in 2021. The resistance rates in the *E. cloacae* complex were 6–9% in 2020 and 5–8% in 2021. The rates of resistance to carbapenems (meropenem) were less than 0.1% in *E. coli*, less than or equal to 0.3% in *K. pneumoniae*, but 1–2% in the *E. cloacae* complex (Figures 4.3, 4.5 and 4.7).

Rates of resistance were lower in community settings than in hospitals for most agents with available data (Figures 4.4, 4.6 and 4.8). Except for resistance to cefazolin, the rates in public and private hospitals were similar. For many antimicrobial agents, resistance rates in aged care homes were similar to rates in hospitals (Figures 4.4, 4.6 and 4.8).

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

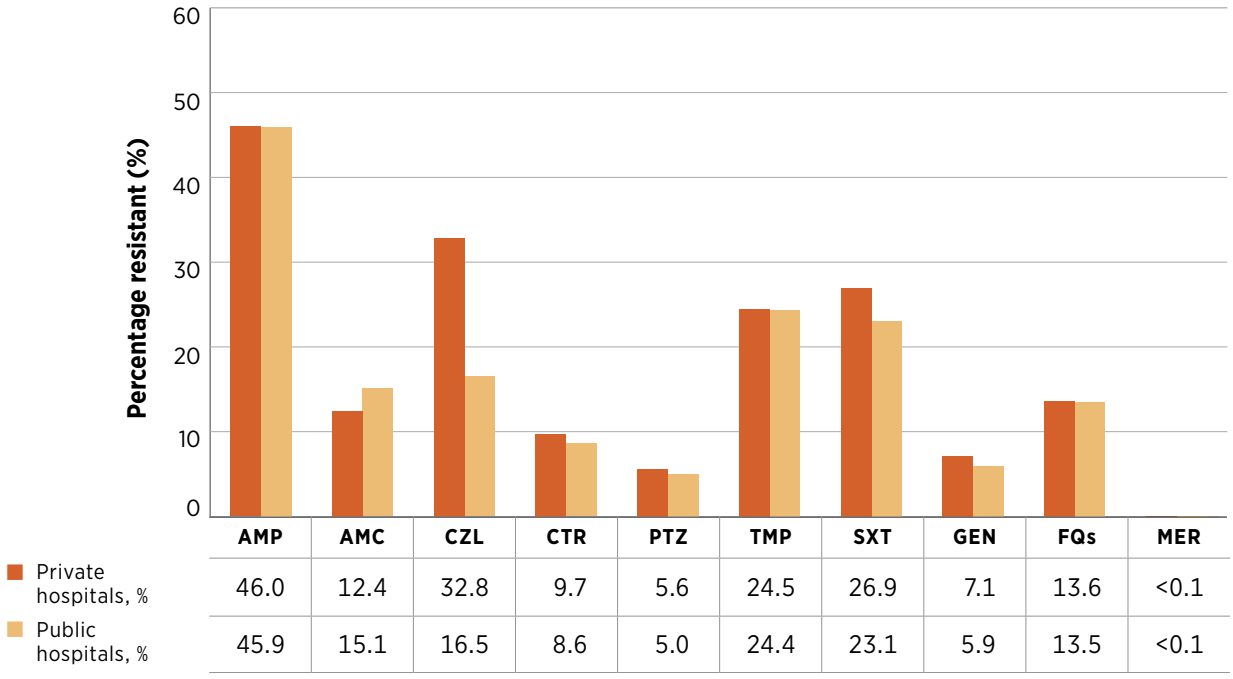
Figure 4.3: *Escherichia coli* acquired resistance, by specimen source, 2020–2021



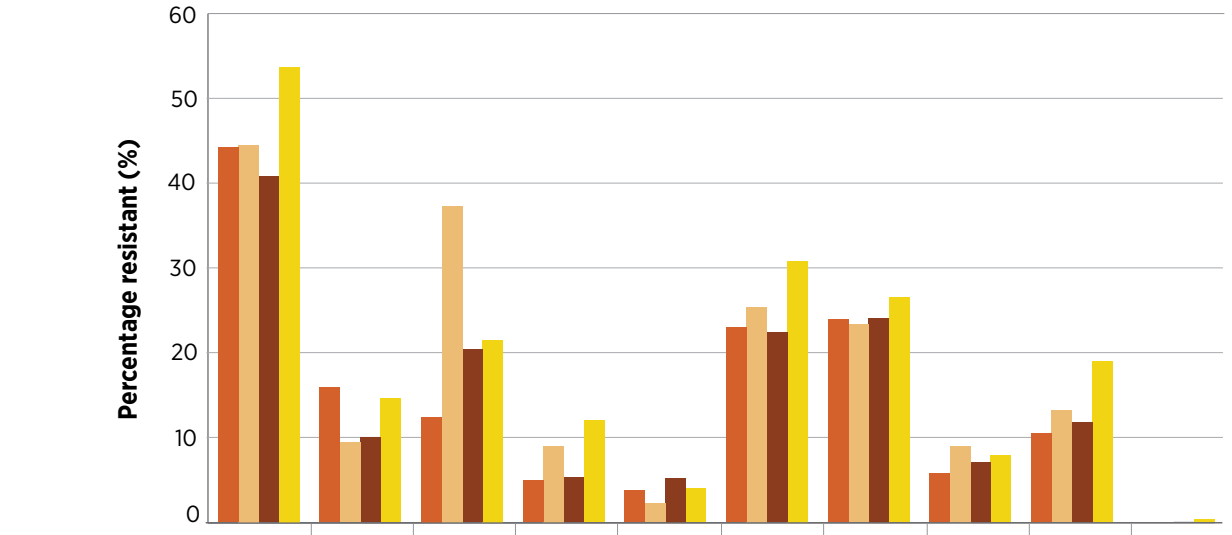
	Blood									Urine									
	AMP	AMC	CZL	CTR	PTZ	SXT	GEN	FQs	MER	AMP	AMC	CLX	CTR	PTZ	TMP	GEN	FQs	NIT	MER
2020, %	51.2	17.4	22.2	12.1	5.5	27.6	8.1	13.5	<0.1	43.9	11.3	8.4	6.7	4.7	24.1	6.2	12.2	1.0	<0.1
2021, %	49.3	17.1	20.3	11.0	5.0	26.5	7.7	11.4	<0.1	41.7	12.1	7.8	6.2	4.3	22.6	5.8	13.9	0.9	<0.1

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); HOTspots (NT); SNP (Qld, northern NSW)

Figure 4.4: *Escherichia coli* acquired resistance, by clinical setting, 2020 and 2021 combined



	AMP	AMC	CZL	CTR	PTZ	TMP	SXT	GEN	FQs	MER
Private hospitals, %	46.0	12.4	32.8	9.7	5.6	24.5	26.9	7.1	13.6	<0.1
Public hospitals, %	45.9	15.1	16.5	8.6	5.0	24.4	23.1	5.9	13.5	<0.1



	AMP	AMC	CZL	CTR	PTZ	TMP	SXT	GEN	FQs	MER
Multi-purpose service, %	44.2	15.9	12.4	4.9	3.7	23.0	23.9	5.7	10.5	0.00
Aged care homes, %	44.5	9.4	37.3	9.0	2.2	25.4	23.3	9.0	13.2	0.00
Community, %	40.8	10.0	20.4	5.3	5.2	22.4	24.1	7.1	11.8	<0.1
Other, %	53.7	14.6	21.5	12.0	4.0	30.8	26.5	7.9	19.0	0.31

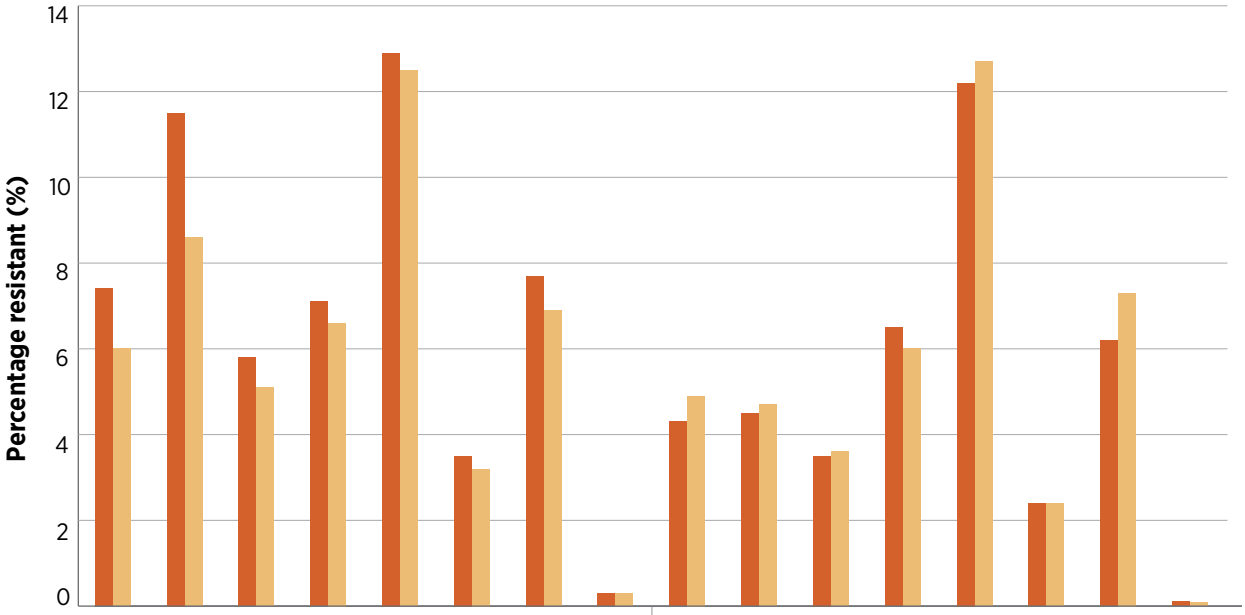
AMC = amoxicillin–clavulanic acid; AMP = ampicillin; CTR = ceftriaxone/cefotaxime; CZL = cefazolin; FQs = ciprofloxacin/norfloxacin; GEN = gentamicin; MER = meropenem; PTZ = piperacillin–tazobactam; SXT = trimethoprim–sulfamethoxazole; TMP = trimethoprim

Notes:

1. For clarity of presentation, data for 2020 and 2021 have been combined. Raw data for the individual years are available in *AURA 2023*: *Supplementary data*.
2. Other settings were predominantly corrective services.

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

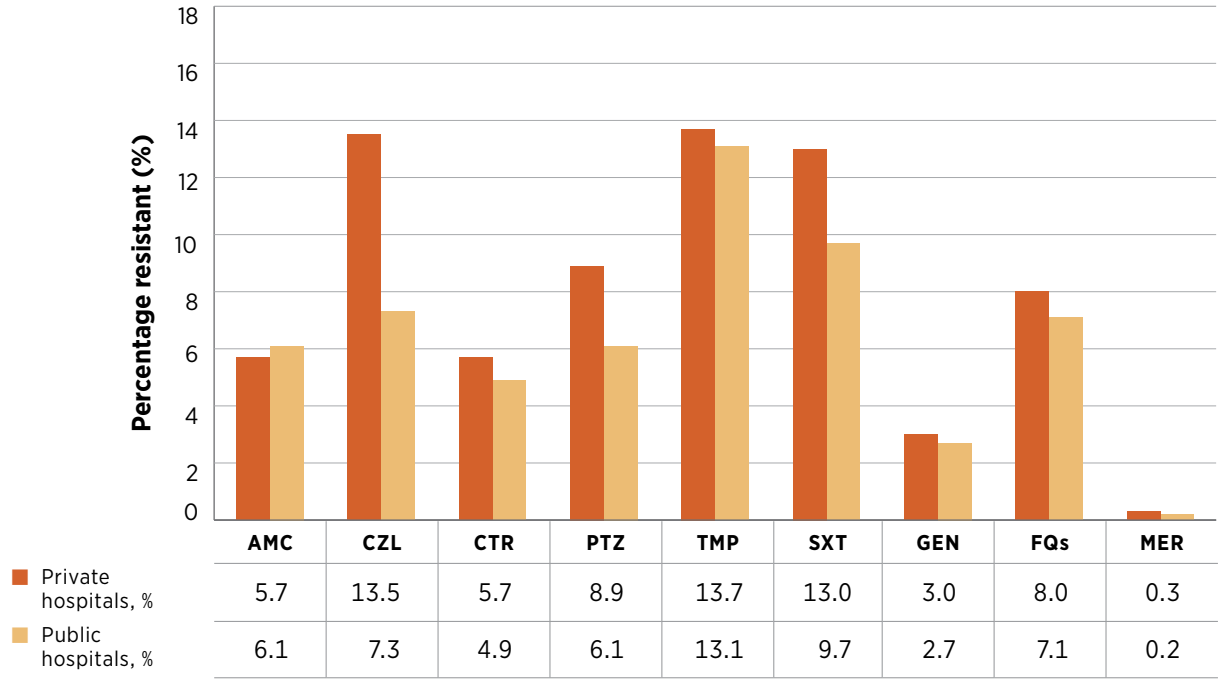
Figure 4.5: *Klebsiella pneumoniae* acquired resistance, by specimen source, 2020–2021



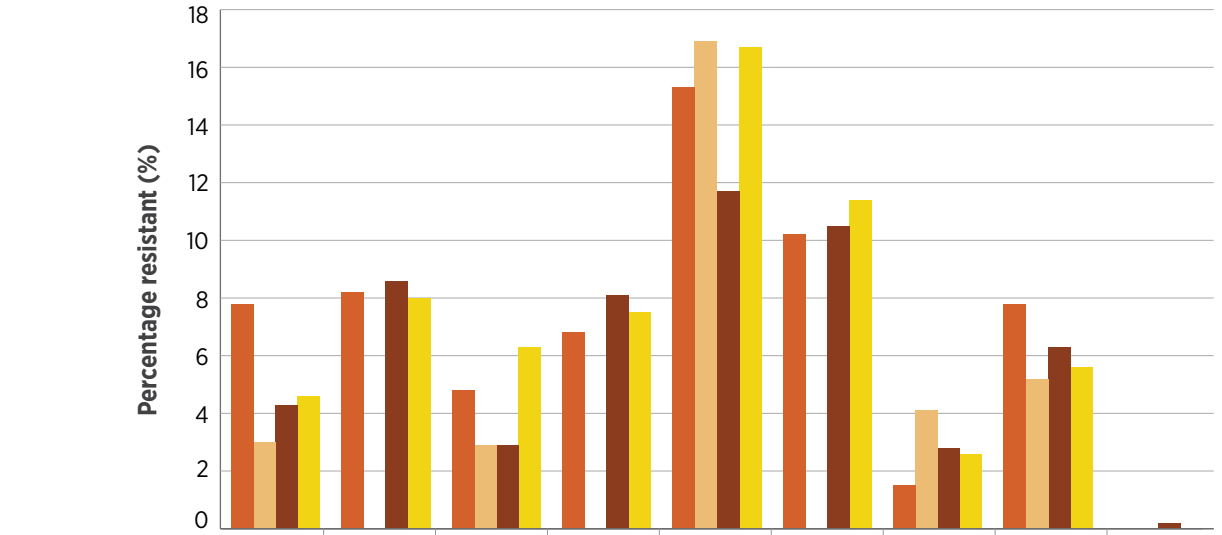
	AMC	CZL	CTR	PTZ	SXT	GEN	FQs	MER	AMC	CLX	CTR	PTZ	TMP	GEN	FQs	MER
	Blood								Urine							
2020, %	7.4	11.5	5.8	7.1	12.9	3.5	7.7	0.3	4.3	4.5	3.5	6.5	12.2	2.4	6.2	0.1
2021, %	6.0	8.6	5.1	6.6	12.5	3.2	6.9	0.3	4.9	4.7	3.6	6.0	12.7	2.4	7.3	<0.1

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); HOTspots (NT); SNP (Qld, northern NSW)

Figure 4.6: *Klebsiella pneumoniae* acquired resistance, by clinical setting, 2020 and 2021 combined



	AMC	CZL	CTR	PTZ	TMP	SXT	GEN	FQs	MER
Private hospitals, %	5.7	13.5	5.7	8.9	13.7	13.0	3.0	8.0	0.3
Public hospitals, %	6.1	7.3	4.9	6.1	13.1	9.7	2.7	7.1	0.2



	AMC	CZL	CTR	PTZ	TMP	SXT	GEN	FQs	MER
Multi-purpose service, %	7.8	8.2	4.8	6.8	15.3	10.2	1.5	7.8	0.0
Aged care homes, %	3.0	nd	2.9	nd	16.9	nd	4.1	5.2	0.0
Community, %	4.3	8.6	2.9	8.1	11.7	10.5	2.8	6.3	0.2
Other, %	4.6	8.0	6.3	7.5	16.7	11.4	2.6	5.6	0.0

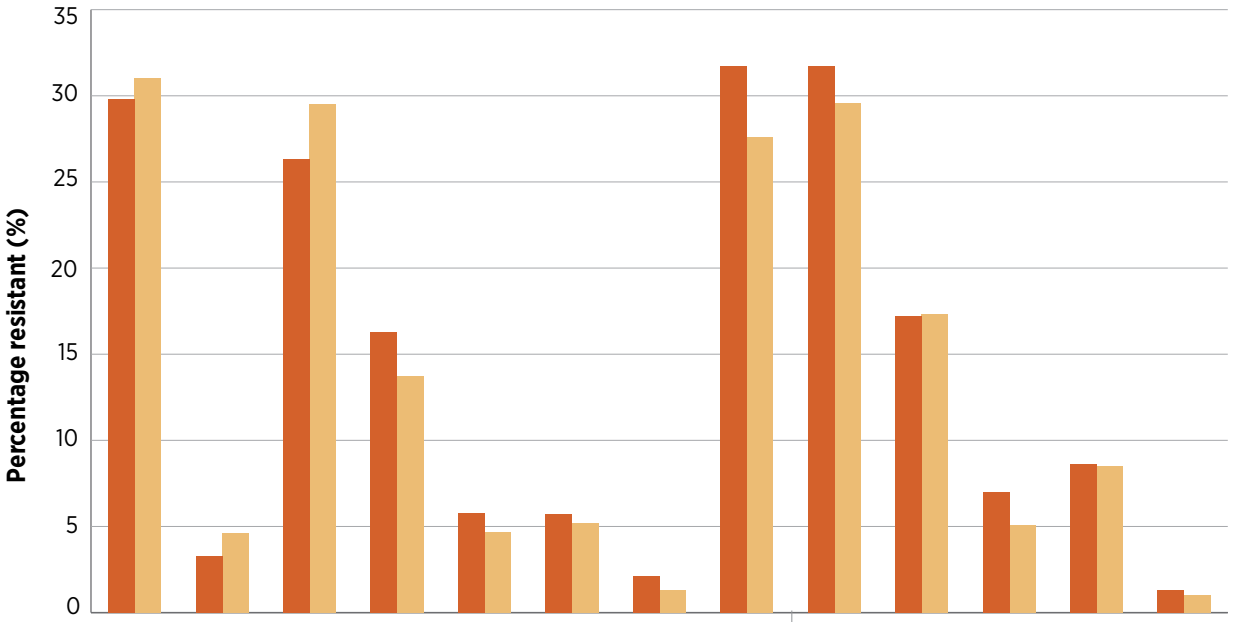
AMC = amoxicillin–clavulanic acid; CTR = ceftriaxone/cefotaxime; CZL = cefazolin; FQs = ciprofloxacin/norfloxacin; GEN = gentamicin; MER = meropenem; nd = no data (either not tested or tested against an inadequate number of isolates); PTZ = piperacillin–tazobactam; SXT = trimethoprim–sulfamethoxazole;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

Notes:

1. For clarity of presentation, data for 2020 and 2021 have been combined. Raw data for the individual years are available in *AURA 2023: Supplementary data*.
2. Other settings were predominantly corrective services.

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

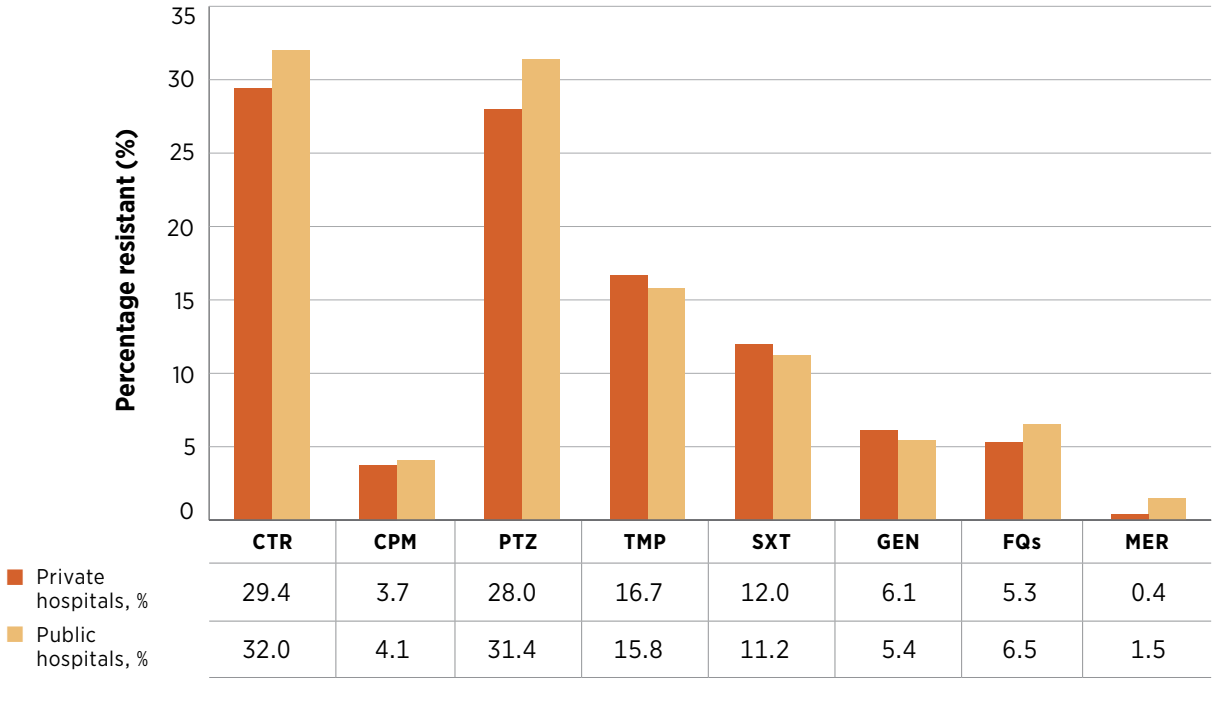
Figure 4.7: *Enterobacter cloacae* complex acquired resistance, by specimen source, 2020–2021



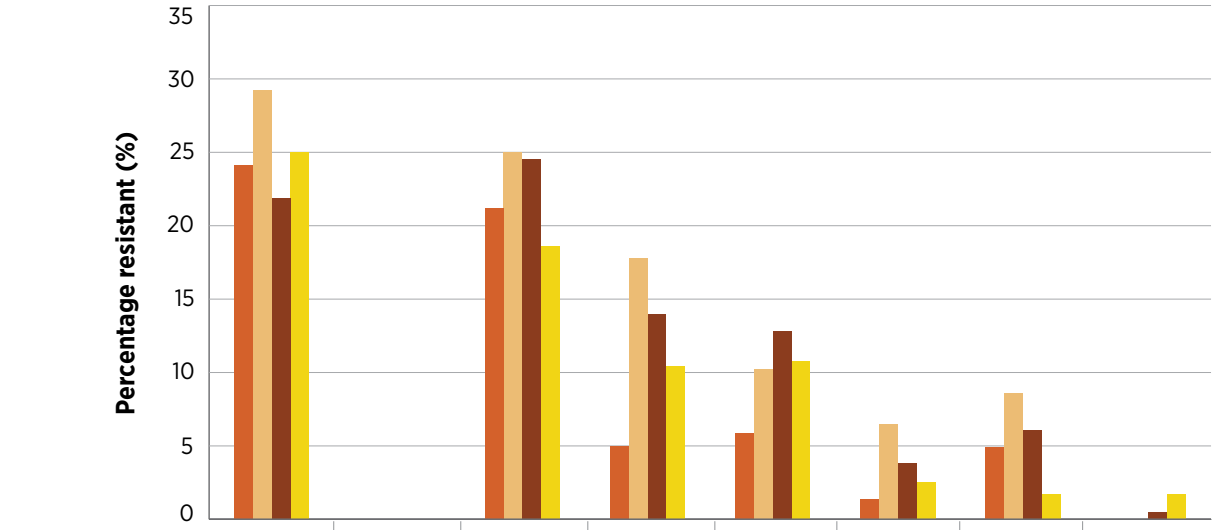
	CTR	CPM	PTZ	SXT	GEN	FQs	MER	CTR	PTZ	TMP	GEN	FQs	MER
	Blood							Urine					
2020, %	29.8	3.3	26.3	16.3	5.8	5.7	2.1	31.7	31.7	17.2	7.0	8.6	1.3
2021, %	31.0	4.6	29.5	13.7	4.7	5.2	1.3	27.6	29.6	17.3	5.1	8.5	1.0

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, 2020 and 2021 combined



	CTR	CPM	PTZ	TMP	SXT	GEN	FQs	MER
Private hospitals, %	29.4	3.7	28.0	16.7	12.0	6.1	5.3	0.4
Public hospitals, %	32.0	4.1	31.4	15.8	11.2	5.4	6.5	1.5



	CTR	CPM	PTZ	TMP	SXT	GEN	FQs	MER
Multi-purpose service, %	24.1	nd	21.2	5.0	5.9	1.4	4.9	0.0
Aged care homes, %	29.2	nd	25.0	17.8	10.2	6.5	8.6	0.0
Community, %	21.9	nd	24.5	14.0	12.8	3.8	6.1	0.5
Other, %	25.0	nd	18.6	10.4	10.8	2.5	1.7	1.7

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

Notes:

1. For clarity of presentation, data for 2020 and 2021 have been combined. Raw data for the individual years are available in *AURA 2023: Supplementary data.*
2. Other settings were predominantly corrective services.

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); APAS (other)

Key findings: states and territories

Data on resistance were analysed 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 2023: Supplementary data*. There were some notable differences in the prevalence of some important resistances between the states and territories (Figure 4.9).

For *E. coli*, acquired resistance to ceftriaxone ranged from 6.0% in Tasmania to 18.3% in the Northern Territory (NT) in 2020, and from 5.5% in Tasmania to 14.2% in Western Australia (WA) in 2021. Acquired resistance to gentamicin ranged from 4.5% in Tasmania to 17.8% in the NT in 2020, and from 3.2% in Tasmania to 15.2% in the NT in 2021. Resistance to ciprofloxacin declined from 2020 to 2021 in all states and territories except Tasmania, most notably in New South Wales (NSW) (17.5% in 2020; 12.1% in 2021) and Victoria (20.0% in 2020; 13.2% in 2021). It ranged from 8.0% in Tasmania to 20.8% in the NT in 2020, and from 8.5% in Queensland and South Australia (SA) to 17.0% in the NT in 2021 (Figure 4.9). Nationally, ciprofloxacin resistance in *E. coli* decreased by just less than a quarter from 16.1% in 2020 to 12.3% in 2021.

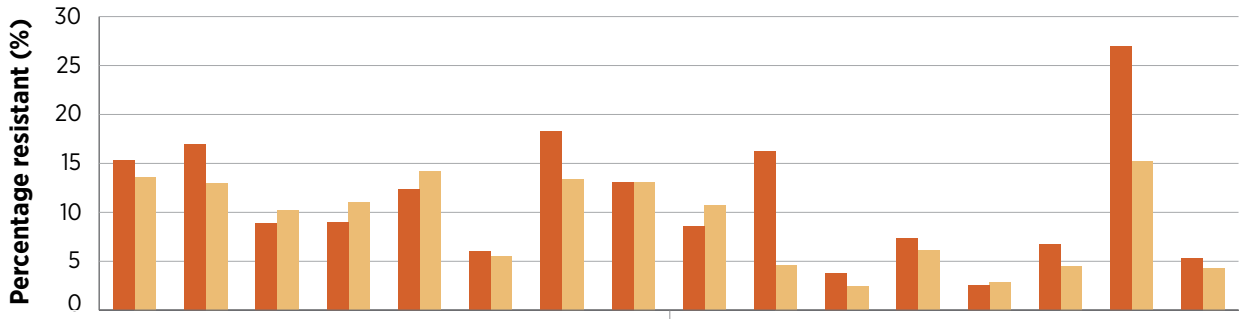
For the *K. pneumoniae* complex, acquired resistance to ceftriaxone ranged from 2.4% in Queensland to 15.2% in the NT, and acquired resistance to gentamicin ranged from 0.0% in Tasmania to 9.1% in the NT in 2021.

Acquired resistance to ciprofloxacin ranged from 3.9% in WA to 9.6% in SA (Figure 4.9). Ciprofloxacin resistance in the *K. pneumoniae* complex declined in all states and territories, except Queensland and WA, from 2020 to 2021. The most notable decrease was in Victoria (17.7% in 2020; 7.3% in 2021). Ceftriaxone resistance declined in all states and territories except NSW from 2020 to 2021, and remained stable in WA. The greatest decline was observed in Victoria (16.2% in 2020; 4.6% in 2021, $P < 0.01$). The decline observed in the NT was not statistically significant (27.0% in 2020; 15.2% in 2021). Gentamicin resistance also declined from 2020 to 2021 in all states and territories except Queensland, SA and WA.

From 2020–2021, *K. pneumoniae* complex resistance to ceftriaxone declined in all states and territories except NSW, and remained stable in WA; and ciprofloxacin resistance declined in all states and territories except Queensland and WA. In that period, *E. coli* resistance to ciprofloxacin declined in all states and territories except Tasmania. Notable variations in the rates of resistance between Australian states and territories continue to be observed.

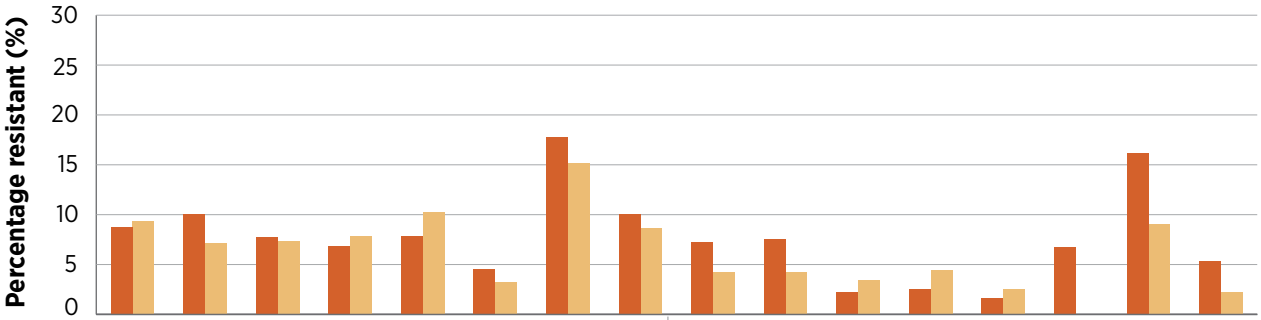
Figure 4.9: *Escherichia coli* and *Klebsiella pneumoniae* complex acquired resistance (blood culture isolates), by state and territory, 2020–2021

Ceftriaxone



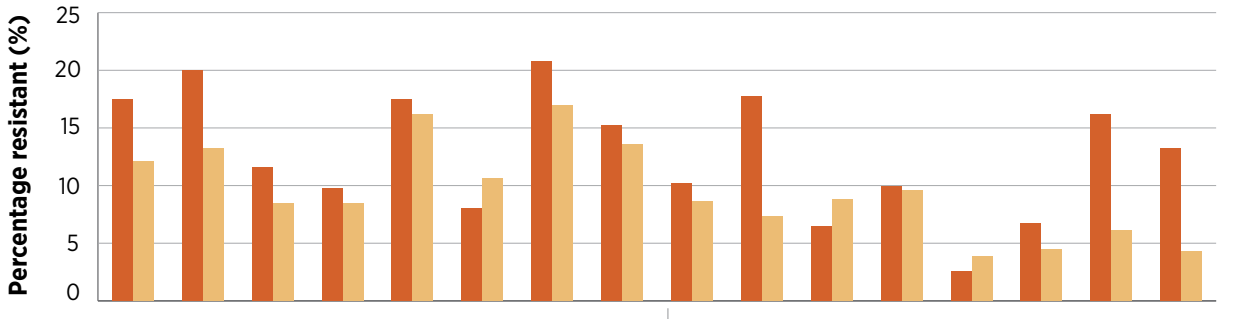
	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
	E. coli								*K. pneumoniae*							
2020, %	15.3	17.0	8.9	9.0	12.4	6.0	18.3	13.1	8.6	16.2	3.8	7.4	2.6	6.7	27.0	5.3
2021, %	13.6	13.0	10.2	11.0	14.2	5.5	13.4	13.1	10.7	4.6	2.4	6.1	2.9	4.5	15.2	4.3

Gentamicin



	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
	E. coli								*K. pneumoniae*							
2020, %	8.8	10.1	7.8	6.9	7.9	4.5	17.8	10.1	7.3	7.6	2.2	2.5	1.6	6.7	16.2	5.3
2021, %	9.4	7.2	7.4	7.9	10.3	3.2	15.2	8.7	4.2	4.2	3.4	4.4	2.5	0.0	9.1	2.2

Ciprofloxacin



	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
	E. coli								*K. pneumoniae*							
2020, %	17.5	20.0	11.6	9.8	17.5	8.0	20.8	15.2	10.2	17.7	6.5	9.9	2.6	6.7	16.2	13.2
2021, %	12.1	13.2	8.5	8.5	16.2	10.6	17.0	13.6	8.6	7.3	8.8	9.6	3.9	4.5	6.1	4.3

Source: AGAR (national)

Key findings: national

From AGAR data, acquired resistance of *E. coli* to key anti-gram-negative antimicrobial agents has generally shown a steady increase over the period 2013–2018. Since 2018, resistance rates have either stabilised or declined. There was a steady increase in *E. coli* resistance to fluoroquinolones from 2013 to 2020, despite no increase in the use of this antimicrobial class in community settings (where access is restricted) or in hospitals (Figure 4.10).

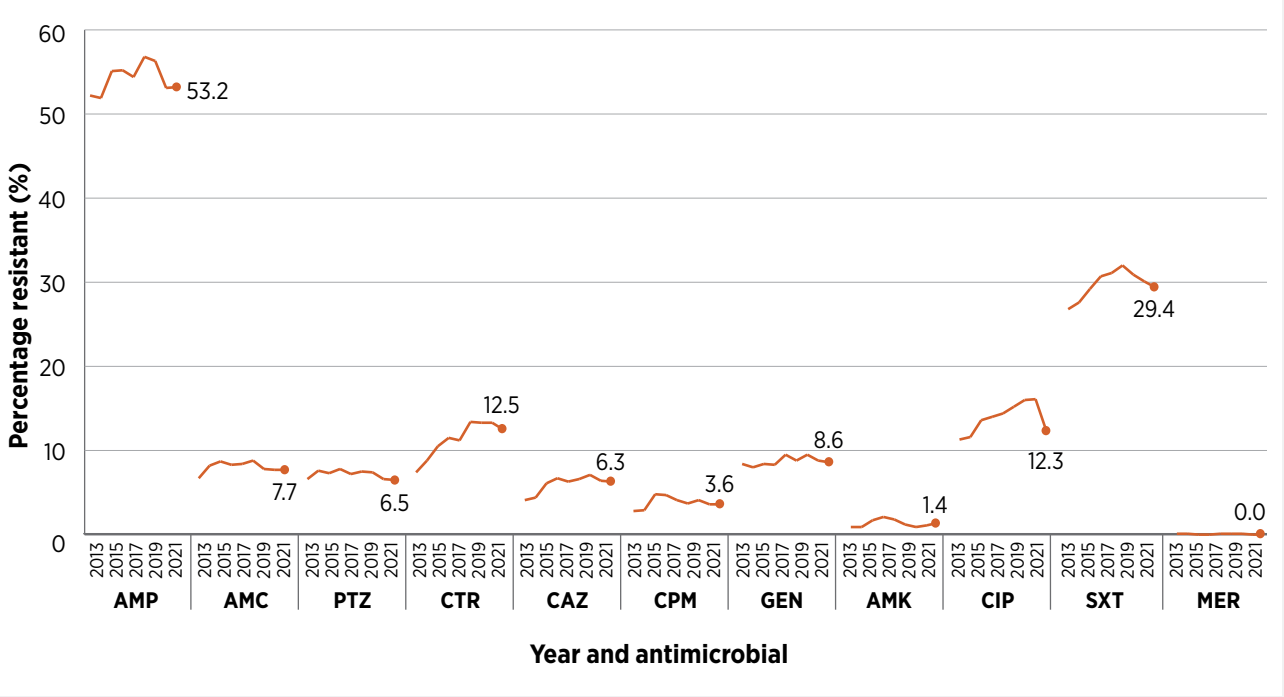
APAS data show substantial increases in fluoroquinolone resistance in *E. coli* in all remoteness areas for 2017–2019 (Figure 4.11). The resistance rates have stabilised in 2020 and 2021, except in remote and very remote areas, where resistance rates continue to increase.

The likely impact of these changes in resistance is:

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

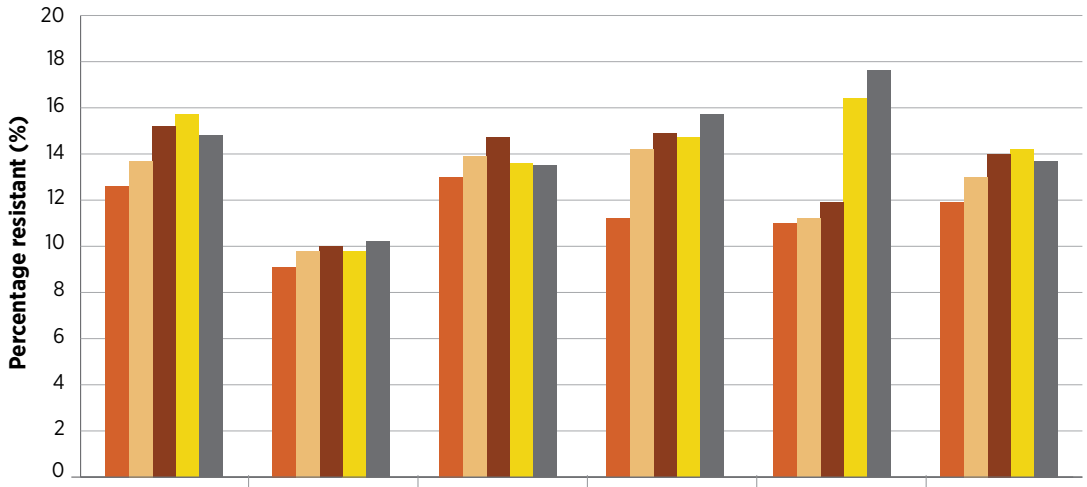
Where there has been increasing resistance in *E. coli* to key antimicrobials, higher treatment failure and greater reliance on last-line treatments are likely.

Figure 4.10: Trends in acquired resistance (EUCAST) of *Escherichia coli* to key antimicrobials (blood culture isolates), 2013–2021



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
Note: Percentage resistance determined using EUCAST 2022 breakpoints for all years. Filled circles indicate 2021 values.
Source: AGAR (national)

Figure 4.11: Percentage of fluoroquinolone-nonsusceptible *Escherichia coli* by remoteness area, 2017–2021



	Major cities	Inner regional	Outer regional	Remote	Very remote	All areas combined
2017, %	12.6	9.1	13.0	11.2	11.0	11.9
2018, %	13.7	9.8	13.9	14.2	11.2	13.0
2019, %	15.2	10.0	14.7	14.9	11.9	14.0
2020, %	15.7	9.8	13.6	14.7	16.4	14.2
2021, %	14.8	10.2	13.5	15.7	17.6	13.7
2017, *n*	76,533	23,233	19,014	3,525	2,702	125,007
2018, *n*	76,033	23,831	19,051	3,804	2,712	125,431
2019, *n*	80,143	25,650	21,201	3,730	2,572	133,296
2020, *n*	79,157	25,757	21,154	3,653	2,483	132,204
2021, *n*	83,377	29,228	22,648	3,615	2,408	141,276

Notes:
1. Fluoroquinolone refers to ciprofloxacin or norfloxacin.
2. The postcode of a patient's place of residence, where known, was used to stratify data in terms of remoteness using the Australian Bureau of Statistics Australian Statistical Geography Standard.[1]

Sources: APAS (national, excluding NT); HOTspots (NT)

Additional findings from targeted surveillance

AGAR also captured data on 30-day all-cause mortality in 2020 and 2021 (Table 4.2). Unless otherwise stated, these findings apply to all species of *Enterobacterales* detected.

E. coli showed substantially higher 30-day all-cause mortality in both 2020 and 2021 for hospital-onset bacteraemia than for community-onset bacteraemia. The effect of ESBLs *(E. coli* and *K. pneumoniae*) on 30-day all-cause mortality was negligible. All-cause mortality rates were generally higher in hospital-onset bacteraemia than in community-onset bacteraemia, most likely because of greater comorbidities in hospitalised patients.

The frequency of multi-drug resistance (resistance to one or more agents in three or more of the five key antimicrobial categories)

in *E. coli* was highest among hospital-onset isolates (Figure 4.12). Overall, multi-drug resistance increased from 8.3% in 2013 to 11.1% in 2017, remained steady at 12% from 2018 to 2020, and decreased to 9.9% in 2021.

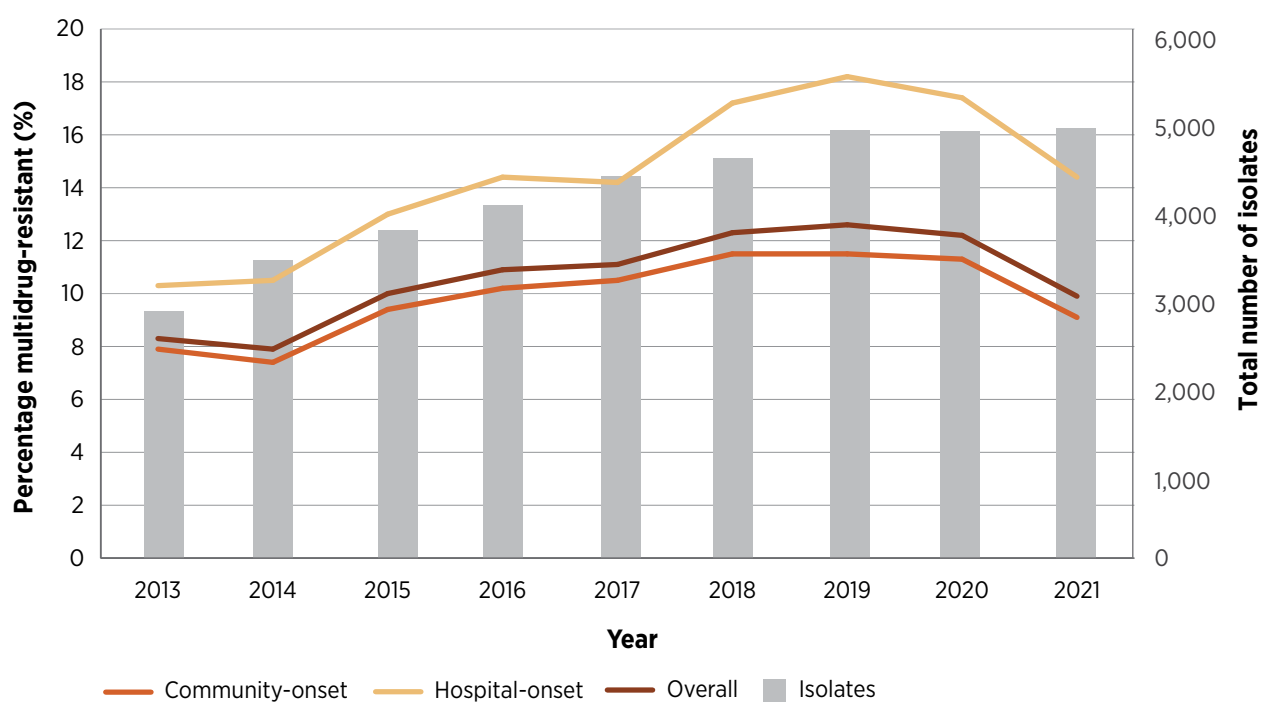
Data for gram-negative bacteria can be found in reports on the Australian Commission on Safety and Quality in Health Care (the Commission)[2] and AGAR[3] websites.

Table 4.2: 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, 2020–2021

Species	Year	ESBL phenotype	Community-onset, *n*	Community-onset mortality, % (*n*)	Hospital-onset, *n*	Hospital-onset mortality, % (*n*)	Total, *n*	Total mortality, % (*n*)
Escherichia coli	2020	Total	2,761	8.6 (238)	547	15.0 (82)	3,308	9.7 (320)
		Non-ESBL	2,384	8.7 (207)	432	15.5 (67)	2,816	9.7 (274)
		ESBL	377	8.2 (31)	115	13.0 (15)	492	9.3 (46)
	2021	Total	2,711	9.8 (266)	593	13.3 (79)	3,304	10.4 (345)
		Non-ESBL	2,327	9.4 (218)	470	13.4 (63)	2,797	10.0 (281)
		ESBL	384	12.5 (48)	123	13.0 (16)	507	12.6 (64)
Klebsiella pneumoniae complex	2020	Total	593	11.6 (69)	224	15.2 (34)	817	12.6 (103)
		Non-ESBL	534	11.4 (61)	194	16.0 (31)	728	12.6 (92)
		ESBL	59	13.6 (8)	30	10.0 (3)	89	12.4 (11)
	2021	Total	621	15.0 (93)	278	12.6 (35)	899	14.2 (128)
		Non-ESBL	574	15.2 (87)	250	13.2 (33)	824	14.6 (120)
		ESBL	47	12.8 (6)	28	7.1 (2)	75	10.7 (8)

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

Figure 4.12: Multidrug-resistant *Escherichia coli* (blood culture isolates), by onset, 2013–2021



Notes:
1. Multi-drug resistance was defined as resistance to one or more agents in three or more antimicrobial categories.
2. Antimicrobial categories (agents) were aminoglycosides (gentamicin or tobramycin), carbapenems (meropenem), extended-spectrum cephalosporins (ceftriaxone or ceftazidime), fluoroquinolones (ciprofloxacin) and penicillins (ampicillin).

Source: AGAR (national)

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. This species may cause infections in vulnerable people, such as the very elderly or those who are immunosuppressed.

The most common clinical syndromes associated with enterococcal bacteraemia are biliary and urinary tract infections. Enterococci are a cause of UTI 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 bacteraemia. *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. Orally administered amoxicillin is the most common treatment for minor infections. More serious infections are treated with intravenous

ampicillin or amoxicillin; and for endocarditis treatment, one of these antibiotics is often combined with low-dose gentamicin. Vancomycin is used for serious infections in patients who are allergic to penicillins.

Types and impact of resistance

In the past 20 years, high levels of ampicillin resistance have emerged in *E. faecium* worldwide, including in Australia. This has led to the 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 two main gene complexes responsible for VRE are *vanA* and *vanB*. Until 2018, VRE in Australia have been dominated by the *vanB* rather than the *vanA* genotype, in contrast to most other countries.[4] VRE require treatment with agents that are usually reserved, such as teicoplanin or daptomycin.

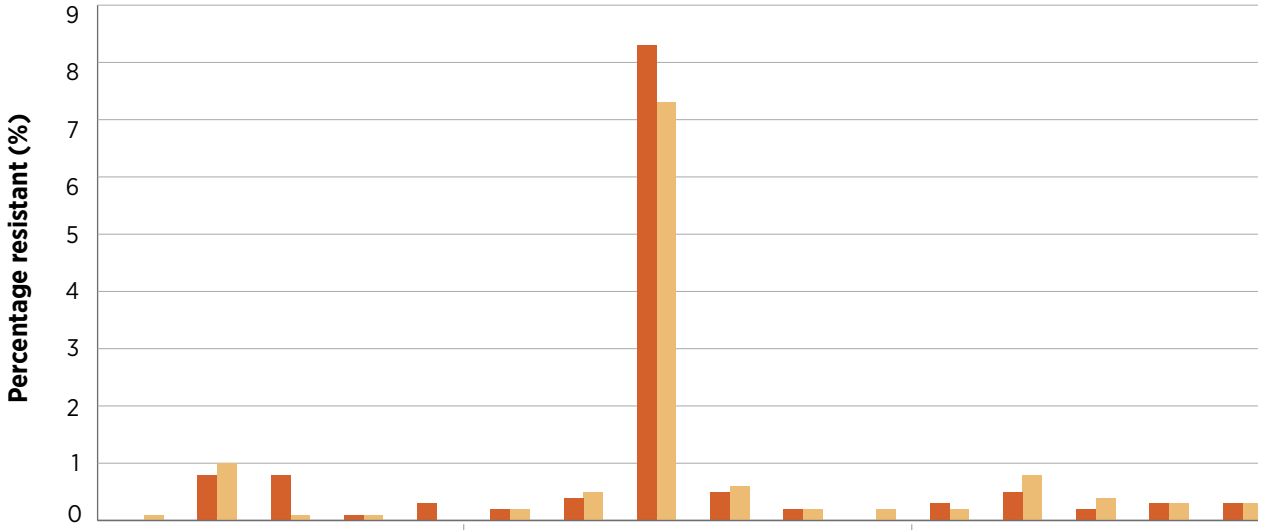
Key findings: national

In *E. faecalis*, the rates of acquired resistance to key antimicrobials were very low in 2021. Less than 1% of isolates were resistant to ampicillin, nitrofurantoin, linezolid, vancomycin or teicoplanin in 2020–2021 (Figure 4.13). Rates of resistance showed little difference between clinical settings (Figure 4.14).

In contrast, rates of resistance in *E. faecium* to ampicillin, ciprofloxacin/norfloxacin and vancomycin were high (Figures 4.15 and 4.16). Linezolid resistance remains rare. The specimen source did not substantially influence rates of resistance (Figure 4.15). Setting-dependent variations in the rates of vancomycin resistance in *E. faecium* were observed (Figure 4.16).

Data from APAS and HOTspots showed a downward trend in vancomycin resistance in all remoteness areas during the period 2017–2020 (Figure 4.17). In 2021, vancomycin resistance increased in all remoteness areas except very remote areas.

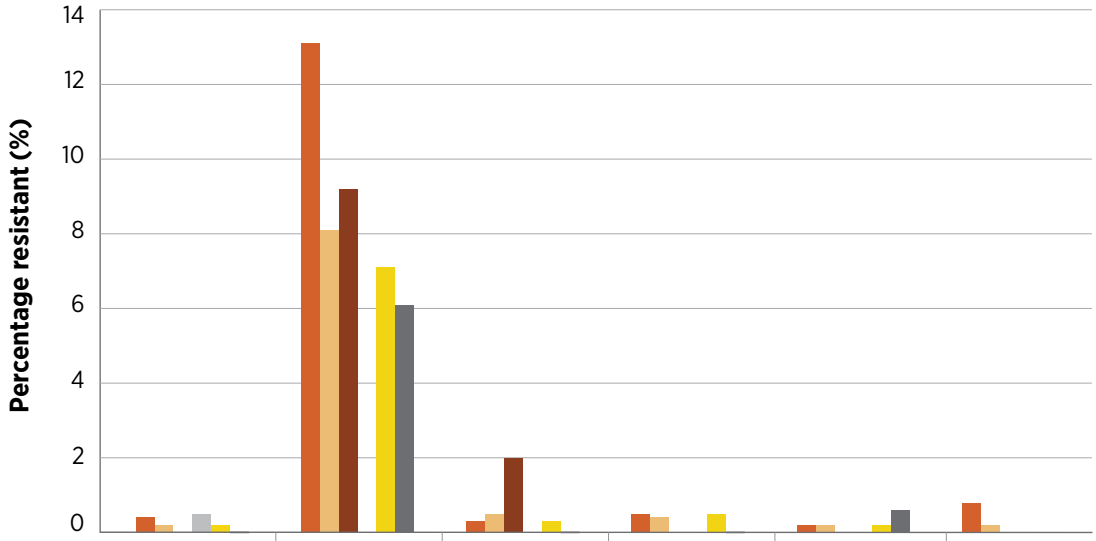
Figure 4.13: *Enterococcus faecalis* resistance, by specimen source, 2020–2021



	AMP	NIT	LNZ	VAN	TEI	AMP	NIT	CIP/NOR	LNZ	VAN	TEI	AMP	NIT	LNZ	VAN	TEI
	Blood					Urine						Other*				
2020, %	0.0	0.8	0.8	0.1	0.3	0.2	0.4	8.3	0.5	0.2	0.0	0.3	0.5	0.2	0.3	0.3
2021, %	0.1	1.0	0.1	0.1	0.0	0.2	0.5	7.3	0.6	0.2	0.2	0.2	0.8	0.4	0.3	0.3
2020, *n*	1,563	243	1,446	1,637	311	15,042	15,027	3,160	8,290	13,437	2,832	3,413	740	3,022	3,601	383
2021, *n*	1,649	311	1,540	1,703	370	14,920	14,902	2,823	8,570	13,974	2,848	3,428	728	3,114	3,623	380

* Specimen sources other than blood or urine
AMP = ampicillin; CIP/NOR = ciprofloxacin/norfloxacin; LNZ = linezolid; NIT = nitrofurantoin; TEI = teicoplanin; VAN = vancomycin
Note: Other settings were predominantly corrective services.
Sources: AGAR (national); APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); SNP (Qld, northern NSW)

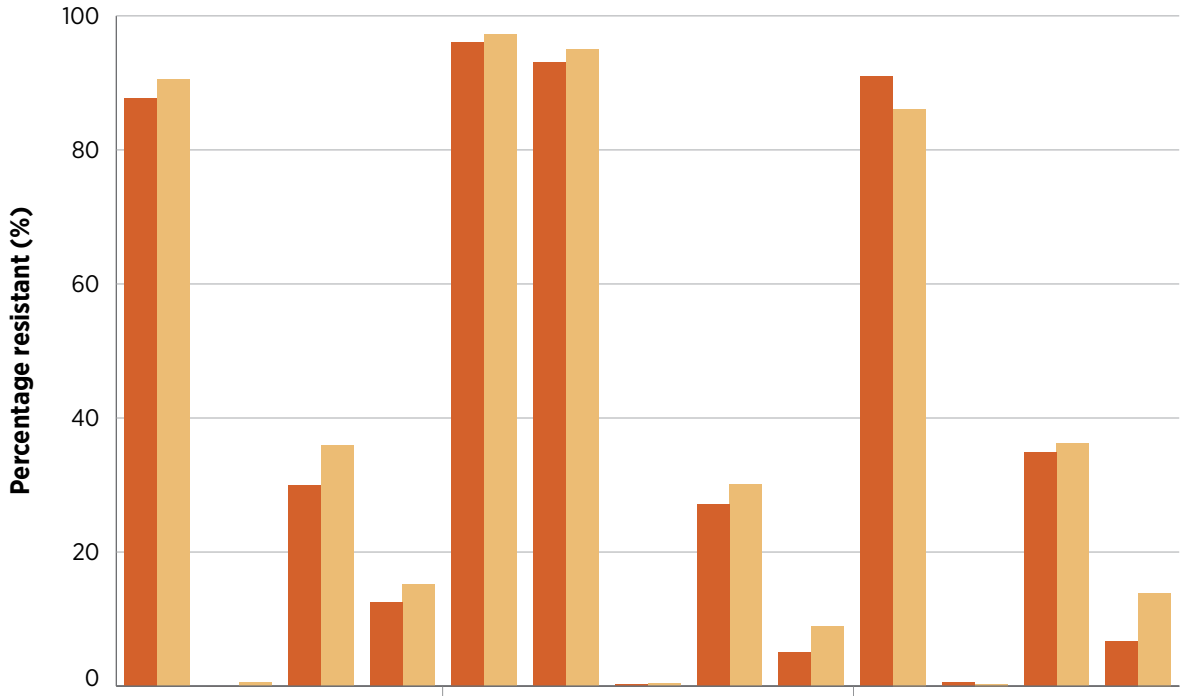
Figure 4.14: *Enterococcus faecalis* resistance, by clinical setting, 2020 and 2021 combined



	AMP	CIP/NOR	NIT	LNZ	VAN	TEI
Private hospitals, %	0.4	13.1	0.3	0.5	0.2	0.8
Public hospitals, %	0.2	8.1	0.5	0.4	0.2	0.2
Multi-purpose service, %	0.0	9.2	2.0	0.0	0.0	0.0
Aged care homes, %	0.5	nd	0.0	nd	nd	nd
Community, %	0.2	7.1	0.3	0.5	0.2	0.0
Other, %	0.0	6.1	0.0	0.0	0.6	0.0
Private hospitals, *n*	1,318	107	1,156	825	1,208	121
Public hospitals, *n*	28,412	5,271	22,404	16,939	27,862	4,606
Multi-purpose service, *n*	182	65	151	150	179	57
Aged care homes, *n*	204	19	203	13	16	1
Community, *n*	9,303	1,300	7,452	7,542	8,166	2,307
Other, *n*	213	33	206	131	161	32

AMP = ampicillin; CIP/NOR = ciprofloxacin/norfloxacin; LNZ = linezolid; nd = no data (either not tested or tested against an inadequate number of isolates); NIT = nitrofurantoin; TEI = teicoplanin; VAN = vancomycin
Notes:
1. For clarity of presentation, data for 2020 and 2021 have been combined. Raw data for the individual years are available in *AURA 2023: Supplementary data*.
2. Other settings were predominantly corrective services.
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 service); APAS (other)

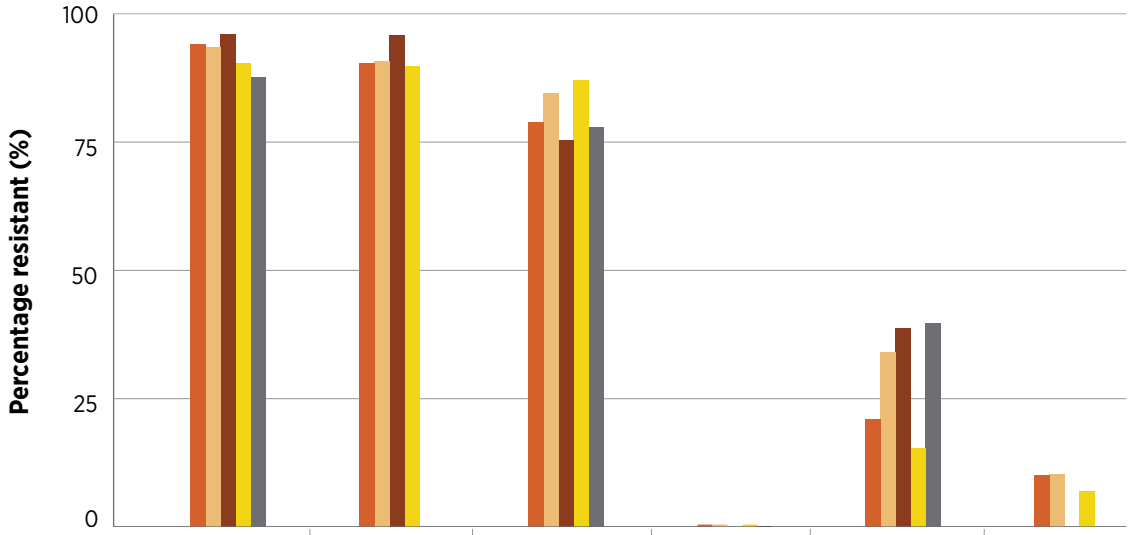
Figure 4.15: *Enterococcus faecium* resistance, by specimen source, 2020–2021



	AMP	LNZ	VAN	TEI	AMP	CIP/NOR	LNZ	VAN	TEI	AMP	LNZ	VAN	TEI
	Blood				Urine					Other*			
2020, %	87.7	0.0	29.9	12.5	96.1	93.0	0.2	27.1	5.0	91.0	0.5	34.9	6.7
2021, %	90.5	0.5	35.9	15.2	97.2	95.0	0.4	30.1	8.9	86.1	0.3	36.2	13.9
2020, *n*	871	853	895	224	3,135	660	2,594	3,142	562	1,648	1,628	1,724	180
2021, *n*	1,019	978	1,045	250	3,454	477	2,997	3,475	584	1,952	1,920	2,018	244

* Specimen sources other than blood or urine
AMP = ampicillin; CIP/NOR = ciprofloxacin/norfloxacin; LNZ = linezolid; TEI = teicoplanin; VAN = vancomycin
Note: Other settings were predominantly corrective services.
Sources: AGAR (national); APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); HOTspots (NT); SNP (Qld, northern NSW)

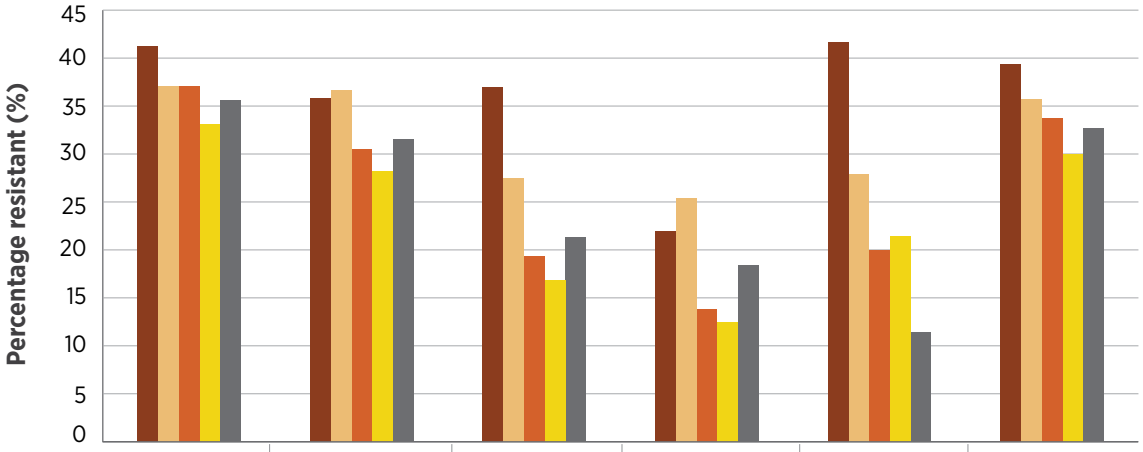
Figure 4.16: *Enterococcus faecium* resistance, by clinical setting, 2020 and 2021 combined



	AMP	CIP/NOR	NIT	LNZ	VAN	TEI
Private hospitals, %	94.0	90.4	78.8	0.3	21.0	10.0
Public hospitals, %	93.5	90.7	84.4	0.3	34.0	10.3
Aged care homes,%	95.9	95.7	75.3	nd	38.6	nd
Community, %	90.4	89.7	87.0	0.3	15.4	6.9
Other, %	87.5	nd	77.8	0.0	39.6	nd
Private hospitals, *n*	587	136	416	373	719	120
Public hospitals, *n*	9,392	1,137	4,202	8,903	9,505	1,386
Aged care homes, *n*	97	46	97	11	88	9
Community, *n*	1,643	213	818	1,332	1,628	521
Other, *n*	48	6	45	45	48	4

AMP = ampicillin; CIP/NOR = ciprofloxacin/norfloxacin; LNZ = linezolid; nd = no data (either not tested or tested against an inadequate number of isolates); TEI = teicoplanin; VAN = vancomycin
Notes:
1. For clarity of presentation, data for 2020 and 2021 have been combined. Raw data for the individual years are available in *AURA 2023: Supplementary data*.
2. Multi-purpose services are excluded because of an insufficient number of isolates from this setting (<30).
3. Other settings were predominantly corrective services.
Sources: AGAR and APAS and HOTspots (public hospitals); AGAR, APAS (Qld, SA) and SNP (private hospitals); APAS, HOTspots and SNP (community and aged care homes); APAS (other)

Figure 4.17: Percentage of vancomycin-resistant *Enterococcus faecium* by remoteness area, 2017–2021



	Major cities	Inner regional	Outer regional	Remote	Very remote	All areas combined
2017, %	41.2	35.8	37.0	22.0	41.7	39.4
2018, %	37.1	36.6	27.5	25.4	27.9	35.7
2019, %	37.1	30.5	19.3	13.8	20.0	33.7
2020, %	33.1	28.2	16.8	12.5	21.4	30.0
2021, %	35.6	31.5	21.3	18.4	11.4	32.7
2017, *n*	3,596	1,060	648	59	48	5,411
2018, *n*	3,607	989	593	63	68	5,320
2019, *n*	3,589	978	503	58	40	5,168
2020, *n*	3,560	980	613	32	70	5,255
2021, *n*	3,996	1,148	656	76	70	5,946

Note: The postcode of a patient's place of residence, where known, was used to stratify data in terms of remoteness using the Australian Bureau of Statistics Australian Statistical Geography Standard.[1]
Sources: APAS (national, excluding NT) and HOTspots (NT)

Key findings: states and territories

The percentages of *Enterococcus* species that were resistant to key antimicrobials are shown in Tables 4.3 and 4.4. The main AMR issue for the *Enterococcus* species is vancomycin-resistant *E. faecium*. In *E. faecium*, there are significant differences in vancomycin resistance between states and territories.[2]

The prevalence of the main genotypes of vancomycin-resistant *E. faecium* circulating in Australia (*vanA* and *vanB*) have varied over the past few years since the inception of AURA. 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.

Prior to 2017, the main type of vancomycin-resistant *E. faecium* circulating in Australia was the *vanB* type; however, in 2017, the *vanA* type was as prevalent as *vanB*, and by 2018 the *vanA* type was the more dominant type circulating. In 2019, nationally, *vanA* and *vanB* were circulating equally again (Figure 4.18). In 2020, the proportion of *vanA* type declined to 13.5% and was sustained at a similar level of 14.6% in 2021. In 2021, *vanA* type was predominant in blood culture isolates in NSW, Queensland and WA (Figure 4.19).

Of note is the small proportion of strains with *vanA* or *vanB* genes that tested as 'susceptible' in routine susceptibility testing. These strains highlight the problem of a hidden reservoir of resistance gene complexes (Figure 4.18).

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 resistance gene complexes.

AGAR data for 30-day all-cause mortality 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.[2] Vancomycin resistance in *E. faecium* appeared to have an even greater association with 30-day mortality than vancomycin susceptibility in *E. faecium* (Table 4.5).

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 4.20). This emphasises the importance of local infection prevention and control practices in the containment and spread of VRE strains and ongoing surveillance of sequence types.

Four sequence types – ST17, ST1424, ST796, and ST80 – accounted for 65% of all *E. faecium* in Australia in 2020. In 2021, ST78 replaced ST80. However, ST1424, ST796 and ST78 harboured the greatest proportion of *van* genes. Sequence type ST1424 harboured *vanA* genes, while ST796 and ST78 harboured *vanB* genes (Figure 4.21). This accounts for the different VRE teicoplanin susceptibility patterns observed in each state and territory in AGAR national reports.

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

Consistent with rapid local or regional spread, different sequence types of *E. faecium* have become established in each state and territory. This emphasises the importance of local infection prevention and control practices in the containment of the spread of vancomycin-resistant strains and ongoing surveillance of sequence types.

Table 4.3: Percentage of *Enterococcus faecalis* resistance (blood culture isolates), by state and territory, 2020–2021

Antimicrobial	Year	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	National % (*n*)
Ampicillin	2020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 (666)
	2021	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1 (701)
Vancomycin	2020	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.2 (666)
	2021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 (702)
Teicoplanin	2020	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.2 (666)
	2021	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1 (702)
Linezolid	2020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 (663)
	2021	0.0	0.0	0.0	0.0	0.9	0.0	0.0	2.8	0.3 (698)
Total number of isolates tested	**2020**	**224**	**134**	**97**	**59**	**89**	**27**	**5**	**31**	**666**
	2021	**178**	**169**	**101**	**70**	**107**	**33**	**8**	**36**	**702**

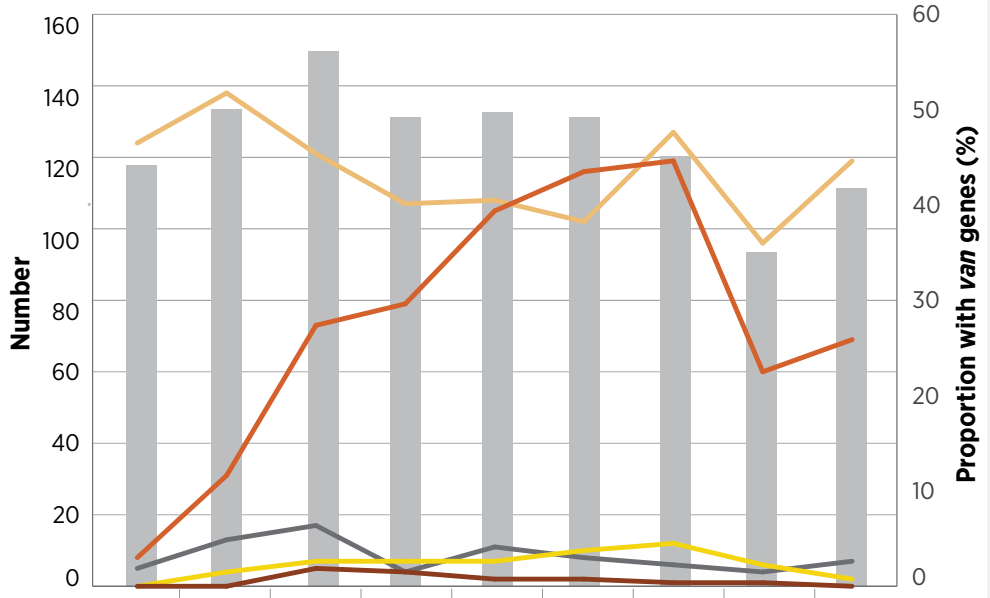
Notes:
1. Resistance was determined using European Committee on Antimicrobial Susceptibility Testing interpretive criteria.
2. Not all antimicrobial agents were reported for all isolates.
Source: AGAR (national)

Table 4.4: Percentage of *Enterococcus faecium* resistance (blood culture isolates), by state and territory, 2020–2021

Antimicrobial	Year	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	National % (*n*)
Ampicillin	2020	88.3	91.9	82.4	77.5	87.5	90.0	83.3	96.8	88.3 (487)
	2021	93.5	93.3	97.9	97.9	94.9	92.9	100.0	100.0	94.7 (491)
Vancomycin	2020	29.4	64.2	14.3	7.9	8.1	20.0	83.3	19.4	32.6 (485)
	2021	33.1	61.6	14.9	40.4	13.6	42.9	87.5	28.6	40.2 (492)
Teicoplanin	2020	22.2	9.8	5.7	0.0	8.1	10.0	0.0	9.7	13.0 (486)
	2021	22.3	12.8	10.6	4.3	10.2	14.3	0.0	14.3	14.0 (492)
Linezolid	2020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 (489)
	2021	0.7	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.4 (490)
Total number of isolates tested	**2020**	**180**	**123**	**35**	**40**	**64**	**10**	**6**	**31**	**489**
	2021	**139**	**164**	**47**	**47**	**59**	**14**	**8**	**14**	**492**

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)

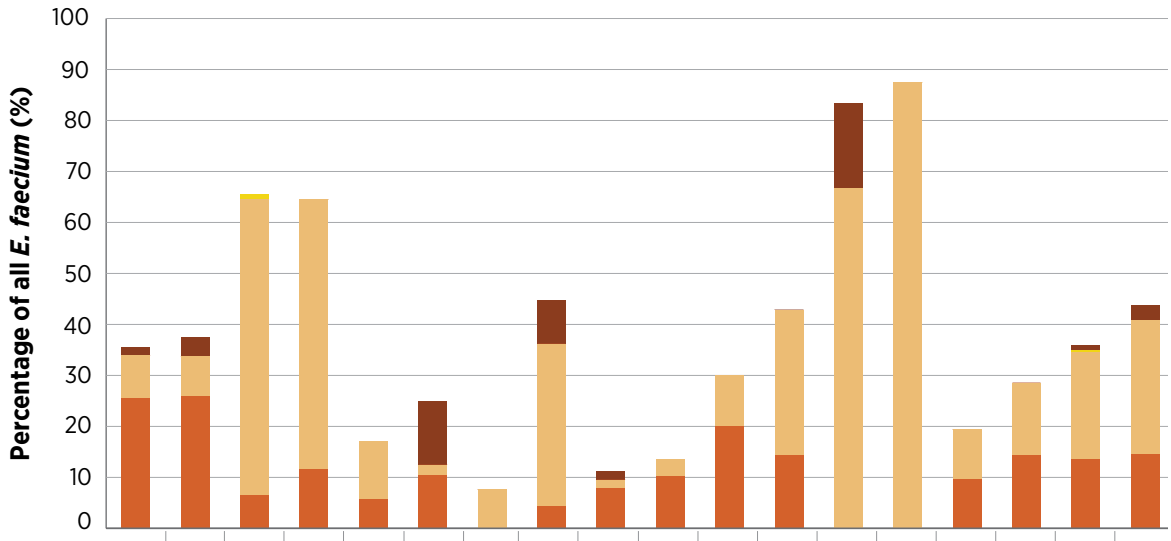
Figure 4.18: *Enterococcus faecium* genotype and vancomycin susceptibility (blood culture isolates), 2013–2021



	2013	2014	2015	2016	2017	2018	2019	2020	2021
van gene, % of *E.faecium*	44.2	50.1	56.2	49.3	49.8	49.3	45.2	35.1	41.8
vanA, vancomycin-resistant	8	31	73	79	105	116	119	60	69
vanB, vancomycin-resistant	124	138	121	107	108	102	127	96	119
vanA + *vanB*, vancomycin-resistant	0	0	5	4	2	2	1	1	0
vanA, vancomycin-susceptible	0	4	7	7	7	10	12	6	2
vanB, vancomycin-susceptible	5	13	17	4	11	8	6	4	7
Total, *n*	137	186	223	201	233	238	265	167	197

Note: Number of contributors per year were: 2013–2014, *n* = 27; 2015, *n* = 35; 2016, *n* = 33; 2017, *n* = 35; 2018, *n* = 38; 2019, *n* = 41; 2020, *n* = 42; 2021, *n* = 41.
Source: AGAR (national)

Figure 4.19: *Enterococcus faecium* vancomycin resistance genotype (blood culture isolates), by state and territory and nationally, 2020–2021



	NSW		Vic		Qld		SA		WA		Tas		NT		ACT		Australia	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Not determined*	1.7	3.6	0.0	0.0	0.0	12.5	0.0	8.5	1.6	0.0	0.0	0.0	16.7	0.0	0.0	0.0	1.0	3.0
vanA and *vanB*	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
vanB	8.3	7.9	58.1	53.0	11.4	2.1	7.7	31.9	1.6	3.4	10.0	28.6	66.7	87.5	9.7	14.3	21.1	26.2
vanA	25.6	25.9	6.5	11.6	5.7	10.4	0.0	4.3	7.9	10.2	20.0	14.3	0.0	0.0	9.7	14.3	13.5	14.6

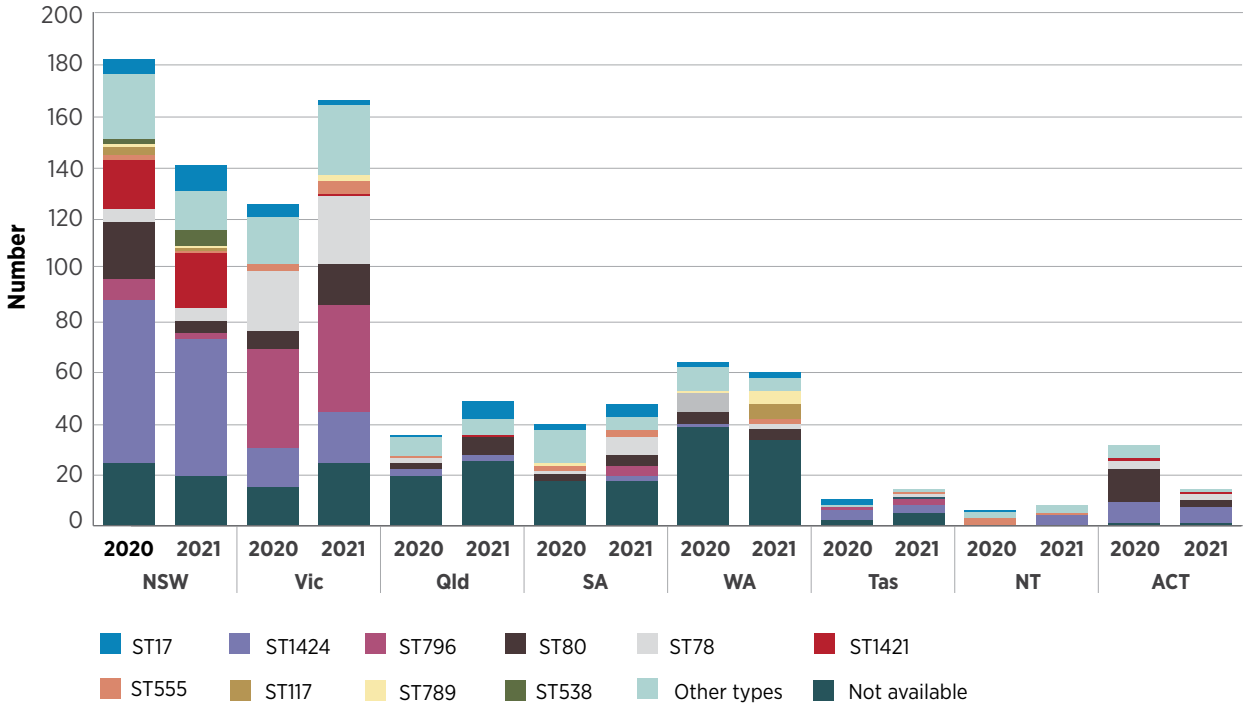
* Isolate not available for confirmation
Notes:
1. Total number of isolates were: *n* = 488 in 2020; *n* = 493 in 2021.
2. There were low numbers of *E. faecium* (<10) from the NT in 2020 and 2021.
Source: AGAR (national)

Table 4.5: Onset setting and 30-day all-cause mortality for infections with *Enterococcus* (blood culture isolates), 2020–2021

Species	Year	Community-onset, *n*	Community-onset mortality, % (*n*)	Hospital-onset, *n*	Hospital-onset mortality, % (*n*)	Total, *n*	Total mortality, % (*n*)
Enterococcus faecalis	2020	365	17.3 (63)	148	17.6 (26)	513	17.3 (89)
	2021	394	14.5 (57)	195	14.4 (28)	589	14.4 (85)
Enterococcus faecium	2020	130	13.8 (18)	262	22.5 (59)	392	19.6 (77)
	2021	116	28.4 (33)	305	25.6 (78)	421	26.4 (111)
Vancomycin-susceptible *E. faecium*	2020	97	11.3 (11)	161	24.2 (39)	258	19.4 (50)
	2021	81	25.9 (21)	155	21.3 (33)	236	22.9 (54)
Vancomycin-resistant *E. faecium*	2020	31	19.4 (6)	100	20.0 (20)	131	19.8 (26)
	2021	35	34.3 (12)	149	30.2 (45)	184	31.0 (57)

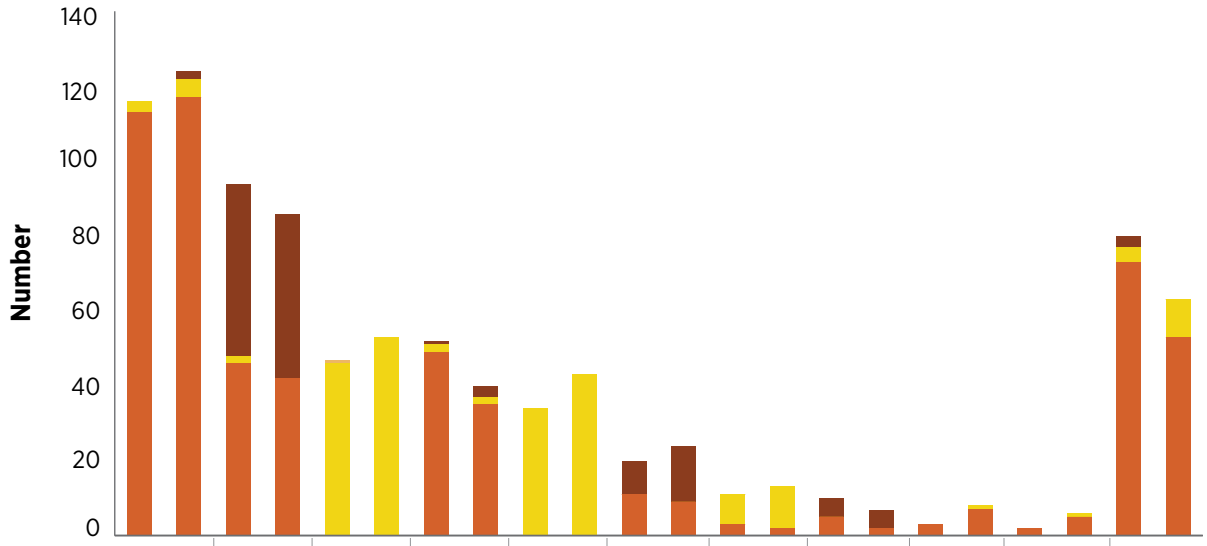
Source: AGAR (national)

Figure 4.20: Distribution of *Enterococcus faecium* sequence types (blood culture isolates), by state and territory, 2020–2021



Source: AGAR (national)

Figure 4.21: *Enterococcus faecium* multi-locus sequence types harbouring *vanA* and/or *vanB* genes (blood culture isolates), 2020–2021



	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
	ST17		ST1424		ST796		ST80		ST78		ST1421		ST555		ST117		ST789		ST538		Other types	
vanA	0	2	46	44	0	0	1	3	0	0	9	15	0	0	5	5	0	0	0	0	3	0
vanB	3	5	2	0	46	53	2	2	34	43	0	0	8	11	0	0	0	1	0	1	4	10
vanA and *vanB*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neither *vanA* nor *vanB*	113	117	46	42	0	0	49	35	0	0	11	9	3	2	5	2	3	7	2	5	73	53

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. About 85% 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 protocol for tuberculosis caused by fully susceptible strains. When the strain is susceptible, isoniazid is 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. Worldwide, the most common forms of resistance are 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.

In 2021, the World Health Organization (WHO) announced updated definitions of extensively drug-resistant tuberculosis[5]:

- Strains are considered to be multidrug-resistant tuberculosis (MDR-TB) if they are resistant to at least one of isoniazid and rifampicin, with or without resistance to the other two first-line agents.
- Strains are considered to be extensively drug-resistant tuberculosis (XDR-TB) if they are also resistant to any of the fluoroquinolones and at least one of linezolid and bedaquiline.
- Strains are considered to be pre-XDR-TB if they are resistant to isoniazid, rifampicin and any of the fluoroquinolones (levofloxacin, moxifloxacin).

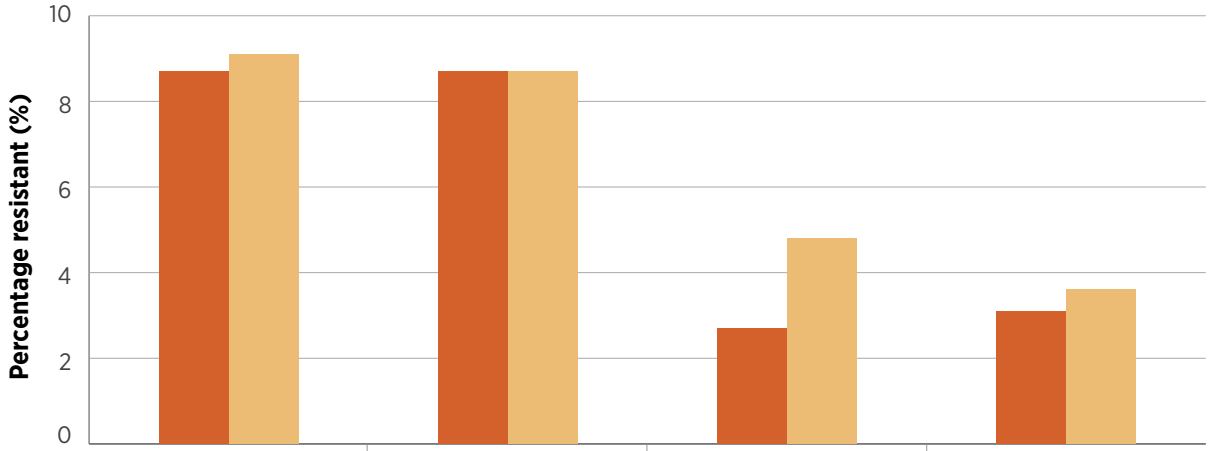
Treatment success is significantly lower, and costs are significantly higher, for MDR-TB, and even more so for XDR-TB.

Key findings: national

In 2020, 1,619 cases of tuberculosis were notified nationally (6.3 cases per 100,000 population). In 2021, 1,477 cases were notified (5.7 cases per 100,000 population).[6] Of these, 1,116 cases in 2020 and 962 cases in 2021 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 4.22.

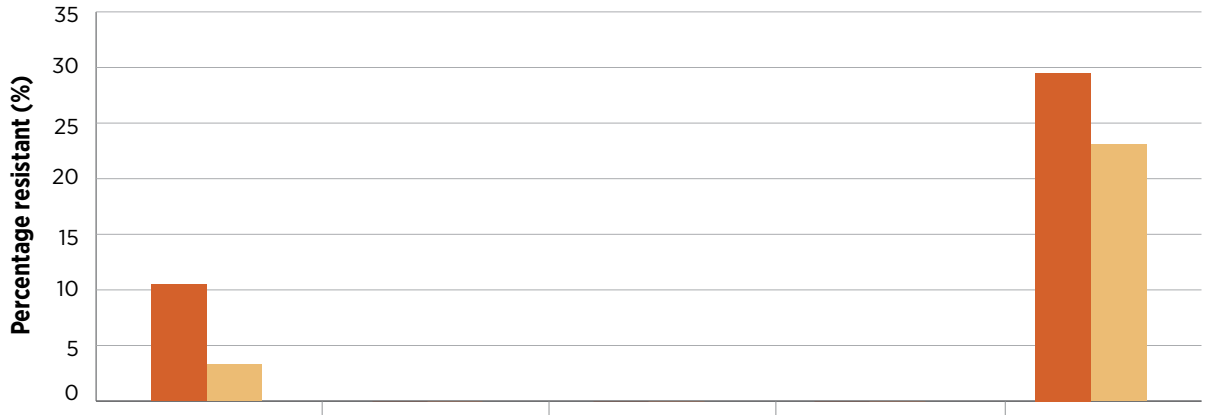
Figure 4.22: *Mycobacterium tuberculosis* resistance to individual first-line agents and selected additional agents, 2020–2021

First-line agents



	INH	RIF	EMB	PZA
2020, %	8.7	8.7	2.7	3.1
2021, %	9.1	8.7	4.8	3.6
2020, *n*	1,089	1,100	1,087	1,089
2021, *n*	946	957	944	946

Selected additional agents (mostly tested after resistance to first-line agents is established)



	FLQ	KAN	CAP	AMK	INN
2020, %	10.5	0.0	0.0	0.0	29.5
2021, %	3.3	0.0	0.0	0.0	23.1
2020, *n*	95	63	85	84	78
2021, *n*	90	53	64	64	65

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

Notes:

1. First-line agents (INH, RIF, EMB, PZA) were tested against (almost) all strains. Selected additional agents (FLQ, KAN, CAP, AMK and INN) 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

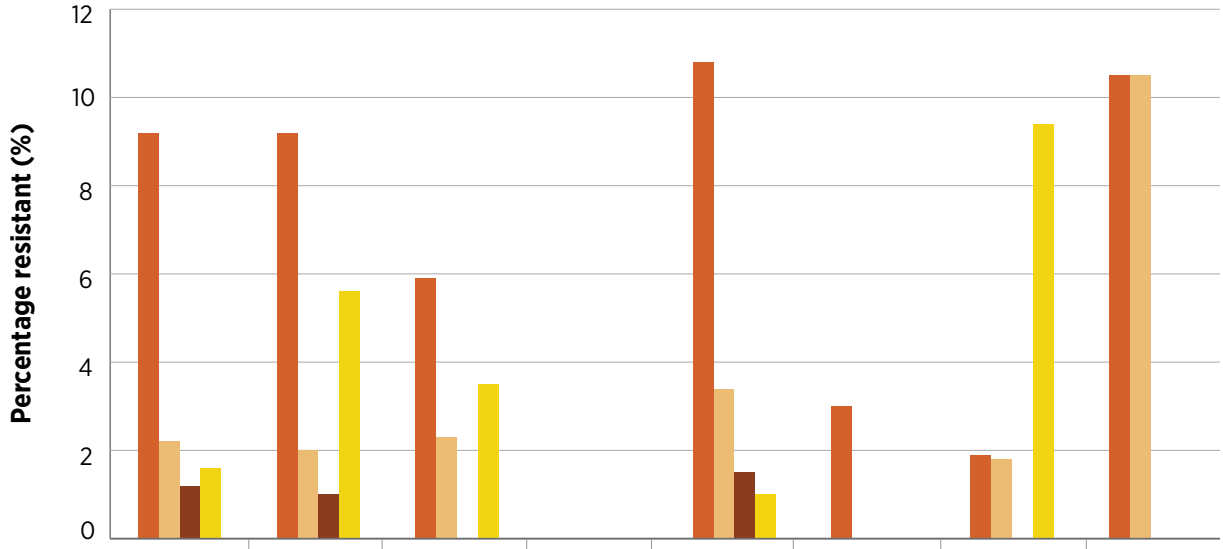
The resistance rates to first-line agents varied across the states and territories in 2020 and 2021 (Figure 4.23 and *AURA 2023: Supplementary data*).

National trends

Overall, rates of resistance have not changed substantially in the past decade (Figure 4.24).

The proportion of MDR-TB strains (resistant to at least isoniazid and rifampicin) over the last four years remains steady at an average of 1.7%, and ranging from 1.4% (2020) to 1.9% (2021). XDR-TB strains remain rare (<0.1%), with one report in 2018, one in 2019 and no reports in 2020 and 2021.

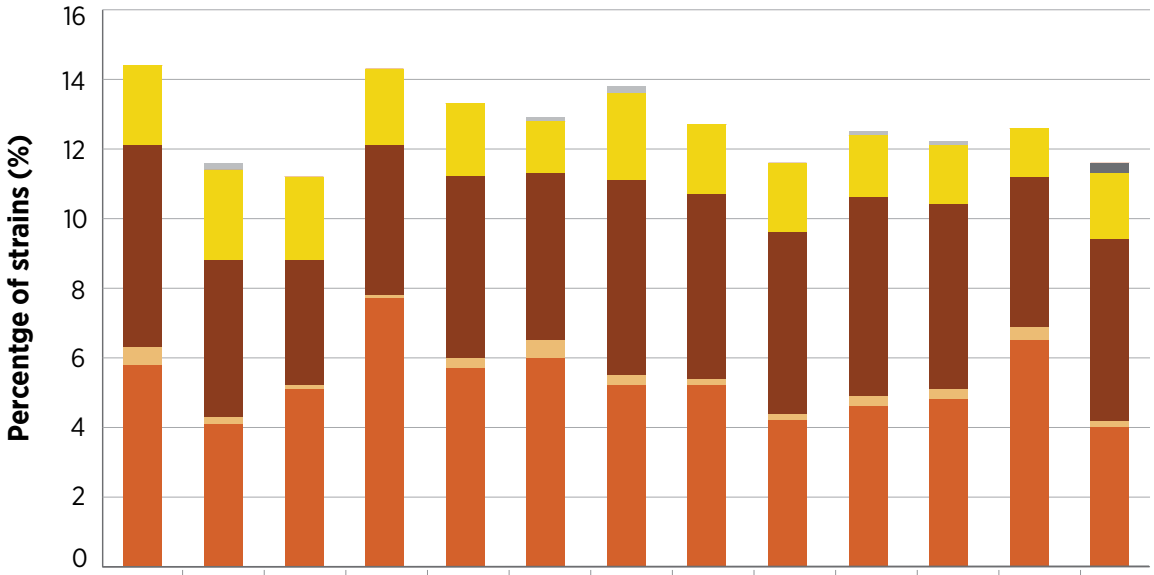
Figure 4.23: *Mycobacterium tuberculosis* resistance to first-line agents, by state and territory, 2020 and 2021 combined



	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
Isoniazid	9.2	9.2	5.9	nd	10.8	3.0	1.9	10.5
Rifampicin	2.2	2.0	2.3	nd	3.4	0.0	1.8	10.5
Ethambutol	1.2	1.0	0.0	nd	1.5	0.0	0.0	0.0
Pyrazinamide	1.6	5.6	3.5	nd	1.0	0.0	9.4	0.0
Total, *n*	760	698	273	162	203	35	55	38

nd = no data (not available due to data transfer issues for 2020 and 2021)
Note: For clarity of presentation, data for 2020 and 2021 have been combined. Raw data for the individual years are available in *AURA 2023: Supplementary data*.
Source: NNDSS (national)

Figure 4.24: Resistance and multi-drug resistance patterns in *Mycobacterium tuberculosis*, 2009–2021



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
XDR-TB	0.0	0.2	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.1	0.1	0.0	0.0
pre-XDR-TB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
MDR-TB	2.3	2.6	2.4	2.2	2.1	1.5	2.5	2.0	2.0	1.8	1.8	1.4	1.9
Mono-resistance to isoniazid	5.8	4.5	3.6	4.3	5.2	4.8	5.6	5.3	5.2	5.7	5.3	4.3	5.2
Mono-resistance to rifampicin	0.5	0.2	0.1	0.1	0.3	0.5	0.3	0.2	0.2	0.3	0.3	0.4	0.2
Other mono- or poly- resistance not specified above	5.8	4.1	5.1	7.0	5.7	6.0	5.2	5.2	4.2	4.6	4.8	6.5	4.0
Total (all cases with resistance data)	965	1,046	1,058	976	922	1,023	968	1,037	1,067	1,095	1,093	1,116	962

MDR-TB = multidrug-resistant tuberculosis; mono-resistance = resistant to only the specified anti-TB agent and susceptible to all other anti-TB agents; pre-XDR-TB = resistance to isoniazid, rifampicin and any of the fluoroquinolones (levofloxacin and moxifloxacin); XDR-TB = extremely drug-resistant tuberculosis
Note: The 2021 updated WHO XDR definition changes (pre-XDR-TB and XDR-TB) have been applied across all years since 2009.
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 is predominantly sexually transmitted, and most commonly manifests as urethritis in men and cervicitis in women. Many infections in women are asymptomatic, but the infection can ascend to the uterus and fallopian tubes and cause infertility if not treated promptly. Infection in late pregnancy can result in vertical transmission during delivery, causing infection and potentially severe neonatal eye disease. Most infections are diagnosed using nucleic acid testing for gonococcal infection, and specimens for culture are not collected. Currently, approximately one-quarter of gonococcal infections in Australia are diagnosed by culture and have antimicrobial susceptibility testing performed.

Treatment

Treatment strategies for gonococcal infections globally are reliant on the third-generation cephalosporin, ceftriaxone. Ceftriaxone has superseded penicillin and ciprofloxacin for first-line treatment because resistance to these latter agents has emerged. Since 2014, azithromycin was added to ceftriaxone as a combination therapy for gonococcal disease to contain the emergence of ceftriaxone resistance.

Most gonococcal infections are treated empirically, based on national and specialist guidelines informed by the Australian Gonococcal Surveillance Programme (AGSP) data. Immediate empirical treatment is the most effective tool for preventing further transmission.

Types and impact of resistance

Resistance to ceftriaxone in *N. gonorrhoeae* is an emerging global AMR concern. Failures of ceftriaxone treatment have been documented in Australia and internationally in strains that have reduced susceptibility (the minimum inhibitory concentration [MIC] value exceeds that of the wild type).[7,8]

Key findings: national

As reported by the AGSP Annual Report 2021, the emergence of gonococcal AMR in Australia has long been influenced by the introduction of MDR strains from overseas.[9] In 2020 and 2021, physical distancing and travel restrictions imposed as public health measures in response to the COVID-19 pandemic had an impact on many communicable diseases in Australia, including gonorrhoea. In 2020, 29,817 cases of gonococcal infection were notified nationally (a rate of 116.2 per 100,000 population)[6,10] – down from 34,760 in 2019, or a decrease of 14%. Of these cases, 7,222 had positive laboratory cultures that were submitted for susceptibility testing.[9] In 2021, 26,861 cases were notified (a rate of 104.6 per 100,000 population[6,10]) and of these cases, 6,254 had positive laboratory cultures submitted for susceptibility testing.[11]

Overall rates of resistance to the main agents used for treatment are shown in Figure 4.25. In these and subsequent figures, the resistant percentage refers to decreased susceptibility compared with wild-type strains, which have no acquired resistance mechanisms (ceftriaxone MIC ≥0.06 mg/L).

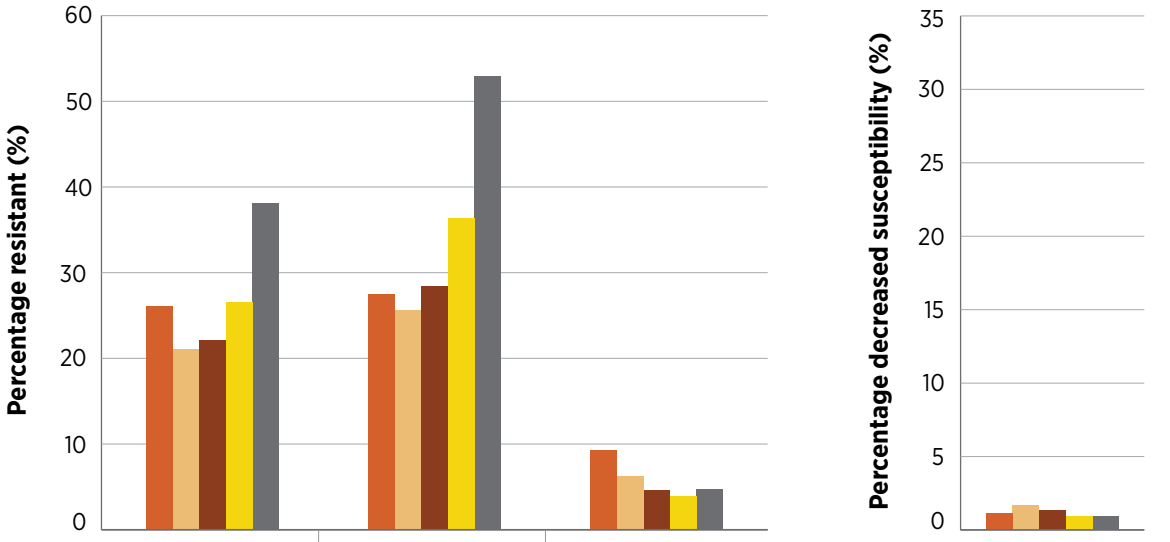
In 2017, the first evidence of sustained spread of MDR gonorrhoea was reported internationally[12], followed by coincident reports from Australia and the United Kingdom of the first extensively drug-resistant *N. gonorrhoeae* isolates in 2018.[13,14] While the background rate of isolates with decreased susceptibility to ceftriaxone in Australia has

remained low 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.[15] Decreased susceptibility to ceftriaxone in *N. gonorrhoeae* was less than 1% in 2020 and 2021 (Figure 4.25).

Resistance to azithromycin (MIC ≥1.0 mg/L) in *N. gonorrhoeae* declined from 9.3% in 2017 to 3.9% in 2020 and 4.7% in 2021. Isolates with high-level resistance to azithromycin (MIC ≥256 mg/L) are identified sporadically in Australia, with one report in 2020 and no reports in 2021.

Sporadic notifications of *N. gonorrhoeae* isolates with raised MIC values to ceftriaxone are reported in Australia. Culture-based surveillance is essential to monitor AMR; to detect imported or novel resistance; and to inform treatment guidelines.

Figure 4.25: *Neisseria gonorrhoeae* resistance, 2017–2021



	Benzylpenicillin	Ciprofloxacin	Azithromycin
2017 (*n* = 7,835)	26.1	27.5	9.3
2018 (*n* = 9,006)	21.1	25.6	6.2
2019 (*n* = 9,668)	22.1	28.4	4.6
2020 (*n* = 7,222)	26.6	36.3	3.9
2021 (*n* = 6,254)	38.1	52.9	4.7

	Ceftriaxone
2017	1.1
2018	1.7
2019	1.3
2020	0.9
2021	0.9

Note: Decreased susceptibility to ceftriaxone is defined as an MIC greater than 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)

Key findings: states and territories

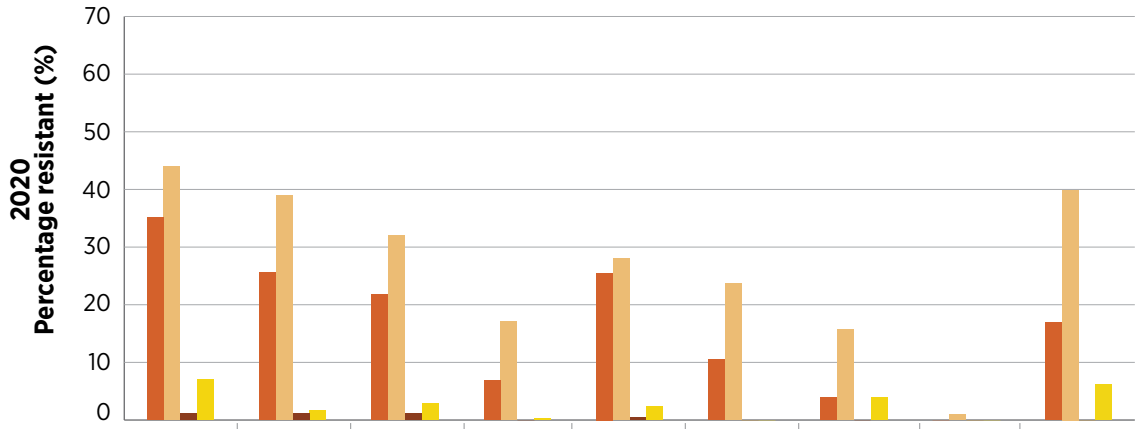
Variation in resistance rates to first-line agents across states and territories in both 2020 and 2021 (Figure 4.26) was observed. Most noticeable are the low rates of resistance in the remote areas of the NT. A high proportion of the population in these parts of the country are Aboriginal and Torres Strait Islander peoples. Nationally, the rate of decreased susceptibility to ceftriaxone was 0.9% in both 2020 and 2021 (Figure 4.25), compared with 1.3% in 2019.[9] Azithromycin resistance was 3.9% in 2020 and 4.7% in 2021. The highest rates were in NSW, where resistance increased from 6.0% in 2019[9] to 7.0% in 2020 and 9.9% in 2021 (Figure 4.26).

National trends

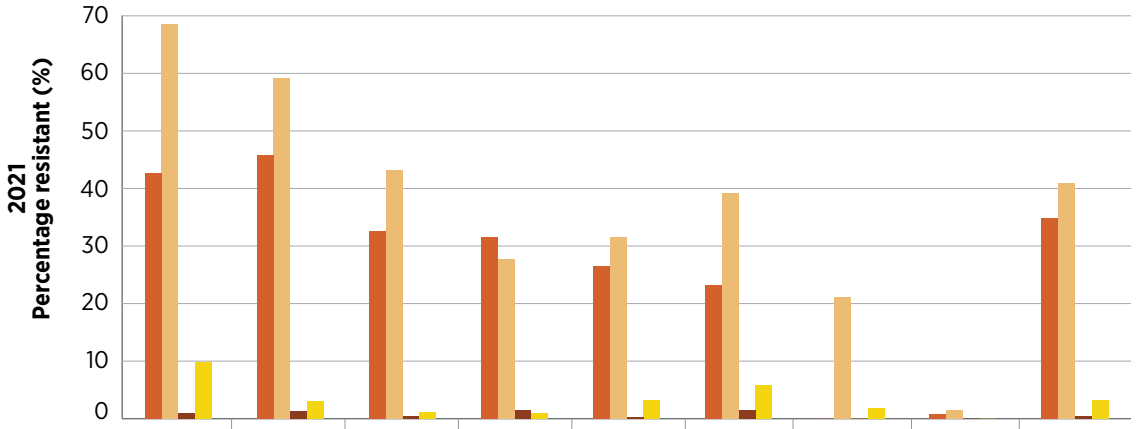
In the past 22 years, resistance rates to the four first-line agents have fluctuated (Figure 4.27). Resistance to benzylpenicillin and ciprofloxacin trended upwards from 2003 to 2008, then declined somewhat to stabilise at about 30% from 2011 to 2018. Since 2019, there has been a sharp upward trend. The 2021 rates for benzylpenicillin (38.1%) and ciprofloxacin (52.9%) approached the 2008 rates (44.0% and 53.1% respectively). The rates of reduced susceptibility to ceftriaxone are low, having peaked in 2013 (8.8%) and then declined; they have remained between 0.9% and 1.8% since 2015.

Detailed reports of susceptibility data on *N. gonorrhoeae* from 1995 to 2021 can be found in the AGSP annual reports.[9]

Figure 4.26: *Neisseria gonorrhoeae* resistance, by state and territory, 2020–2021



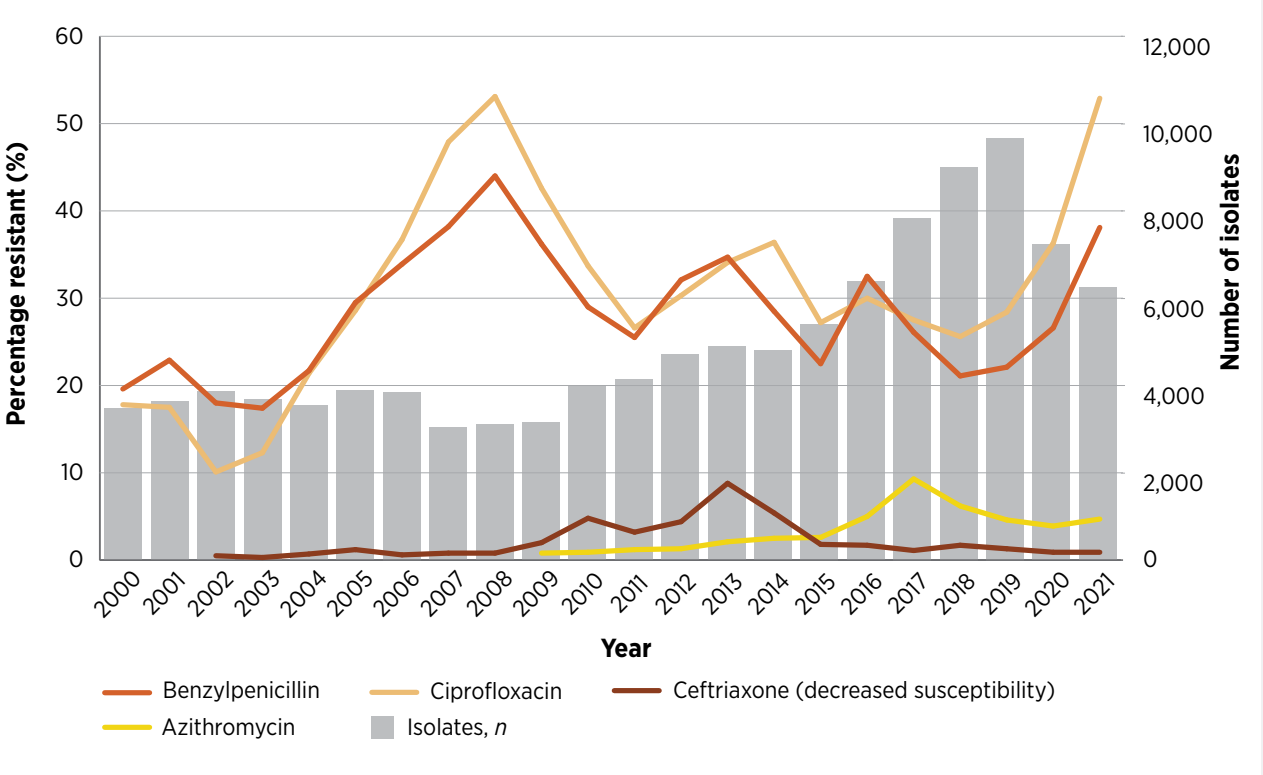
	NSW (2,585)	Vic (1,665)	Qld (1,504)	SA (334)	WA (797)	Tas (38)	NT (non-remote) (51)	NT (remote) (100)	ACT (148)
Benzylpenicillin	35.2	25.6	21.7	6.9	25.5	10.5	3.9	0.0	16.9
Ciprofloxacin	44.0	38.9	32.0	17.1	28.0	23.7	15.7	1.0	39.9
Ceftriaxone (decreased susceptibility)	1.2	1.1	1.1	0.0	0.4	0.0	0.0	0.0	0.0
Azithromycin	7.0	1.7	2.9	0.3	2.4	0.0	3.9	0.0	6.1



	NSW (1,921)	Vic (1,899)	Qld (1,128)	SA (295)	WA (569)	Tas (69)	NT (non-remote) (57)	NT (remote) (130)	ACT (186)
Benzylpenicillin	42.6	45.8	32.5	31.5	26.5	23.2	0.0	0.8	34.9
Ciprofloxacin	68.6	59.2	43.2	27.8	31.6	39.1	21.1	1.5	40.9
Ceftriaxone (decreased susceptibility)	0.9	1.3	0.4	1.4	0.2	1.4	0.0	0.0	0.5
Azithromycin	9.9	3.1	1.2	1.0	3.2	5.8	1.8	0.0	3.2

Note: Decreased susceptibility to ceftriaxone is defined as an MIC greater than that of the wild type.
Source: NNN Australian Gonococcal Surveillance Programme (public and private hospitals, and health services)

Figure 4.27: Trends in *Neisseria gonorrhoeae* resistance: decreased susceptibility to ceftriaxone and multi-drug resistance, 2000–2021



Note: Decreased susceptibility to ceftriaxone is defined as an MIC greater than that of the wild type.
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

N. meningitidis can cause bacteraemia and meningitis, known as invasive meningococcal disease (IMD). IMD is a very uncommon infection in Australia, but it is considered a medical emergency as it can rapidly progress to serious disease and death. IMD can be associated with outbreaks in environments in which there is close prolonged contact, especially in household settings. *N. meningitidis* can also rarely cause conjunctivitis, which can progress to IMD, and IMD can also rarely present as septic arthritis or pneumonia.

In Australia, the main *N. meningitidis* serogroups causing IMD are MenB, MenW and MenY. A surge in MenW and MenY IMD notifications from 2017 led to a change in the National Immunisation Program (NIP) from a monovalent MenC to quadrivalent MenACWY vaccine. Currently, there are two meningococcal vaccines included in the NIP. Infants and adolescents receive a vaccine against meningococcal serogroups A, C, W and Y, and those at high risk of IMD including 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 IMD is potentially life-threatening, it is treated empirically, pending the results of blood cultures and, when necessary, testing of cerebrospinal fluid. The most important antimicrobials for treatment are ceftriaxone (or cefotaxime) and benzylpenicillin. Close contacts of patients with IMD are given antimicrobial prophylaxis to prevent infection by clearing nasopharyngeal colonisation. The most important antimicrobials for prophylaxis are rifampicin and ciprofloxacin, and in certain circumstances ceftriaxone.

Types and impact of resistance

In Australia, resistance to ceftriaxone has not been reported. Resistance to benzylpenicillin has been documented for some time[16], but is not yet associated with treatment failure. 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 (which have no acquired resistance mechanisms) have MICs of ≤0.25 mg/L.

Rarely IMD strains are reported with resistance to rifampicin or reduced susceptibility to ciprofloxacin by the Australian Meningococcal Surveillance Programme (AMSP). These two agents are used for clearance of carriage after treatment.

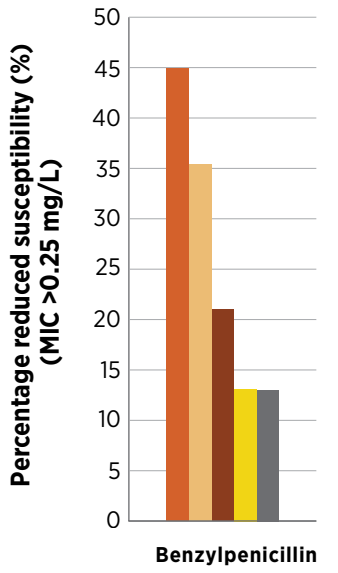
Key findings: national

The number of notified cases of IMD has decreased by 80% since 2017, following the introduction of funded meningococcal ACWY vaccination programs in Australia. In 2020, 90 cases of meningococcal infection were notified nationally (a rate of 0.4 per 100,000 population).[6,10] From these cases, 87 isolates were submitted for susceptibility testing.[16] In 2021, 75 cases of meningococcal infection were notified nationally (a rate of 0.3 per 100,000 population[6,10]), the lowest number recorded since 1991 when records began. From these cases, 67 were submitted for susceptibility testing.[16]

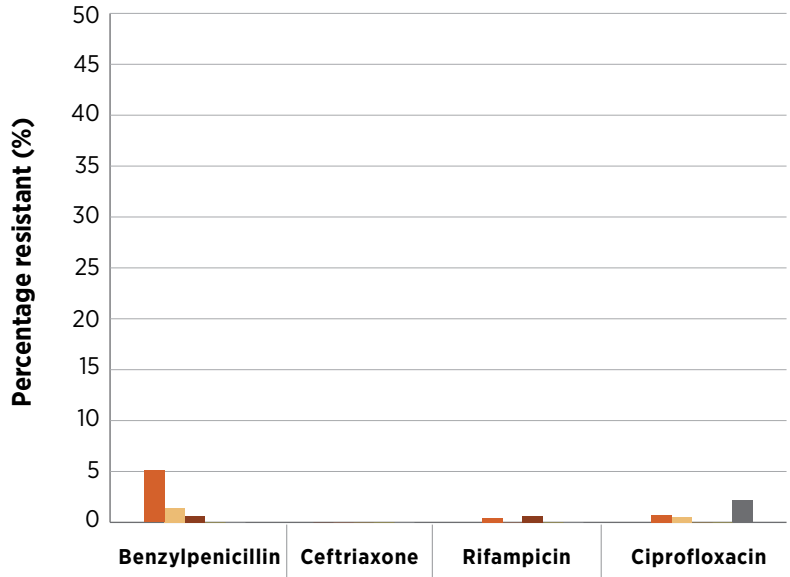
The recent national rates of resistance to the four key agents used for treatment or prophylaxis are shown in Figure 4.28.

The rates of reduced susceptibility and resistance to benzylpenicillin have declined since 2017 (44.9% and 5.1%, respectively), to 13.0% and 0.0%, respectively, in 2021. Ceftriaxone resistance has not ever been reported in Australia.

Figure 4.28: *Neisseria meningitidis* resistance, 2017–2021



	Benzylpenicillin
2017 (*n* = 274)	44.9
2018 (*n* = 212)	35.4
2019 (*n* = 167)	21.0
2020 (*n* = 61)	13.1
2021 (*n* = 46)	13.0



	Benzylpenicillin	Ceftriaxone	Rifampicin	Ciprofloxacin
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
2020	0.0	0.0	0.0	0.0
2021	0.0	0.0	0.0	2.2

Notes:
1. Reduced susceptibility or resistance to benzylpenicillin; in most test systems, wild-type strains' MICs are ≤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)

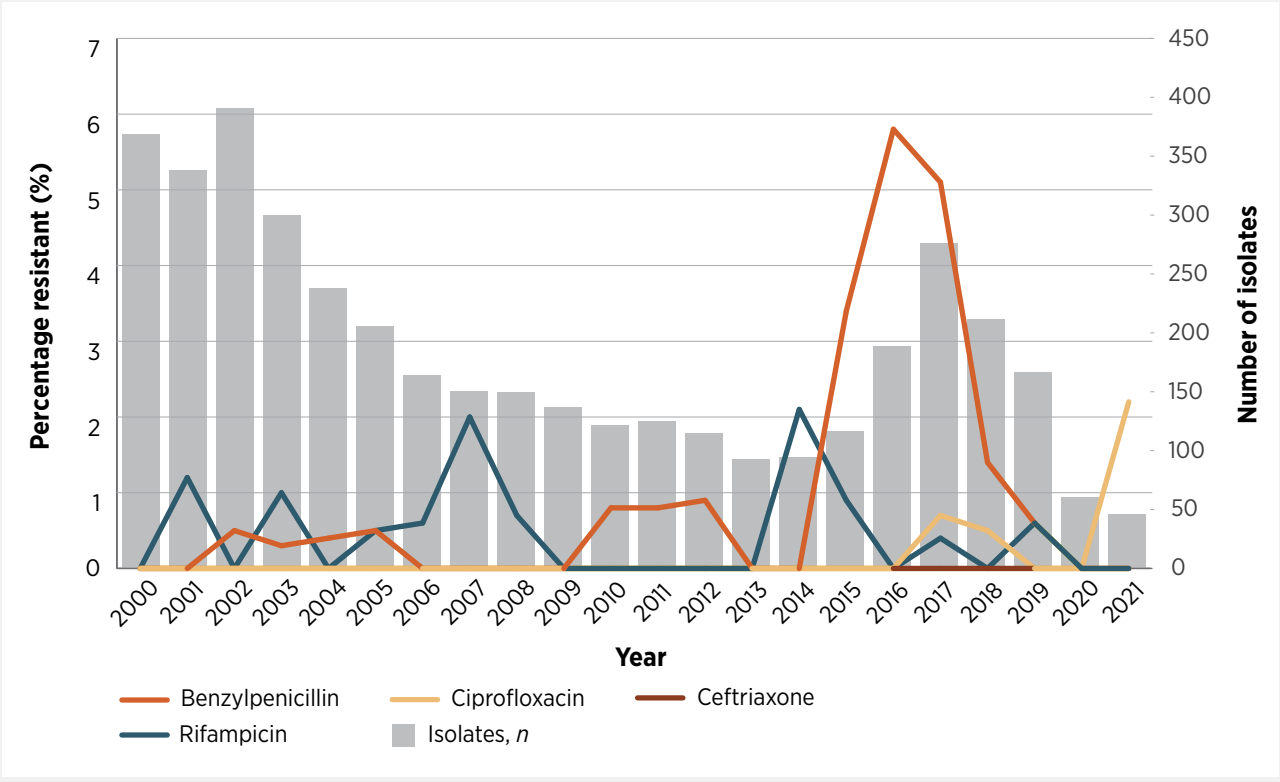
National trends

In the past 22 years, there has been little change in the (very low or zero) rates of resistance to any of the four key agents, except benzylpenicillin (Figure 4.29). Resistance to benzylpenicillin in this context is defined as an MIC ≥1 mg/L. Benzylpenicillin 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, and there was none in either 2020 or 2021. 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, 21% in 2019, and 13% in 2020 and 2021 (Figure 4.30). This decrease can be attributed to the declining incidence of the resistant serogroup W clone following the change in the immunisation schedule in Australia.

Detailed reports of susceptibility data for *N. meningitidis* from 1997 to 2021 can be found in the AMSP annual reports.[16]

Raised benzylpenicillin MIC values and resistance in *N. meningitidis* have been reported in Australia and continue to be monitored. Resistance to ciprofloxacin and rifampicin is rarely reported.

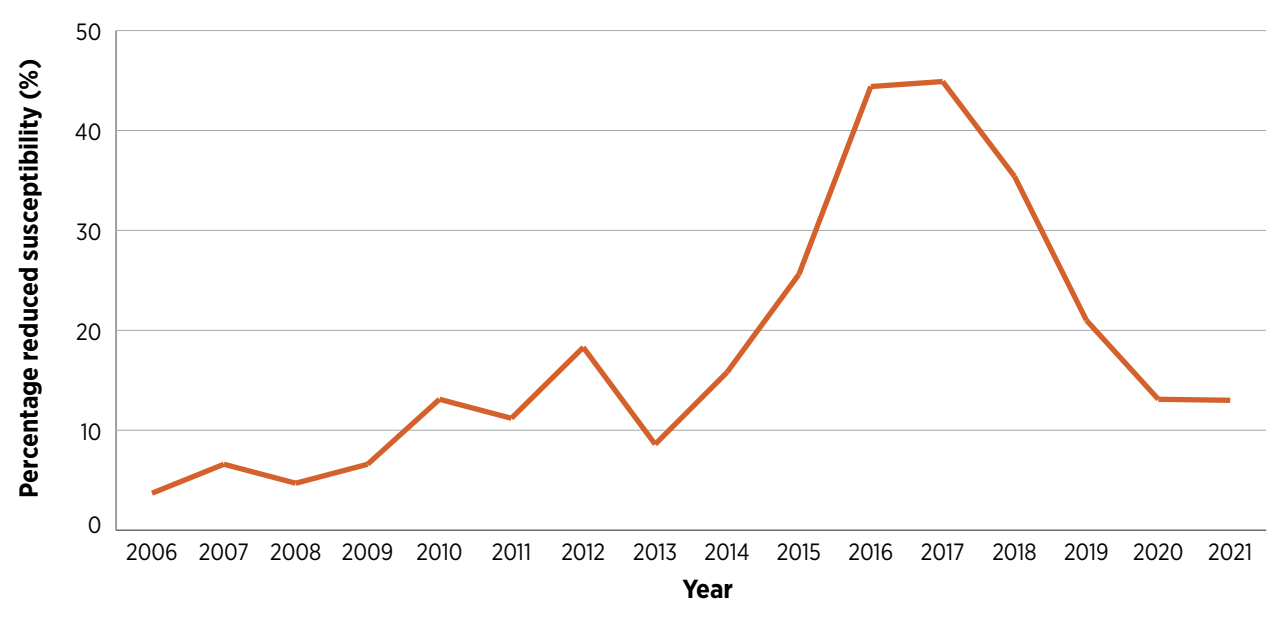
Figure 4.29: Trends in resistance in *Neisseria meningitidis*, 2000–2021



Notes:
1. Resistance to benzylpenicillin is defined as an MIC of ≥1 mg/L.
2. There was one meningococcal strain in 2016 with an elevated MIC to ceftriaxone (0.125 mg/L). No ceftriaxone resistance has been reported.

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

Figure 4.30: Trends in *Neisseria meningitidis* reduced susceptibility to benzylpenicillin, 2006–2021



Note: Reduced susceptibility is defined as an MIC 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. A nosocomial pathogen is an infectious agent that is acquired during the process of receiving healthcare, causing a healthcare-associated infection (HAI). *P. aeruginosa* 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 is a ubiquitous organism found in moist environments. It can cause UTIs 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 infections in patients with cystic fibrosis. *P. aeruginosa* also causes bacteraemia, 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 tobramycin; there is insufficient evidence that *P. aeruginosa* is a good target for therapy with gentamicin – in 2023 the Clinical and Laboratory Standards Institute (CLSI) removed this agent from its clinical breakpoint table, in line with EUCAST
- Some fluoroquinolones, such as ciprofloxacin.

UTIs 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.

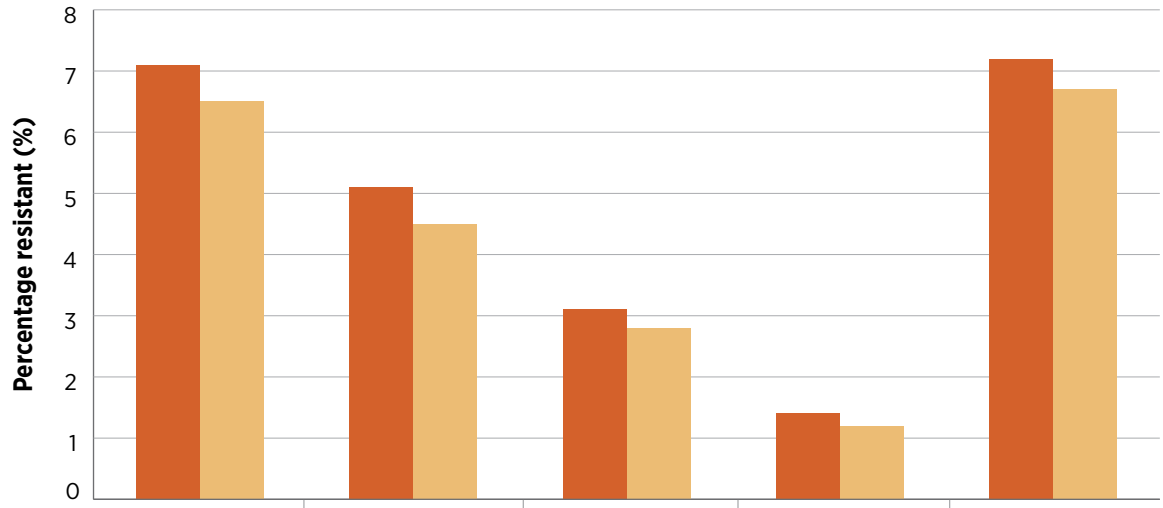
Types and impact of resistance

P. aeruginosa is intrinsically resistant to many antimicrobial classes because of the presence of several efflux pumps in its cell membrane and cell wall. Upregulation of its 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. Although there is no globally recognised definition for multi-drug resistance in this species, 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

The resistance rates of *P. aeruginosa* to key antimicrobial agents are low overall, as shown in Figure 4.31. Rates of resistance to carbapenems and aminoglycosides were substantially higher in public hospitals than in private hospitals (Figure 4.32), possibly due in part to the influence of isolates from patients with cystic fibrosis who are often 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.

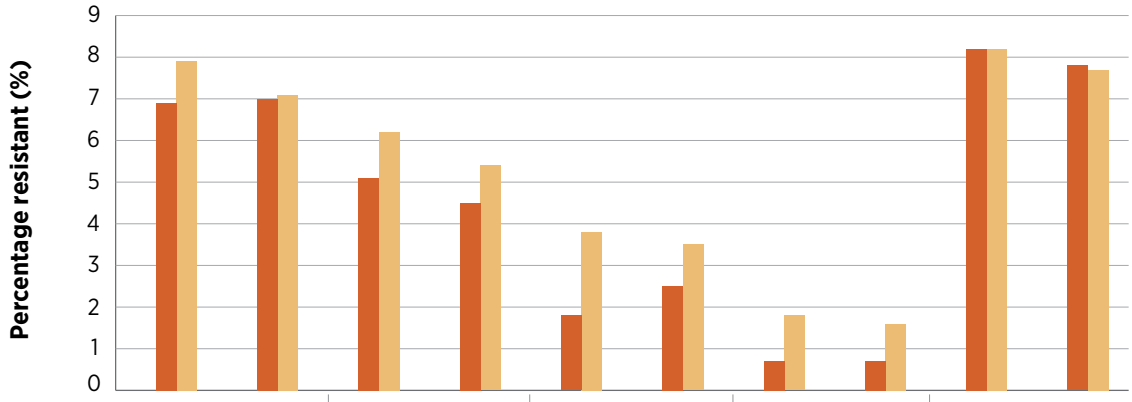
Figure 4.31: *Pseudomonas aeruginosa* resistance, 2020–2021



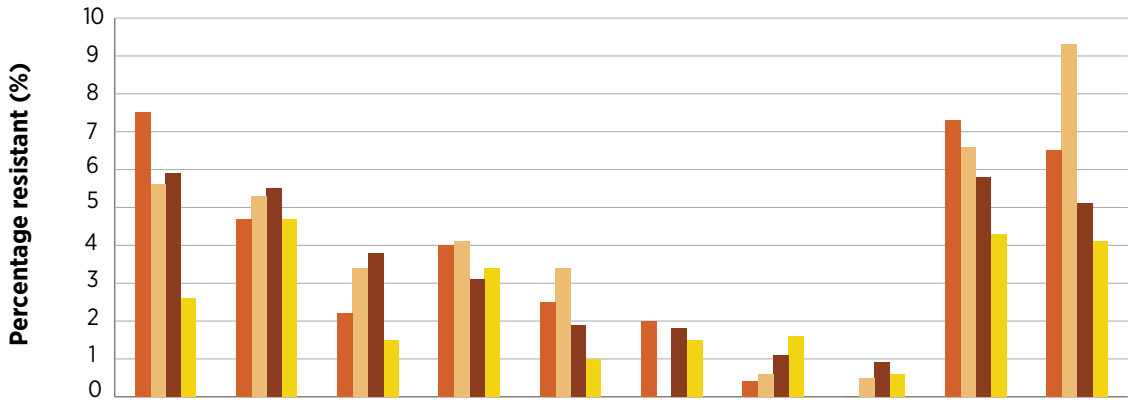
	PTZ	CAZ	MER	TOB	CIP
2020, %	7.1	5.1	3.1	1.4	7.2
2021, %	6.5	4.5	2.8	1.2	6.7
2020, *n*	54,469	53,486	48,804	47,741	48,376
2021, *n*	56,847	55,924	51,044	51,496	50,297

CAZ = ceftazidime; CIP = ciprofloxacin; MER = meropenem; PTZ = piperacillin–tazobactam; TOB = tobramycin
Note: There is insufficient evidence that *P. aeruginosa* is a good target for therapy with gentamicin. In 2023 CLSI removed this agent from their clinical breakpoint table, in line with EUCAST.
Sources: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); HOTspots (NT); SNP (Qld, northern NSW)

Figure 4.32: *Pseudomonas aeruginosa* resistance, by clinical setting, 2020–2021



	PTZ		CAZ		MER		TOB		CIP	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Private hospitals, %	6.9	7.0	5.1	4.5	1.8	2.5	0.7	0.7	8.2	7.8
Public hospitals, %	7.9	7.1	6.2	5.4	3.8	3.5	1.8	1.6	8.2	7.7
Private hospitals, *n*	3,420	3,567	3,396	3,521	733	767	3,364	3,345	736	772
Public hospitals, *n*	28,443	29,796	27,376	28,605	28,089	29,294	22,339	25,460	28,176	29,318



	PTZ		CAZ		MER		TOB		CIP	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Multi-purpose service, %	7.5	4.7	2.2	4.0	2.5	2.0	0.4	0.0	7.3	6.5
Aged care homes, %	5.6	5.3	3.4	4.1	3.4	0.0	0.6	0.5	6.6	9.3
Community, %	5.9	5.5	3.8	3.1	1.9	1.8	1.1	0.9	5.8	5.1
Other, %	2.6	4.7	1.5	3.4	1.0	1.5	1.6	0.6	4.3	4.1
Multi-purpose service, *n*	401	386	267	321	283	342	224	317	398	384
Aged care homes, *n*	1,081	1,037	1,089	1,038	119	96	1,080	971	121	97
Community, *n*	20,602	21,218	20,043	20,720	18,262	18,821	19,430	19,695	18,423	18,880
Other, *n*	233	338	201	321	206	329	190	309	232	340

CAZ = ceftazidime; CIP = ciprofloxacin; MER = meropenem; PTZ = piperacillin–tazobactam; TOB = tobramycin
Notes:
1. Other settings were predominantly corrective services.
2. There is insufficient evidence that *P. aeruginosa* is a good target for therapy with gentamicin. In 2023 CLSI removed this agent from their clinical breakpoint table, in line with EUCAST.

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

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 bacteraemia, 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 bacteraemia), 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 the intestinal carriage of the organism after disease resolution, increasing the risk of transmission. Antimicrobial therapy is indicated in patients with severe disease or bacteraemia (typhoidal *Salmonella* infection, in particular), and patients who have prosthetic vascular grafts. Ciprofloxacin, azithromycin and ceftriaxone are the standard treatment options.

Types and impact of resistance

Resistance to older treatment agents, such as ampicillin and chloramphenicol, emerged in 2017. Resistance to newer treatments has only been problematic with ciprofloxacin and other fluoroquinolones, such as norfloxacin.

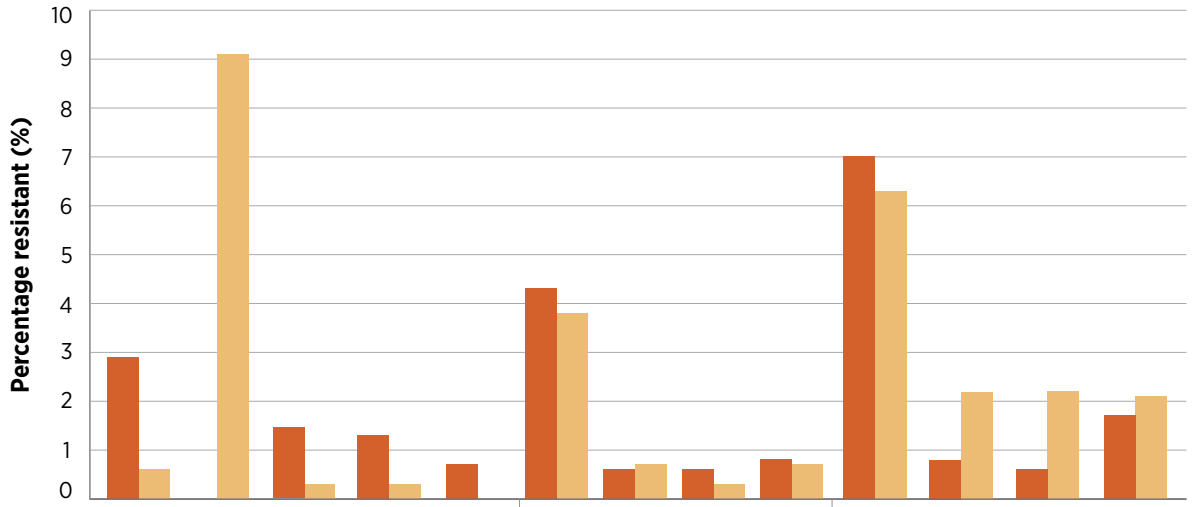
Key findings: national

In non-typhoidal *Salmonella* species, rates of resistance to ampicillin, ceftriaxone and fluoroquinolones were less than 10% (Figure 4.33). In contrast, the rate of resistance to the fluoroquinolone ciprofloxacin in typhoidal *Salmonella* species was 74% in 2020 for blood isolates (Figure 4.34); in 2021, there were only four isolates reported.

Since 2019, the number of typhoidal *Salmonella* isolates has fallen dramatically, coinciding with the closure of international borders in response to the COVID-19 pandemic.

The high rates of resistance to ciprofloxacin in typhoidal *Salmonella* species mean that ciprofloxacin is no longer recommended as initial therapy for these infections.[17]

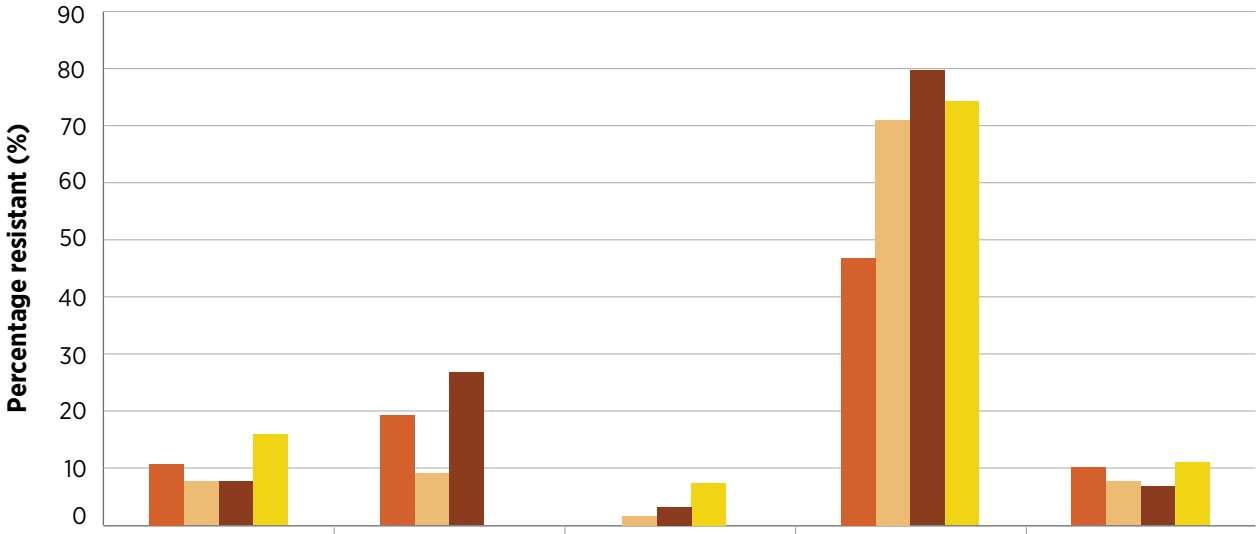
Figure 4.33: Non-typhoidal *Salmonella* species resistance, by specimen source, 2020–2021



	Blood					Faeces				Other*			
	AMP	AZI	CTR/CTX	CIP	SXT	AMP	CTR/CTX	CIP/NOR	SXT	AMP	CTR/CTX	CIP/NOR	TMP
2020, %	2.9	0.0	1.3	1.3	0.7	4.3	0.6	0.6	0.8	7.0	0.8	0.6	1.7
2021, %	0.6	9.1	0.3	0.3	0.0	3.8	0.7	0.3	0.7	6.3	2.2	2.2	2.1
2020, *n*	308	11	309	316	305	4,134	2,818	2,857	4,102	187	131	179	180
2021, *n*	317	11	317	320	313	3,838	2,615	2,723	3,811	252	180	178	239

AMP = ampicillin; AZI = azithromycin; CIP = ciprofloxacin; CTR = ceftriaxone; CTX = cefotaxime; NOR = norfloxacin; SXT = trimethoprim–sulfamethoxazole; TMP = trimethoprim
* Specimen sources other than blood or faeces
Note: Isolates were included if 10 or more per specimen sources per year.
Sources: AGAR (national); APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); SNP (Qld, northern NSW)

Figure 4.34: Typhoidal *Salmonella* species resistance (blood culture isolates), 2017–2021



	AMP	AZI	CTR/CTX	CIP	SXT
2017, %	10.7	19.2	0.0	46.8	10.1
2018, %	7.6	9.1	1.7	71.0	7.6
2019, %	7.7	26.7	3.2	79.7	6.7
2020, %	15.9	nd	7.4	74.3	10.9
2021, %	nd	nd	nd	nd	nd
2017, *n*	122	26	122	111	119
2018, *n*	119	11	118	100	105
2019, *n*	155	15	155	153	149
2020, *n*	63	8	68	70	55
2021, *n*	4	2	4	4	4

AMP = ampicillin; AZI = azithromycin; CIP = ciprofloxacin; CTR = ceftriaxone; CTX = cefotaxime; nd = no data (either not tested or tested against an inadequate number of isolates, *n* <10); 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. Infections may be transmitted person-to-person or sexually transmitted. Genetically, *Shigella* 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.

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 and trimethoprim–sulfamethoxazole.

Types and impact of resistance

Resistance, including multi-drug resistance to conventional treatments, is well documented worldwide. Azithromycin is considered a suitable option for infections caused by strains that are resistant to standard treatments.

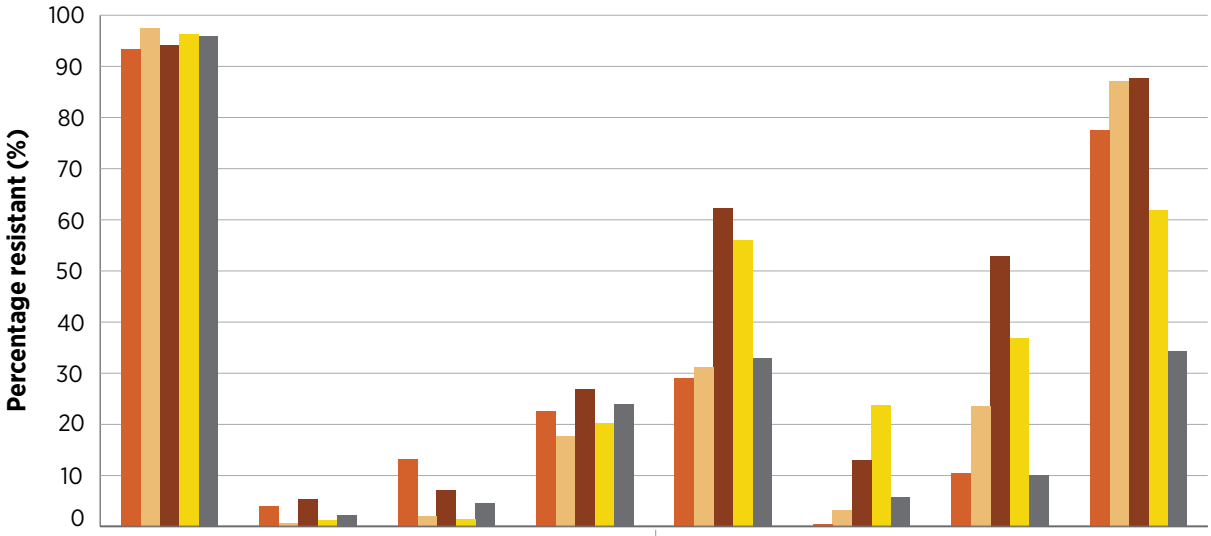
Key findings: national

The genus *Shigella* consists of four species, *S. boydii*, *S. dysenteriae*, *S. flexneri* and *S. sonnei*.

Since 2017, the prevalence of *S. flexneri* resistance to ampicillin has remained extremely common, but the prevalence of resistance to ciprofloxacin and ceftriaxone was very low (mostly <5.0%) (Figure 4.35). The presence of any resistance to ciprofloxacin in Australia is of concern, given the potential of this organism to cause outbreaks.

In 2018 and 2019, *S. sonnei* resistance to ceftriaxone, ciprofloxacin and ampicillin increased rapidly. There was a prolonged outbreak of an ESBL-producing strain ($bla_{CTX\text{-}M\text{-}27}$) circulating in Australia, especially in NSW and Victoria, which was also multidrug-resistant.[19,20] In 2020, the rates of resistance began to decline and continued to decline in 2021, until they were similar to 2017 rates.

Figure 4.35: *Shigella* species resistance (faecal isolates), 2017–2021



	S. flexneri				*S. sonnei*			
	Ampicillin	Ceftriaxone	Ciprofloxacin	SXT	Ampicillin	Ceftriaxone	Ciprofloxacin	SXT
2017, %	93.3	4.1	13.2	22.6	29.0	0.4	10.5	77.5
2018, %	97.5	0.6	1.9	17.6	31.1	3.2	23.6	87.2
2019, %	94.1	5.3	7.2	26.9	62.2	13.0	52.9	87.7
2020, %	96.2	1.3	1.4	20.2	56.0	23.8	36.8	61.8
2021, %	96.0	2.3	4.5	24.0	32.9	5.7	10.0	34.3
2017, *n*	210	194	204	212	314	262	305	316
2018, *n*	318	312	262	318	254	217	250	257
2019, *n*	286	263	265	286	209	161	208	211
2020, *n*	182	158	144	183	191	160	190	191
2021, *n*	50	43	44	50	70	70	70	70

SXT = trimethoprim–sulfamethoxazole
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 bacteraemia. *S. aureus* is also a common cause of HAIs, especially surgical site infections, intravascular line infections with bacteraemia, and infections of prosthetic devices. Infections associated with bacteraemia (positive blood cultures) have a 30-day crude mortality of 15–30%.

Comprehensive data from AGAR surveys of *S. aureus* can be found on the AGAR website.[3]

Treatment

Many staphylococcal skin infections can be managed without antimicrobial therapy, but moderate and serious infections require treatment. The preferred treatment agent is flucloxacillin (or dicloxacillin), or first-generation cephalosporins such as cefazolin or cefalexin for penicillin-allergic patients.

Types and impact of resistance

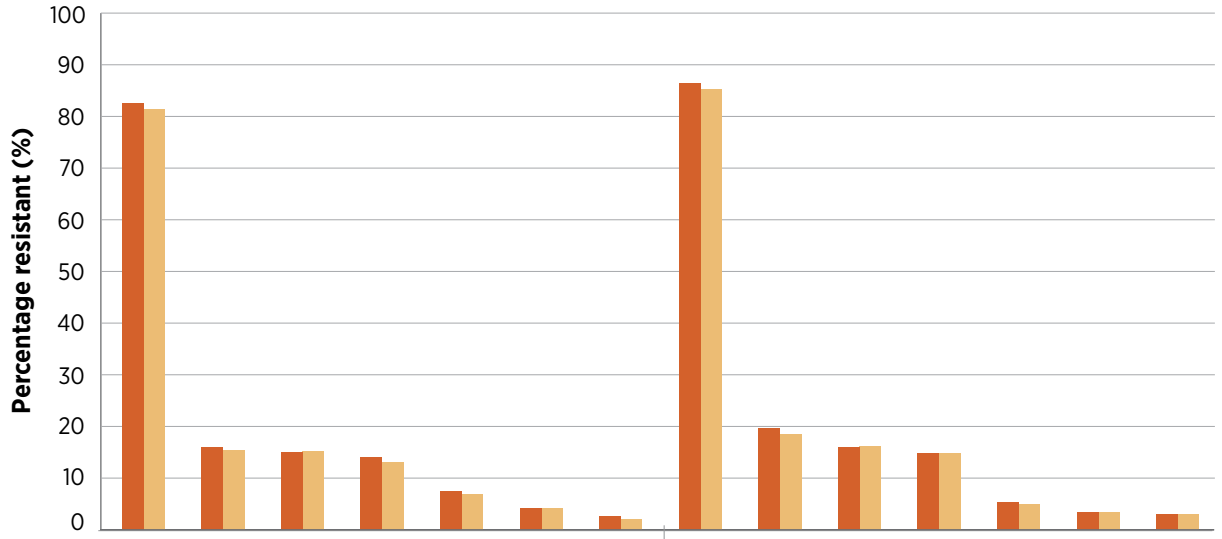
Around 85–90% of *S. aureus* strains in community settings are resistant to penicillin, and this has been consistent for decades. Healthcare-associated strains that are resistant to flucloxacillin and first-generation cephalosporins, commonly called MRSA, emerged in the 1970s and are now common in many 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 emerged in the 1980s and are distinct from healthcare-associated clones. 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 is believed 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 81–85% of *S. aureus* isolates were observed to be resistant to benzylpenicillin in 2020–2021 (Figure 4.36). Oxacillin (methicillin) resistance was stable at 15–19%. There was little difference in the rates of resistance between different clinical settings, apart from oxacillin resistance, which was highest in aged care homes, multi-purpose services, and other settings (mostly corrective services), suggesting that these are important reservoirs for MRSA (Figure 4.37).

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 4.38).

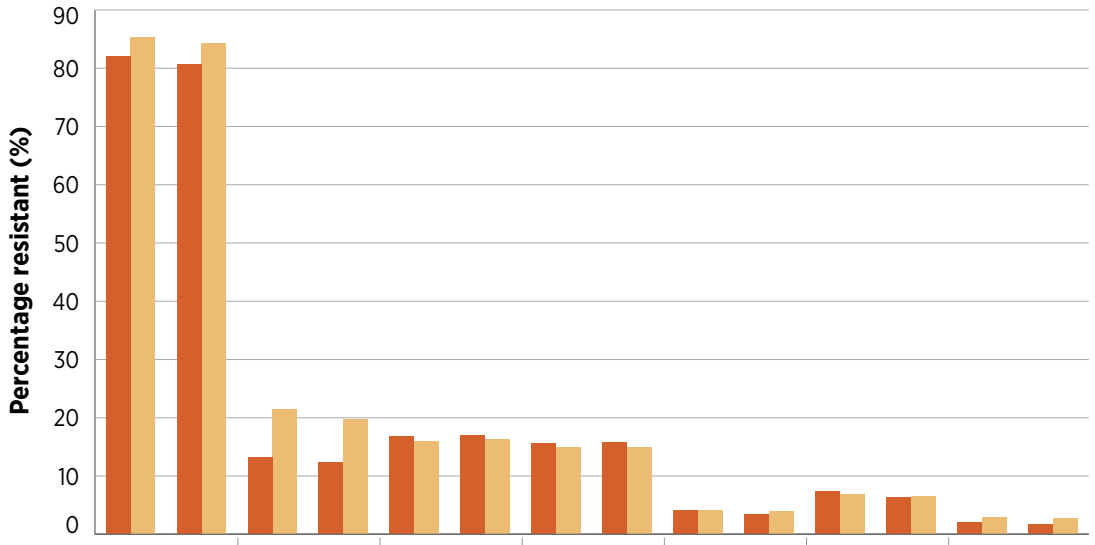
Figure 4.36: *Staphylococcus aureus* resistance, by specimen source, 2020–2021



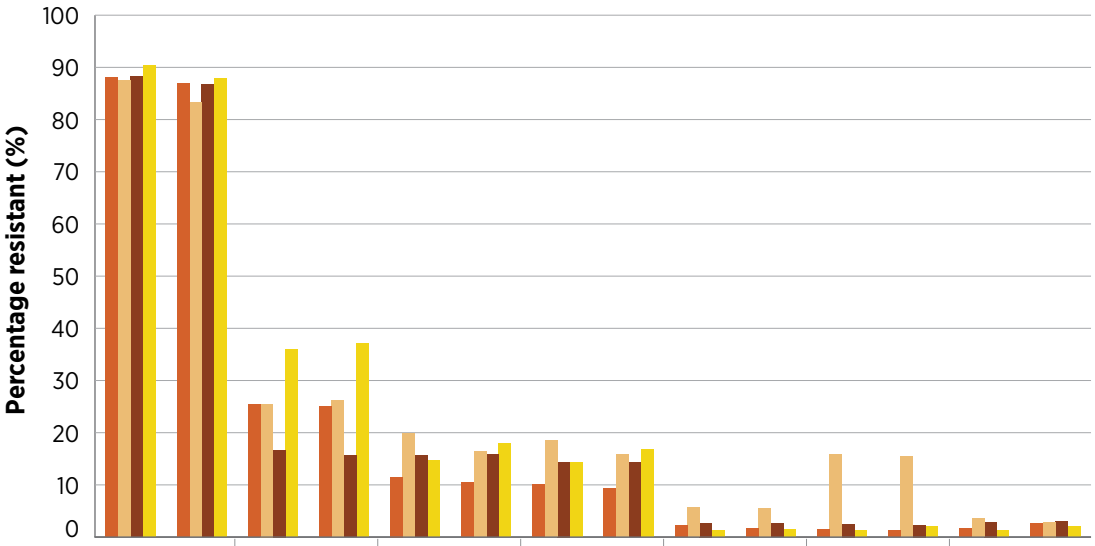
	PEN	OXA	ERY	CLN	CIP	TET	SXT	PEN	OXA	ERY	CLN	CIP	TET	SXT
	Blood							Other*						
2020, %	82.5	16.0	15.0	14.1	7.5	4.2	2.6	86.5	19.7	15.9	14.8	5.3	3.4	3.0
2021, %	81.4	15.3	15.2	13.0	6.9	4.1	2.1	85.3	18.5	16.2	14.8	5.0	3.3	3.0

CIP = ciprofloxacin; CLN = clindamycin; ERY = erythromycin; OXA = oxacillin; PEN = penicillin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines
* Specimen sources other than blood
Sources: AGAR (national), APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); HOTspots (NT); SNP (Qld, northern NSW)

Figure 4.37: *Staphylococcus aureus* resistance, by clinical setting, 2020–2021



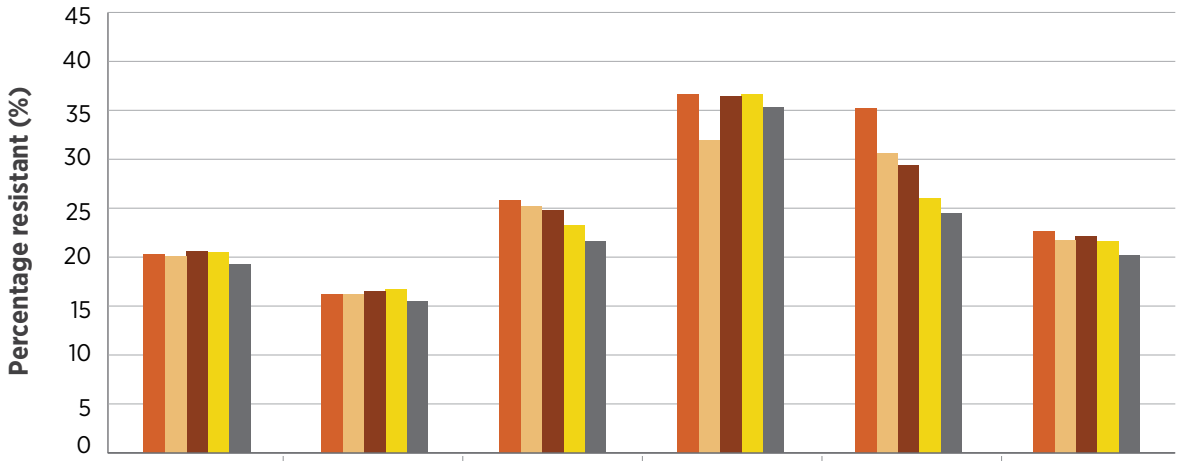
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
	PEN		OXA		ERY		CLN		TET		CIP		SXT	
Private hospitals, %	82.0	80.7	13.3	12.3	16.8	17.0	15.6	15.8	4.2	3.5	7.4	6.3	2.0	1.7
Public hospitals, %	85.4	84.3	21.4	19.8	16.0	16.3	15.0	15.0	4.2	4.0	6.9	6.5	2.9	2.8



	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
	PEN		OXA		ERY		CLN		TET		CIP		SXT	
Multi-purpose service, %	88.0	86.9	25.4	25.1	11.5	10.5	10.0	9.3	2.2	1.7	1.5	1.2	1.6	2.6
Aged care homes, %	87.5	83.3	25.5	26.1	19.8	16.4	18.5	15.9	5.6	5.4	15.9	15.5	3.6	2.9
Community, %	88.3	86.7	16.7	15.7	15.7	15.9	14.4	14.3	2.7	2.6	2.5	2.3	2.9	3.0
Other, %	90.3	87.9	36.0	37.1	14.7	17.9	14.3	16.8	1.3	1.5	1.3	2.1	1.3	2.0

CIP = ciprofloxacin; CLN = clindamycin; ERY = erythromycin; OXA = oxacillin; PEN = penicillin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines
Note: Other settings were mainly corrective services.
Sources: AGAR, APAS and HOTspots (public hospitals); AGAR, APAS (Qld, SA) and SNP (private hospitals); APAS, HOTspots and SNP (community); APAS and SNP (aged care homes); APAS (multi-purpose services); APAS (other)

Figure 4.38: Percentage of methicillin-resistant *Staphylococcus aureus* by remoteness area, 2020–2021



	Major cities of Australia	Inner regional Australia	Outer regional Australia	Remote Australia	Very remote Australia	All areas combined
2017, %	20.3	16.2	25.8	36.6	35.2	22.6
2018, %	20.1	16.2	25.2	31.9	30.6	21.7
2019, %	20.6	16.5	24.8	36.4	29.4	22.1
2020, %	20.5	16.7	23.2	36.6	26.0	21.6
2021, %	19.3	15.5	21.6	35.3	24.5	20.2
2017, *n*	67,092	25,449	28,727	7,372	9,796	138,436
2018, *n*	66,216	24,391	27,109	6,086	9,399	133,201
2019, *n*	69,166	25,072	28,018	7,098	9,397	138,751
2020, *n*	67,744	24,772	28,572	6,867	9,365	137,320
2021, *n*	69,779	26,857	30,667	6,932	9,878	144,113

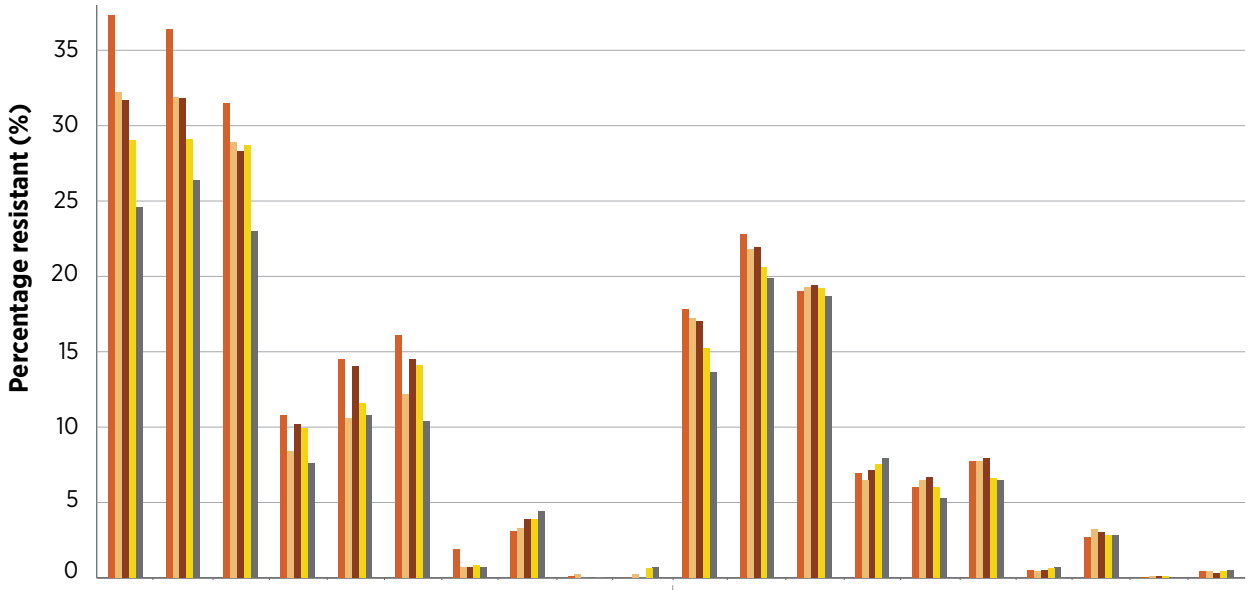
Note: The postcode of a patient's place of residence, where known, was used to stratify data in terms of remoteness using the Australian Bureau of Statistics (ABS) Australian Statistical Geography Standard (ASGS).[1]
Sources: APAS (national, excluding NT) and HOTspots (NT)

Resistance to ciprofloxacin, erythromycin and clindamycin was high in MRSA, especially in blood isolates (24.6–29.1% in 2020 and 2021). Resistance to linezolid and daptomycin in MRSA was negligible (Figure 4.39). There were noticeable differences in resistance to ciprofloxacin, erythromycin, clindamycin and gentamicin in MRSA strains between clinical settings (Figure 4.40). This is possibly related to variation in the distribution of healthcare-associated clones compared with community-associated clones (Figures 4.41 and 4.42).

Healthcare-associated clones of MRSA had high rates of resistance to ciprofloxacin (98.7%), erythromycin (79.5%) and clindamycin (72.2%), and moderate levels of resistance to trimethoprim–sulfamethoxazole (33.3%) and gentamicin (39.3%) in 2013

(Figure 4.41). The rates have declined dramatically since 2015 for all of these agents except ciprofloxacin, largely due to the substantial decline in the multi-resistant ST239-III clone. The rates of resistance to other 'anti-MRSA' agents were low. Relative to other non-hospital settings, aged care homes recorded high rates of MRSA that were resistant to ciprofloxacin and erythromycin (Figure 4.40), a pattern most closely associated with the EMRSA-15 ST22-IV clone (ST22-IV). Rates of resistance to ciprofloxacin, erythromycin and clindamycin were much lower in community-associated clones than in healthcare-associated clones (Figure 4.42). The increase in resistance to ciprofloxacin, gentamicin and tetracycline in community-associated clones corresponds with an increasing prevalence of the MDR ST45-V clone.

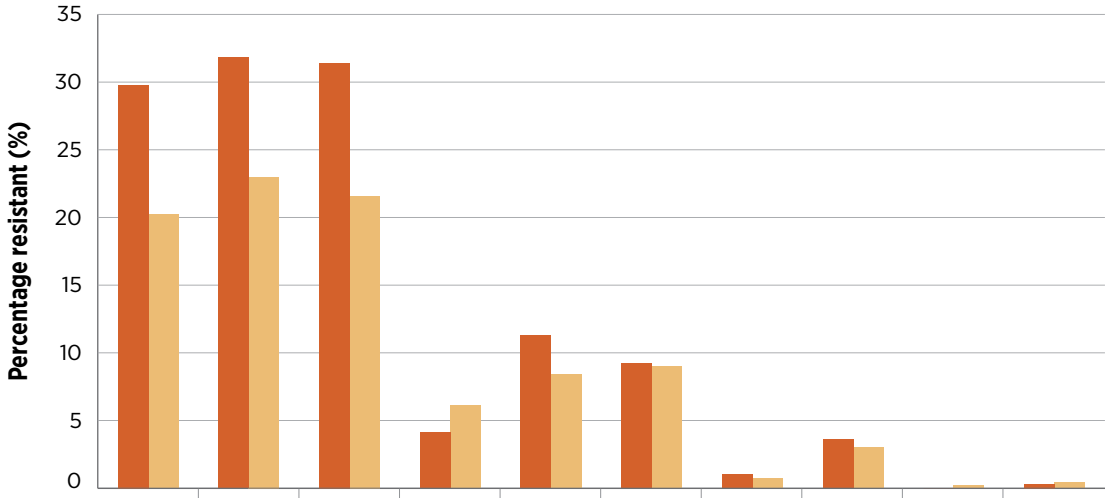
Figure 4.39: Methicillin-resistant *Staphylococcus aureus* resistance to non-β-lactam agents, by specimen source, 2017–2021



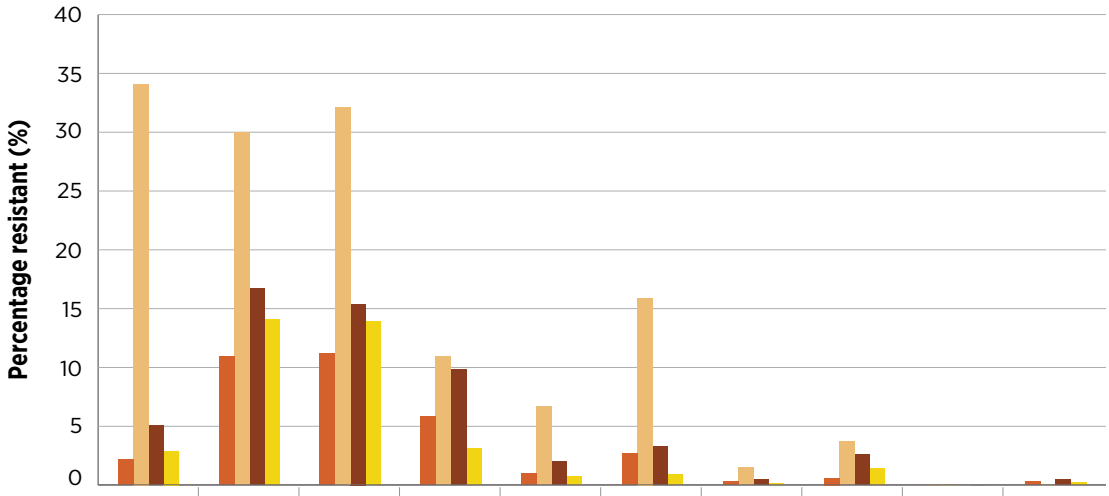
	Blood										Other*									
	CIP	ERY	CLN	SXT	GEN	TET	RIF	FUS	LNZ	DAP	CIP	ERY	CLN	SXT	GEN	TET	RIF	FUS	LNZ	DAP
2017, %	37.3	36.4	31.5	10.8	14.5	16.1	1.9	3.1	0.1	0.0	17.8	22.8	19.0	6.9	6.0	7.7	0.5	2.7	0.02	0.4
2018, %	32.2	31.9	28.9	8.4	10.6	12.2	0.7	3.3	0.2	0.2	17.2	21.8	19.3	6.5	6.5	7.7	0.4	3.2	0.08	0.4
2019, %	31.7	31.8	28.3	10.2	14.0	14.5	0.7	3.9	0.0	0.0	17.0	21.9	19.4	7.1	6.7	7.9	0.5	3.0	0.1	0.3
2020, %	29.0	29.1	28.7	9.9	11.6	14.1	0.8	3.9	0.0	0.6	15.2	20.6	19.2	7.5	6.0	6.6	0.6	2.8	0.07	0.4
2021, %	24.6	26.4	23.0	7.6	10.8	10.4	0.7	4.4	0.0	0.7	13.6	19.9	18.7	7.9	5.3	6.5	0.7	2.8	0.04	0.5

CIP = ciprofloxacin; CLN = clindamycin; DAP = daptomycin; ERY = erythromycin; FUS = fusidic acid; GEN = gentamicin; LNZ = linezolid; RIF = rifampicin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines
* Specimen sources other than blood or urine
Sources: AGAR (national); APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); HOTspots (NT); SNP (Qld, northern NSW)

Figure 4.40: Methicillin-resistant *Staphylococcus aureus* resistance to non-β-lactam agents, by clinical setting, 2020 and 2021 combined



	CIP	ERY	CLN	SXT	GEN	TET	RIF	FUS	LNZ	DAP
Private hospitals, %	29.8	31.8	31.4	4.1	11.3	9.2	1.0	3.6	0.0	0.3
Public hospitals, %	20.2	23.0	21.6	6.1	8.4	9.0	0.7	3.0	0.1	0.4



	CIP	ERY	CLN	SXT	GEN	TET	RIF	FUS	LNZ	DAP
Multi-purpose service, %	2.2	10.9	11.2	5.8	1.0	2.7	0.3	0.6	0.0	0.3
Aged care homes, %	34.1	30.0	32.1	10.9	6.7	15.9	1.5	3.7	0.0	0.0
Community, %	5.1	16.7	15.4	9.8	2.0	3.3	0.5	2.6	0.0	0.5
Other, %	2.9	14.1	13.9	3.1	0.7	0.9	0.1	1.4	0.0	0.2

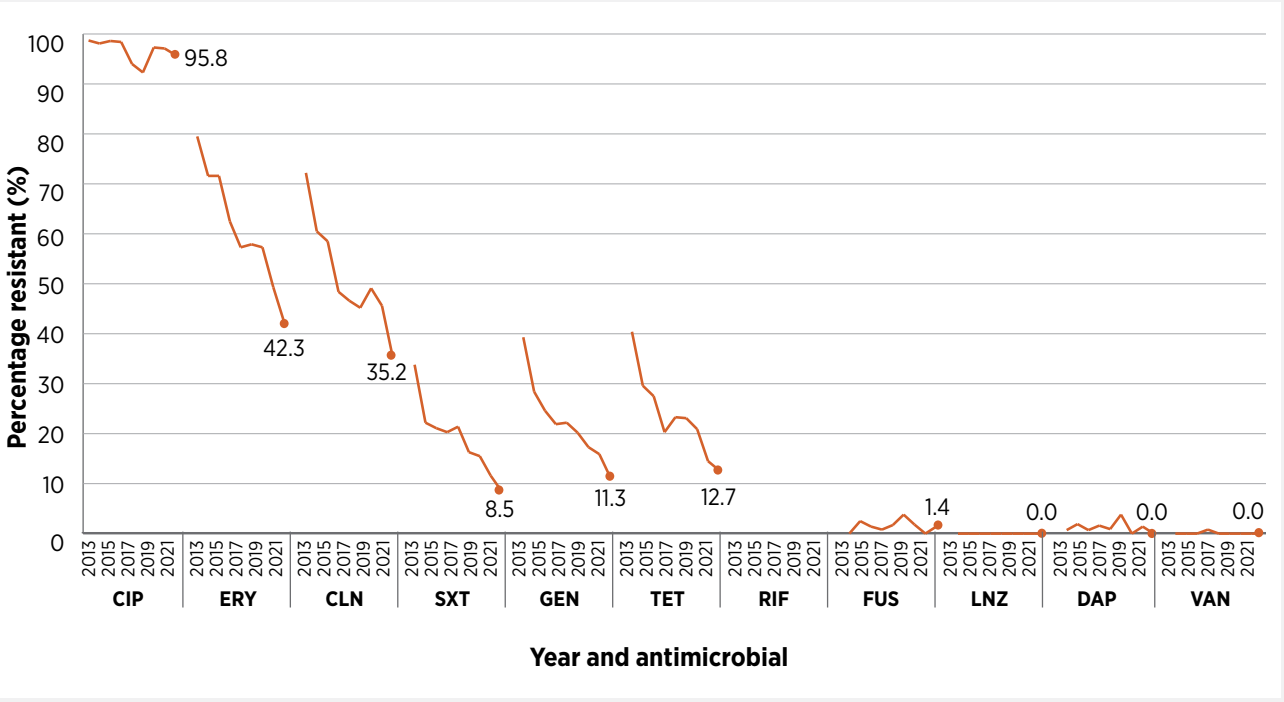
CIP = ciprofloxacin; CLN = clindamycin; DAP = daptomycin; ERY = erythromycin; FUS = fusidic acid; GEN = gentamicin; LNZ = linezolid; RIF = rifampicin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines

Notes:

1. For clarity of presentation, data for 2020 and 2021 have been combined. Raw data for the individual years are available in *AURA 2023*: *Supplementary data*.
2. Other settings were predominantly corrective services.

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

Figure 4.41: Trends in resistance (EUCAST) to other antimicrobials of healthcare-associated clones of methicillin-resistant *Staphylococcus aureus* (blood culture isolates), 2013–2021



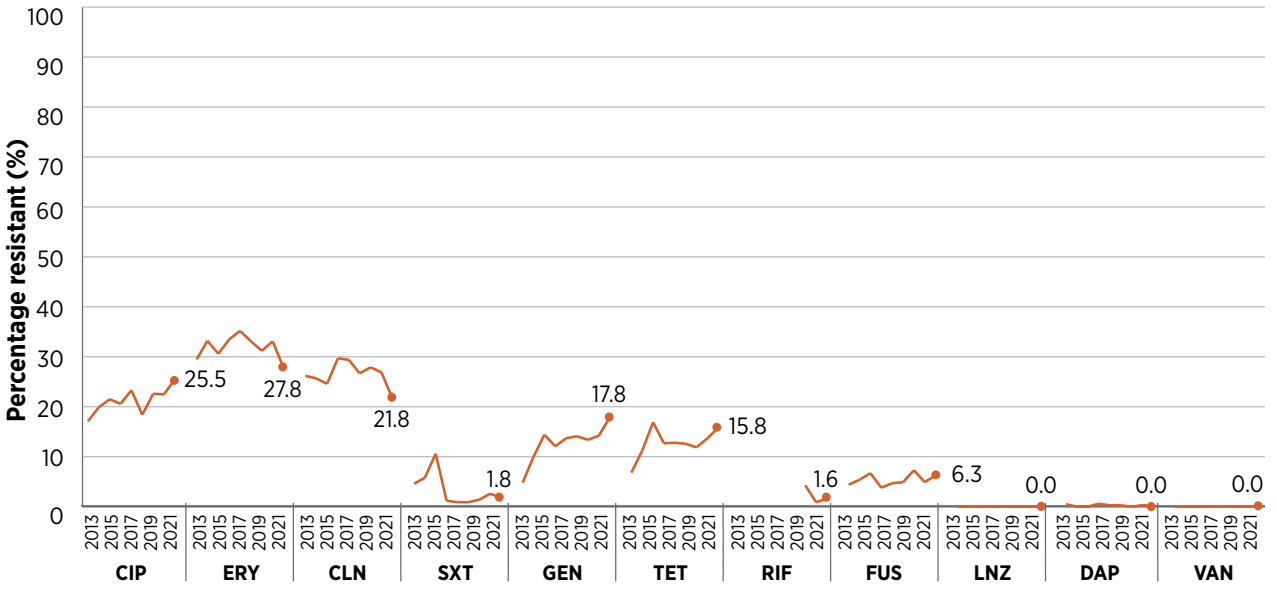
CIP = ciprofloxacin; CLN = clindamycin; DAP = daptomycin; ERY = erythromycin; EUCAST = European Committee on Antimicrobial Susceptibility Testing; FUS = fusidic acid; GEN = gentamicin; LNZ = linezolid; RIF = rifampicin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines; VAN = vancomycin

Notes:

1. Percentage resistance was determined using EUCAST 2022 breakpoints for all years. Filled circles indicate values for 2021.
2. Ability to accurately determine rifampicin resistance was restricted due to limitations of the testing method.

Source: AGAR (national), public and private hospitals; 2013–2014, *n* = 27; 2015, *n* = 35; 2016, *n* = 33; 2017, *n* = 35; 2018, *n* = 38; 2019, *n* = 41; 2020, *n* = 42; 2021, *n* = 41

Figure 4.42: Trends in resistance (EUCAST) to other antimicrobials of community-associated clones of methicillin-resistant *Staphylococcus aureus* (blood culture isolates), 2013–2021



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 was determined using EUCAST 2022 breakpoints for all years. Filled circles indicate values for 2021.
2. Ability to accurately determine rifampicin resistance for all years was restricted due to limitations of the testing method.
Source: AGAR (national), public and private hospitals; 2013–2014, *n* = 27; 2015, *n* = 35; 2016, *n* = 33; 2017, *n* = 35; 2018, *n* = 38; 2019, *n* = 41; 2020, *n* = 42; 2021, *n* = 41

Table 4.6 shows the multi-locus sequence types of MRSA clones across Australia. Community-associated clones continue to dominate in staphylococcal bacteraemia, accounting for 85% of all MRSA in 2021. This may be related, in part, to the continued decline of ST239, the MDR healthcare-associated clone that has been dominant in Australia's eastern states and SA for over 30 years. The dominant healthcare-associated clone is now ST22-IVEMRSA-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 bloodstream infections. In 2021, this clone accounted for almost 1 in 5 MRSA isolates.

Table 4.6: Methicillin-resistant *Staphylococcus aureus* clones (blood culture isolates), 2020–2021

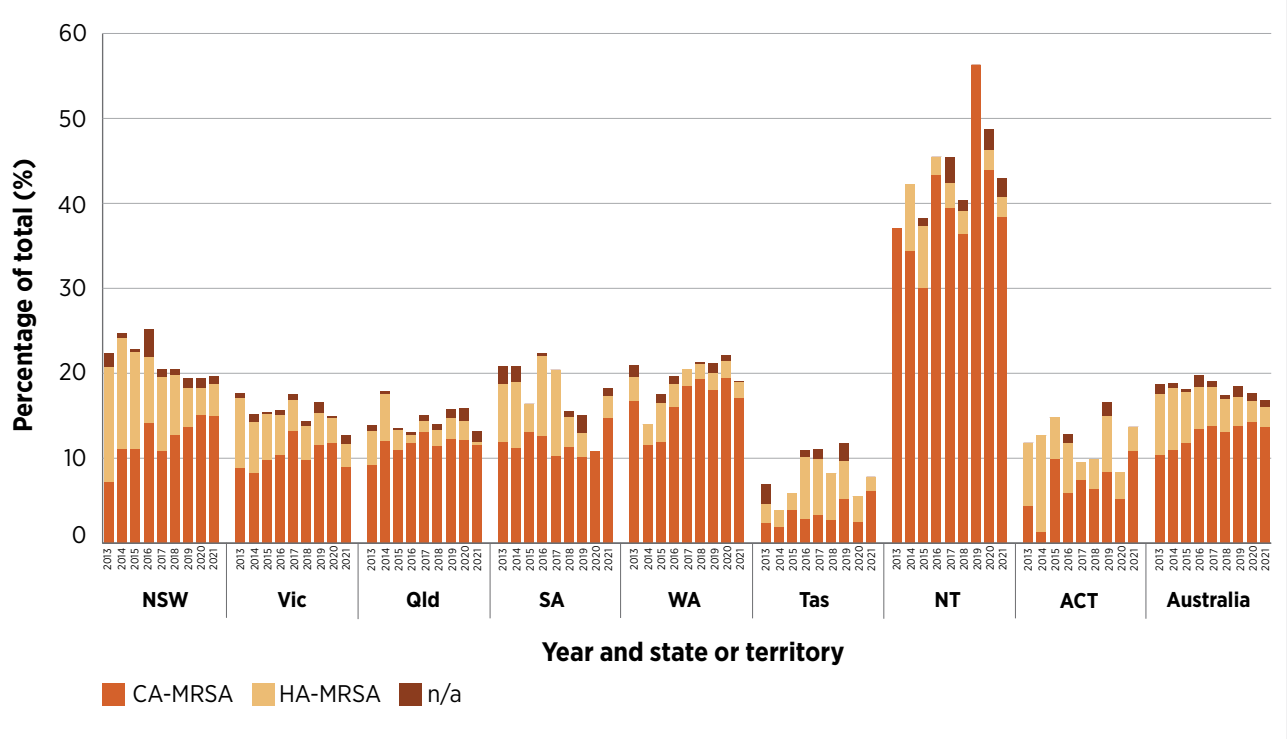
MRSA clone type	Clone	Clonal complex	% of MRSA (*n*)	
			2020	2021
Healthcare-associated	ST22-IV	22	12.9 (59)	13.6 (64)
	ST239-III	8	1.5 (7)	1.3 (6)
	ST5-I	5	0.0 (0)	0.2 (1)
	ST5-II	5	0.2 (1)	0.0 (0)
	ST8-II	8	0.2 (1)	0.0 (0)
	ST36-II	30	0.2 (1)	0.0 (0)
	Total		15.1 (69)	15.0 (71)
Community-associated	ST93-IV	93	21.9 (100)	21.0 (99)
	ST45-V	5	11.0 (50)	13.1 (62)
	ST5-IV	45	12.9 (59)	10.2 (48)
	ST1-IV	1	6.4 (29)	5.9 (28)
	ST30-IV	30	4.6 (21)	4.2 (20)
	ST97-IV	78	3.1 (14)	3.2 (15)
	ST8-IV	97	3.5 (16)	1.5 (7)
	ST78-IV	8	2.2 (10)	1.1 (5)
	ST953-IV	97	1.8 (8)	1.5 (7)
	ST6-IV	22	1.5 (7)	1.5 (7)
	ST22-IV (PVL positive)	5	1.1 (5)	1.9 (9)
	ST88-IV	1	0.9 (4)	1.7 (8)
	ST59-IV	8	1.1 (5)	1.5 (7)
	ST188-IV	45	1.1 (5)	0.8 (4)
	ST872-IV	5	1.1 (5)	0.8 (4)
	ST59-V	not assigned	1.1 (5)	0.4 (2)
	ST5-V	not assigned	0.7 (3)	0.6 (3)
	ST6145-V	8	0.4 (2)	0.8 (4)
	ST72-IV	8	0.0 (0)	1.1 (5)
	Other clones	n/a	8.6 (39)	12.1 (57)
	Total		84.9 (387)	85.0 (401)

MRSA = methicillin-resistant *Staphylococcus aureus*; n/a = not applicable; PVL = Panton–Valentine leucocidin
Note: Total numbers of MRSA blood culture isolates were 456 in 2020 and 472 in 2021.
Source: AGAR (national)

Key findings: states and territories

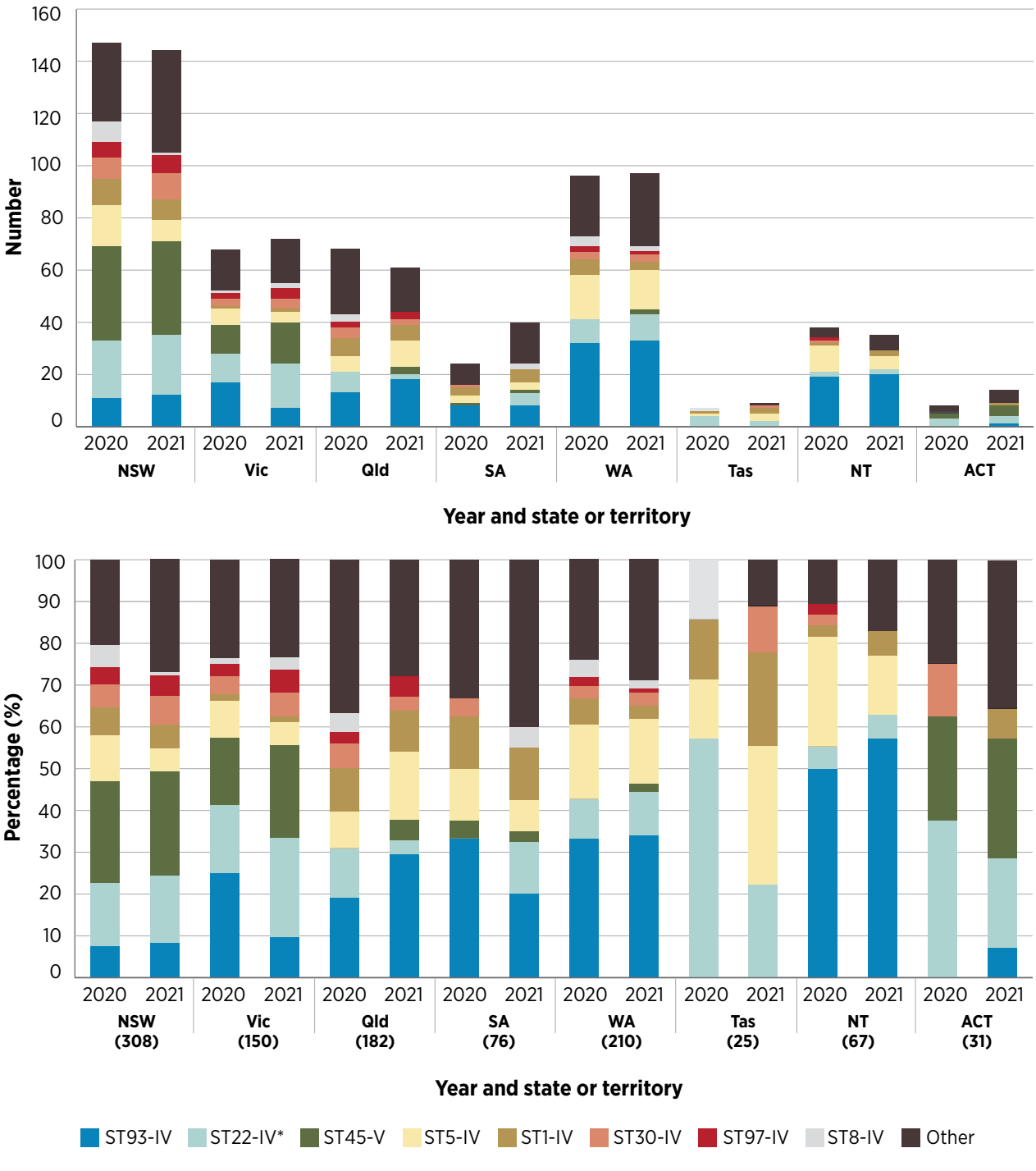
State and territory data are available from the AGAR targeted surveillance program on blood culture isolates. The prevalence and types of MRSA differ significantly between states and territories.[2] In 2021, overall MRSA rates ranged from 7.8% in Tasmania to 43.0% in the NT (Figure 4.43 and *AURA 2023: Supplementary data*). The proportion of community-associated MRSA clones dominated in all states and territories. Multi-locus sequence type analysis revealed a great diversity of clones across the states and territories (Figure 4.44). In 2021, ST93-IV was the dominant (greater than 30%) clone in WA and the NT. In NSW, the MDR ST45-V clone accounted for 31.3% (36/115) of all community-associated MRSA clones.

Figure 4.43: Percentage of *Staphylococcus aureus* blood culture isolates that are methicillin-resistant clones, by state and territory, 2013–2021



CA = community associated; HA = healthcare associated; MRSA = methicillin-resistant *Staphylococcus aureus*; n/a = isolate not available for typing
Source: AGAR (national)

Figure 4.44: Distribution of methicillin-resistant *Staphylococcus aureus* clones (blood culture isolates), by state and territory, 2020–2021



* Healthcare-associated clone
Source: AGAR (national)

According to AGAR data, the overall 30-day all-cause mortality rate for *S. aureus* bacteraemia was 14.2% in 2018 and 14.3% in 2019.[4,21] The 30-day all-cause mortality was lowest in methicillin-susceptible strains, higher for community-onset bacteraemia, and highest for hospital-onset bacteraemia. The overall 30-day all-cause mortality rate was similar in 2021 (14.4%) to that in 2020 (13.5%) and in 2019 (14.3%). The rate was higher for hospital-onset bacteraemia than for community-onset bacteraemia (Table 4.7). There was no difference in mortality for methicillin-susceptible and methicillin-resistant strains.

Table 4.7: Onset setting and 30-day all-cause mortality for *Staphylococcus aureus* infections (blood culture isolates), 2020–2021

***Staphylococcus aureus* strain**	**Year**	**Community-onset, *n***	**Community-onset mortality, % (*n*)**	**Hospital-onset, *n***	**Hospital-onset mortality, % (*n*)**	**Total, *n***	**Total mortality, % (*n*)**
Methicillin-susceptible	2020	1,438	12.4 (179)	367	16.6 (61)	1,805	13.3 (240)
	2021	1,537	14.2 (219)	445	14.4 (64)	1,982	14.3 (283)
Methicillin-resistant	2020	302	14.6 (44)	93	12.9 (12)	395	14.2 (56)
	2021	320	12.8 (41)	90	22.2 (20)	410	14.9 (61)
Community-associated MRSA clones	2020	246	13.8 (34)	75	14.7 (11)	321	14.0 (45)
	2021	261	11.9 (31)	64	20.3 (13)	325	13.5 (44)
Healthcare-associated MRSA clones	2020	39	12.8 (5)	15	6.7 (1)	54	11.1 (6)
	2021	43	18.6 (8)	20	30.0 (6)	63	22.2 (14)
Not determined	2020	17	29.4 (5)	3	0.0 (0)	20	25.0 (5)
	2021	16	12.5 (2)	6	16.7 (1)	22	13.6 (3)
Total	**2020**	**1,740**	**12.8 (223)**	**460**	**15.9 (73)**	**2,200**	**13.5 (296)**
	2021	**1,857**	**14.0 (260)**	**535**	**15.7 (84)**	**2,392**	**14.4 (344)**

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 bacteraemia, and bone and joint infections. Its greatest significance is as the main cause of neonatal bacteraemia and meningitis, which can have high morbidity and mortality.

Treatment

Screening mothers in late pregnancy for carriage of GBS is standard practice in Australia. If a pregnant woman tests positive for GBS, antimicrobials are administered to her during delivery to prevent transmission to the baby, regardless of the mode of delivery. Benzylpenicillin is recommended for this purpose. Alternatively, cefazolin or lincomycin/clindamycin are recommended for penicillin allergy, depending on the type and severity of the allergy.

Types and impact of resistance

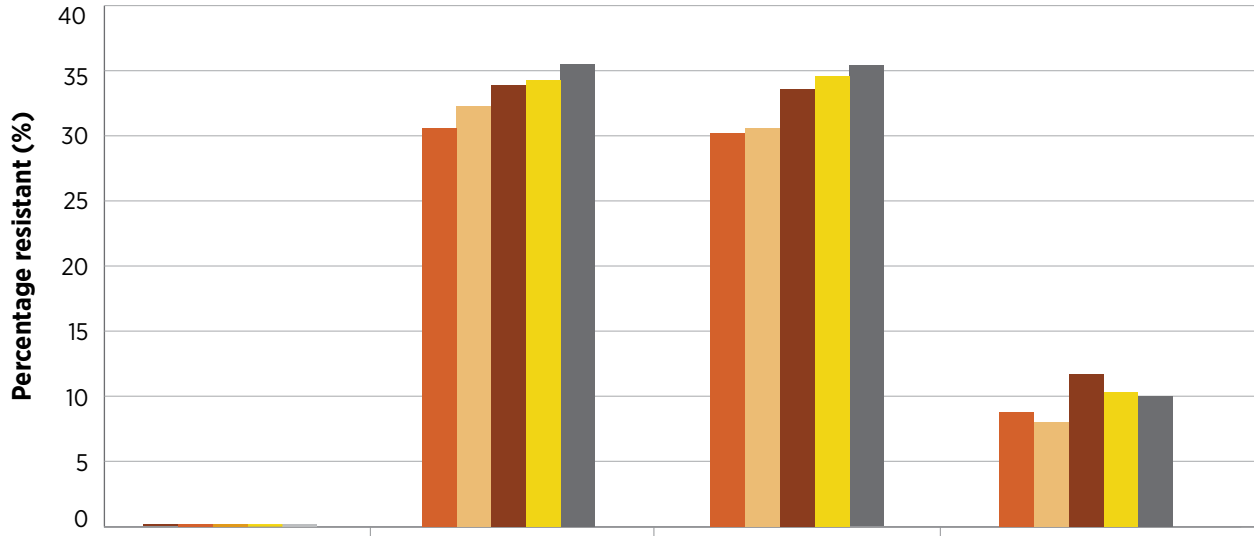
Resistance to benzylpenicillin and cefazolin is emerging but still uncommon in Australia; however, resistance to erythromycin, lincomycin and clindamycin is common, at around 30%. Lincomycin/clindamycin resistance is strongly linked to resistance to macrolides such as erythromycin, which is often used 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

Since 2017, resistance to benzylpenicillin has remained extremely low, but resistance to erythromycin and clindamycin has steadily increased to reach around 35% in 2021 (Figure 4.45). Most of this resistance is of the constitutive MLS_B type. Clindamycin is currently recommended for penicillin-allergic pregnant women who require intrapartum prophylaxis, but this recommendation will need to be reviewed.

Resistance to erythromycin and clindamycin is increasing in *S. agalactiae*. As a result, the recommendation to give clindamycin to penicillin-allergic mothers needs to be reviewed.

Figure 4.45: *Streptococcus agalactiae* resistance, 2017–2021



	Penicillin	Erythromycin	Clindamycin	Trimethoprim
2017, %	0.05	30.6	30.2	8.8
2018, %	0.08	32.3	30.6	8.0
2019, %	0.09	33.9	33.6	11.7
2020, %	0.07	34.3	34.6	10.3
2021, %	0.1	35.5	35.4	10.0
2017, *n*	13,693	8,089	7,562	1,364
2018, *n*	12,716	8,321	7,225	1,196
2019, *n*	12,927	8,285	6,134	1,183
2020, *n*	13,086	8,333	6,131	1,155
2021, *n*	13,545	9,087	6,775	1,076

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 bacteraemia (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 NIP. 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 usually 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 strains that are non-susceptible to penicillin. Strains that cause pneumonia or meningitis and 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 its relatively poor penetration 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 antimicrobial agents.

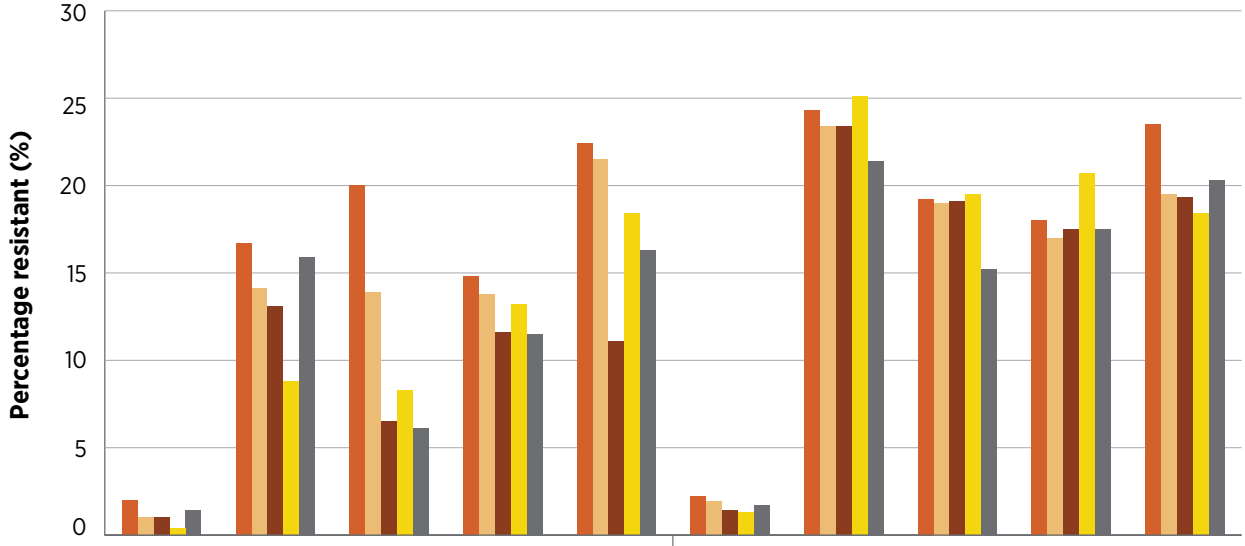
Resistance to tetracycline predicts resistance to doxycycline, the usual agent in this class used for treatment in adolescents and adults. It is a feature of MDR strains.

Key findings: national

Since 2017, resistance to benzylpenicillin has been low and is declining, but overall rates of resistance to macrolides (erythromycin), tetracyclines and trimethoprim–sulfamethoxazole have remained above 15% (Figure 4.46) in isolates from specimens other than blood. In isolates from blood, a decrease in resistance to benzylpenicillin, clindamycin and trimethoprim–sulfamethoxazole was observed between 2017 and 2021. Resistance to macrolides declined between 2017 and 2020, but increased in 2021.

The rates of resistance were lower for blood isolates than for isolates from other specimens. This has been noted in studies in the last two decades and is likely due to different serotypes or clones predominating in invasive strains compared with non-invasive strains.[22] In 2021, differences in the resistance rates across different clinical settings were observed (Figure 4.47). The reasons for these differences are not clear.

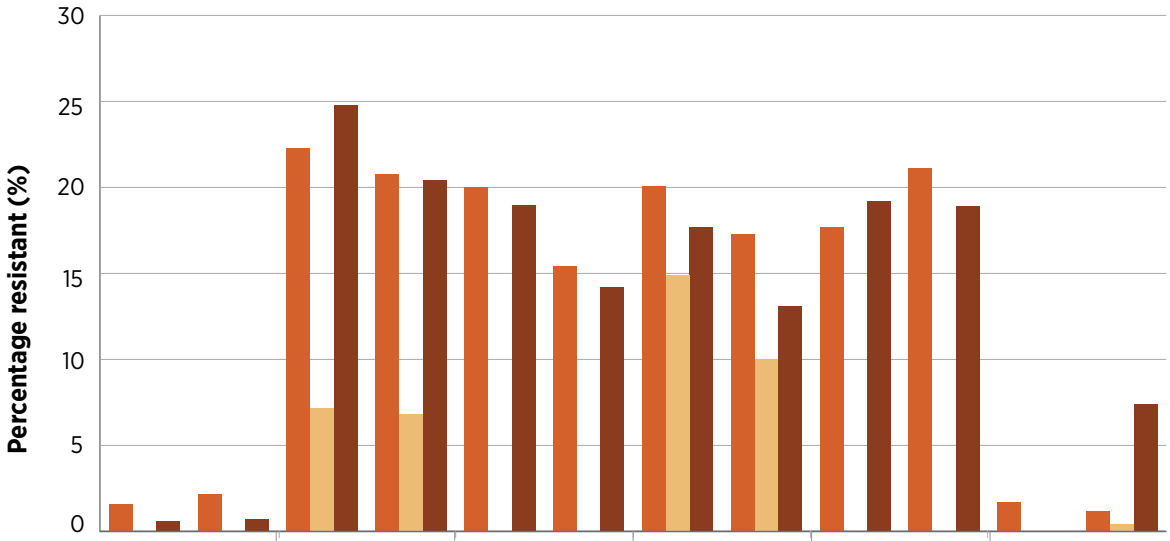
Figure 4.46: *Streptococcus pneumoniae* resistance, by specimen source, 2017–2021



	Blood					Other*				
	PEN	ERY	CLN	TET	SXT	PEN	ERY	CLN	TET	SXT
2017, %	2.0	16.7	20.0	14.8	22.4	2.2	24.3	19.2	18.0	23.5
2018, %	1.0	14.1	13.9	13.8	21.5	1.9	23.4	19.0	17.0	19.5
2019, %	1.0	13.1	6.5	11.6	11.1	1.4	23.4	19.1	17.5	19.3
2020, %	0.4	8.8	8.3	13.2	18.4	1.3	25.1	19.5	20.7	18.4
2021, %	1.4	15.9	6.1	11.5	16.3	1.7	21.4	15.2	17.5	20.3
2017, *n*	1,125	923	30	479	219	6,992	7,471	2,267	3,414	3,957
2018, *n*	1,090	956	101	609	177	7,049	7,093	2,379	3,647	3,960
2019, *n*	1,266	1,033	124	783	351	7,296	7,450	2,573	3,705	4,697
2020, *n*	749	565	36	409	136	4,069	4,156	1,390	2,359	2,527
2021, *n*	856	694	66	494	172	4,261	4,506	1,252	1,865	2,413

* Specimen sources other than blood
CLN = clindamycin; ERY = erythromycin; PEN = benzylpenicillin; SXT = trimethoprim–sulfamethoxazole; TET = tetracyclines
Note: Benzylpenicillin resistance is defined as an MIC of >2 mg/L for infections other than meningitis (European Committee on Antimicrobial Susceptibility Testing).
Sources: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT); HOTspots (NT); SNP (Qld, northern NSW)

Figure 4.47: *Streptococcus pneumoniae* resistance, by clinical setting, 2020–2021



	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
	PEN		ERY		CLN		TET		SXT		CTR	
Hospitals, %	1.6	2.2	22.3	20.8	20.0	15.4	20.1	17.3	17.7	21.1	1.7	1.2
Multi-purpose service, %	0.0	0.0	7.2	6.8	nd	nd	14.9	10.0	nd	nd	nd	nd
Community, %	0.6	0.7	24.8	20.4	19.0	14.2	17.7	13.1	19.2	18.9	0.0	7.4
Hospitals, *n*	2,849	3,108	2,714	3,038	461	299	2,022	1,662	1,240	1,256	181	251
Multi-purpose service, *n*	69	50	69	44	5	2	47	30	25	11	9	4
Community, *n*	1,864	1,900	1,898	2,054	928	969	657	609	1,361	1,260	45	54

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 an MIC 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).
3. Ceftriaxone was included, although in low numbers, due to its importance in the treatment of meningitis.
Sources: APAS, HOTspots and SNP (hospitals and community); APAS (multi-purpose service)

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, bacteraemia, 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 rare in most parts of Australia but are 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).

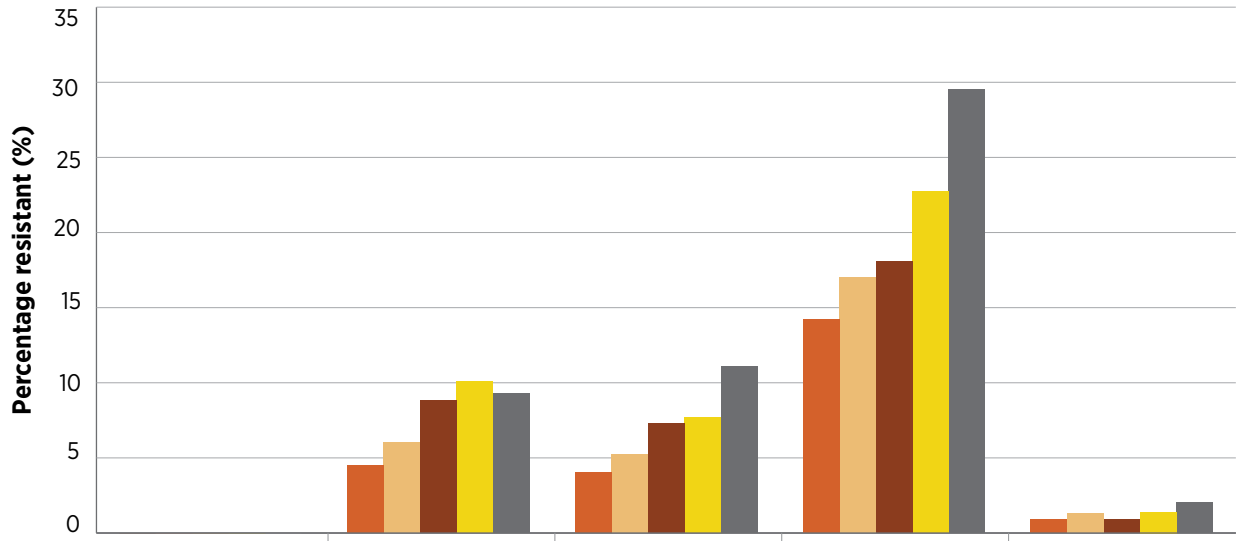
Types and impact of resistance

Confirmed resistance to benzylpenicillin has never been reported anywhere in the world in this species, but the consequences of its emergence would be substantial. Based on observations of other species of *Streptococcus*, it is expected that 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 4.48). Resistance to erythromycin (and therefore other macrolides) is low but has been steadily increasing since 2017. In 2021, variation in macrolide resistance rates between clinical settings was observed, notably in community settings (Figure 4.49).

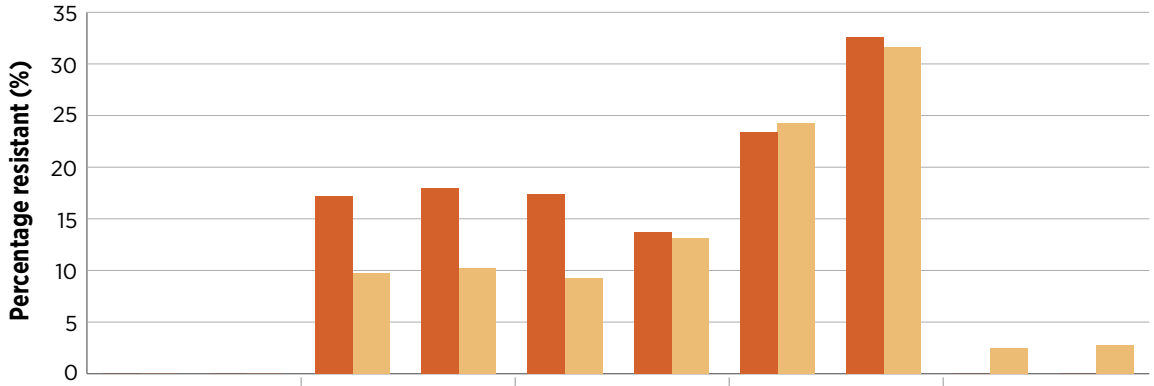
Figure 4.48: *Streptococcus pyogenes* resistance (all specimen sources), 2017–2021



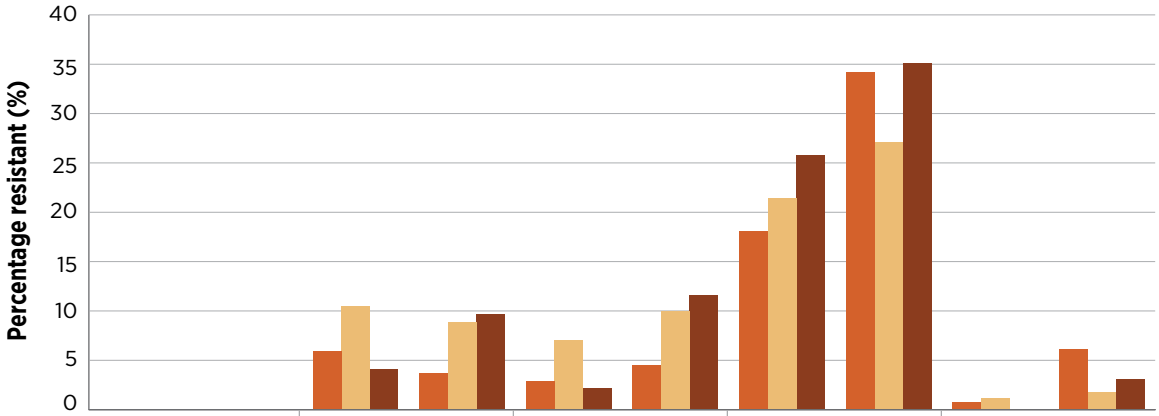
	Penicillin	Erythromycin	Clindamycin	Tetracycline	Trimethoprim–sulfamethoxazole
2017, %	0.0	4.5	4.0	14.2	0.9
2018, %	0.0	6.0	5.2	17.0	1.3
2019, %	0.0	8.8	7.3	18.1	0.9
2020, %	0.0	10.1	7.7	22.7	1.4
2021, %	0.0	9.3	11.1	29.5	2.0
2017, *n*	38,319	38,059	18,005	18,005	12,759
2018, *n*	34,962	33,072	17,144	19,761	10,226
2019, *n*	34,208	31,827	16,450	19,349	12,196
2020, *n*	27,606	26,624	12,172	17,004	9,271
2021, *n*	28,760	28,746	12,421	17,426	10,124

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

Figure 4.49: *Streptococcus pyogenes* resistance, by clinical setting, 2020–2021



	2020 Penicillin	2021 Penicillin	2020 Erythromycin	2021 Erythromycin	2020 Clindamycin	2021 Clindamycin	2020 Tetracycline	2021 Tetracycline	2020 Trimethoprim–sulfamethoxazole	2021 Trimethoprim–sulfamethoxazole
Private hospitals, %	0.0	0.0	17.2	18.0	17.4	13.7	23.4	32.6	0.0	0.0
Public hospitals, %	0.0	0.0	9.7	10.2	9.2	13.1	24.3	31.6	2.5	2.8
Private hospitals, *n*	180	189	180	189	121	153	145	144	90	130
Public hospitals, *n*	10,920	11,262	10,254	11,120	4,130	4,333	7,838	8,005	1,361	1,489



	2020 Penicillin	2021 Penicillin	2020 Erythromycin	2021 Erythromycin	2020 Clindamycin	2021 Clindamycin	2020 Tetracycline	2021 Tetracycline	2020 Trimethoprim–sulfamethoxazole	2021 Trimethoprim–sulfamethoxazole
Multi-purpose service, %	0.0	0.0	5.9	3.7	2.9	4.5	18.1	34.2	0.8	6.1
Community, %	0.0	0.0	10.5	8.9	7.0	10.0	21.4	27.1	1.2	1.8
Other, %	0.0	0.0	4.1	9.7	2.2	11.6	25.8	35.1	nd	3.1
Multi-purpose service, *n*	764	798	597	794	274	199	504	503	236	262
Community, *n*	15,371	16,191	15,240	16,322	7,382	7,505	8,229	8,490	7,479	8,149
Other, *n*	289	258	271	259	184	172	209	222	27	32

nd = no data (either not tested or tested against an inadequate number of isolates)
Notes:
1. Aged care homes are excluded because of an insufficient number of isolates from this setting (<30).
2. Other settings were predominantly corrective services.
Sources: AGAR, APAS and HOTspots (public hospitals); AGAR, APAS (Qld, SA) and SNP (private hospitals); APAS, HOTspots and SNP (community); APAS (multi-purpose services)

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Chapter 5

National Alert System for Critical Antimicrobial Resistances (CARAlert)

National Alert System for Critical Antimicrobial Resistances (CARAlert)

Key findings

- Carbapenemase-producing *Enterobacterales* (CPE) was the most commonly reported critical antimicrobial resistance (CAR) in 2021 and 2022.
- Nationally, there was a 37.4% increase in CPE reports in 2022 compared with 2021. In contrast, 2020 reports decreased 26.6% compared with 2019.
- Three carbapenemase types comprised 97% of *Enterobacterales* with a confirmed carbapenemase (IMP, NDM and OXA-48-like) – either alone or in combination – in 2021 and 2022, with over half having IMP genes.
- CPE comprised 57–76% of all blood specimen CARs, highlighting the clinical spectrum of CPE infections compared with other CARs. Oral therapies may not be available for many of these infections, and intravenous therapy may be the only treatment option.
- Reports of multidrug-resistant *Shigella* species increased. Extended-spectrum β-lactamase (ESBL)-producing *S. sonnei* reports increased from 17 in 2021 to 62 in 2022.
- Reports of ceftriaxone-nonsusceptible *Neisseria gonorrhoeae* increased sharply in 2022 compared with 2021, highlighting the importance of ongoing monitoring of resistance to both azithromycin and ceftriaxone and their impact on current treatment guidelines.
- Across 2021 and 2022, *Candida auris* was reported by all states and territories except the Australian Capital Territory (ACT) and Tasmania.
- CARs reported from aged care settings were predominantly CPE or daptomycin-nonsusceptible *Staphylococcus aureus*.

This chapter outlines the key findings from the National Alert System for Critical Antimicrobial Resistances (CARAlert). CARAlert collects data on confirmed CARs. This chapter reports on CARs that were collected between 1 January 2021 and 31 December 2022.

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 Surveillance System (AURA).

Participating confirming laboratories submit data to CARAlert on priority organisms with critical resistance to last-line antimicrobial agents (Table 5.1). Nationally, 28 confirming laboratories participated in CARAlert in 2021 and 2022. See Appendix 1 for more information on CARAlert.

Table 5.1: Critical antimicrobial resistances included in CARAlert in 2021 and 2022

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- and/or azithromycin-nonsusceptible
*Pseudomonas aeruginosa**	Carbapenemase-producing
Salmonella species	Ceftriaxone-nonsusceptible
Shigella species	Multidrug-resistant
Staphylococcus aureus†	Vancomycin-, linezolid- or daptomycin-nonsusceptible
Streptococcus pyogenes	Penicillin-reduced susceptibility

* Reported from July 2019
† For CARAlert, *S. aureus* includes *S. argenteus* and *S. schweitzeri*

In 2022, the Commission conducted a review of the CARs reported to CARAlert in consultation with states, territories, a range of clinical experts and the Australian Government Department of Health and Aged Care (the Department).

From 1 January 2023, the new CARs reported to CARAlert are:

- Ciprofloxacin-nonsusceptible *N. meningitidis*
- Gentamicin-resistant *N. gonorrhoeae.*

Daptomycin-nonsusceptible *S. aureus* was suspended from reporting to CARAlert from 1 January 2023 and will be considered for reintroduction when more reliable phenotypic testing methods are available.

The Department regularly evaluates national surveillance systems to ensure they continue to meet their purpose and objectives. In 2022–23, the Department conducted an evaluation of CARAlert, which complements the Commission's review of CARs.

The purpose of the CARAlert evaluation was to examine:

- How well the system operates to meet its purposes and objectives
- The appropriateness of the system's purposes and objectives
- Improvements to enhance the system's ability to meet these objectives.

The United States Centers for Disease Control and Prevention (CDC) *Updated Guidelines for Evaluating Public Health Surveillance Systems*[1] was used to evaluate CARAlert's usefulness and performance against system attributes. Once the evaluation has been finalised, the Commission will collaborate with the Department, states and territories and confirming laboratories to consider the recommendations of the evaluation and their feasibility for implementation.

Key concepts in CARAlert

CARAlert is an early warning system for critical antimicrobial resistances

If a microorganism is susceptible to a drug, then it can be treated with it. If a microorganism is resistant to a drug, then that drug will not kill that microorganism. If a microorganism is multidrug-resistant (as are most CARAlert microorganisms) then there will be few or no drugs available for successful therapy.

The emergence and spread of antimicrobial-resistant pathogens that have acquired new resistance mechanisms threaten the effective treatment of many common infections. In line with the latest clinical evidence and to meet emerging needs, CARs are categorised into priority groups according to their importance for public health, impact on antimicrobial resistance (AMR) in hospital and/or community settings and need for surveillance.

Having as much information as possible about the CARs that exist in Australia helps healthcare staff and policymakers prevent and manage these infections. CARAlert detects information on confirmed cases of CARs and can identify seasonal or geographic trends. Most importantly, it acts as a potential early warning system for CAR outbreaks to enable timely infection control responses.

CARAlert reports important information about AMR

AMR occurs over time, typically through acquired genetic changes. Microorganisms can possess several different mechanisms that can lead to AMRs, such as a mutation in an existing gene that an antimicrobial agent targets the product of, or acquiring genes on plasmids that can encode for the production of enzymes that can confer resistance to various antimicrobial agents from other microorganisms.

For example, genes that encode for carbapenemases can confer resistance to carbapenem antimicrobials. Similarly, genes that encode for ESBLs and plasmid-borne AmpC β-lactamases (pAmpCs) are major mechanisms of microbial resistance to β-lactam antimicrobials. Within each of these mechanisms, there are multiple gene variants and subtypes (referred to as types in this chapter) that can be identified in the isolates reported to CARAlert.

CARAlert terminology (see also Appendix 3)

Acquired resistance is the reduction in susceptibility by acquiring resistance genes from other bacteria or through mutation.

Antimicrobial resistance (AMR) is the failure of an antimicrobial to inhibit a microorganism at the antimicrobial concentrations usually achieved over time with standard dosing regimens. Antimicrobial-resistant pathogens are not killed by the drugs that are normally used against them.

Multidrug-resistant (MDR) organisms are resistant to one or more classes of antimicrobial agents. Infections caused by MDR organisms or so-called 'super bugs' are particularly difficult to treat with existing drugs.

Non-susceptible microorganisms are either resistant or less susceptible to at least one antimicrobial.

Resistant microorganisms are resistant to at least one antimicrobial.

5.2 Results from CARAlert 2021–2022

National critical antimicrobial resistances

Between 1 January 2021 and 31 December 2022, a total of 2,739 CARs from 84 originating laboratories across Australia were reported to CARAlert (Table 5.2), averaging 109 entries per month in 2021, and 120 entries per month in 2022. The proportion of CARs associated with priority organisms per month is shown in Figure 5.1. CARs by organism and month of collection for 2021–2022 are shown in Figure 5.2.

> Between 1 January 2021 and 31 December 2022, a total of 2,739 CARs from 84 originating laboratories across Australia were submitted to CARAlert.

There was an overall decrease of 17.5% in CARs reported in 2021 (*n* = 1,303) compared with 2020 (*n* = 1,579), and 27% compared with 2019 (*n* = 1,972). Reports for all CARs decreased in 2021 compared with 2020, except for carbapenemase-producing *Pseudomonas aeruginosa*, daptomycin-nonsusceptible *S. aureus* and, notably, MDR *Shigella* species (*n* = 299 in 2020; *n* = 42 in 2021). In 2022 (*n* = 1,436), there was a 10.2% increase in CARAlert reports compared with 2021 (Table 5.2).

Carbapenemase- and/or ribosomal methyltransferase-producing *Enterobacterales* was the most frequently reported CAR in 2022 (*n* = 837; 58%). This represents a 37% increase in reports compared with 2021 (*n* = 609; 47%) (Table 5.2). In contrast, reports of CPE decreased by 27% when comparing 2020 (*n* = 650) to 2019 (*n* = 886). For 2021, there was a 17% decrease compared to 2019. The number of reports of this CAR in 2022 was similar to levels reported in 2019.

Vancomycin-, linezolid- or daptomycin-nonsusceptible *S. aureus* was the second most frequently reported CAR in both 2021 (*n* = 266; 20%) and 2022 (*n* = 175; 12%). Reports of this CAR decreased by 34% in 2022 compared with 2021.

Ceftriaxone- and/or azithromycin-nonsusceptible *N. gonorrhoeae* was the third most frequently reported CAR in 2021 (*n* = 251; 19%) and 2022 (*n* = 158; 11%). There has been a steady decline in reports of *N. gonorrhoeae* to CARAlert since 2017, when it was the most frequently reported CAR (*n* = 734; 48%).

MDR *Shigella* species was the fifth-ranked CAR in 2021 (*n* = 42; 3%) and fourth-ranked in 2022 (*n* = 99; 7%).

No reports of *Streptococcus pyogenes* with penicillin-reduced susceptibility were submitted in the 2021–2022 reporting period. There have been no reports of this CAR since CARAlert commenced.

All other CARs combined contributed 10–12% of the total number of reports to CARAlert (135/1,303 in 2021; 166/1,436 in 2022).

Table 5.2: Number of critical antimicrobial resistance reports, by state and territory, 1 January 2021 to 31 December 2022

Critical antimicrobial resistance	NSW		Vic		Qld		SA		WA		Tas		NT		ACT		Total		Relative change (%)*
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	
Carbapenemase-producing and/or ribosomal methyltransferase-producing *Enterobacterales*	243	302 ▲	130	203 ■	162	232 ▲	28	41 ■	31	39 ■	0	5†	3	2†	12	13 ■	609	837 ▲	37.4
Vancomycin-, linezolid- or daptomycin-nonsusceptible *Staphylococcus aureus* complex	43	26 ■	24	32 ■	134	27 ▼	17	31 ■	39	47 ■	3	0†	0	0†	6	12 ■	266	175 ▼	−34.2
Ceftriaxone- and/or azithromycin-nonsusceptible *Neisseria gonorrhoeae*	167	39	45	63	13	33	0	2†	16	18	5	3†	1	0†	4	0†	251	158	−37.1
Azithromycin-nonsusceptible	167	12 ▼	45	56 ■	13	32 ▲	0	2	15	16 ■	5	3†	1	0†	4	0†	250	121 ▼	−51.6
Ceftriaxone-nonsusceptible	0	27 ▲	0	7†	0	1†	0	0†	1	2†	0	0†	0	0†	0	0†	1	37 ▲	800
Multidrug-resistant *Shigella* species	19	32 ▲	9	37 ▲	5	20 ▲	1	2†	8	5†	0	1†	0	1†	0	1†	42	99 ▲	136
Carbapenemase-producing *Pseudomonas aeruginosa*§	47	35 ■	13	16 ■	0	2†	0	1†	7	3†	0	0†	0	0†	0	0†	67	57 ■	−14.9
Ceftriaxone-nonsusceptible *Salmonella* species	2	12 ▲	9	17 ■	12	7 ■	0	2†	1	12 ▲	0	0†	0	1†	0	0†	24	51 ▲	113

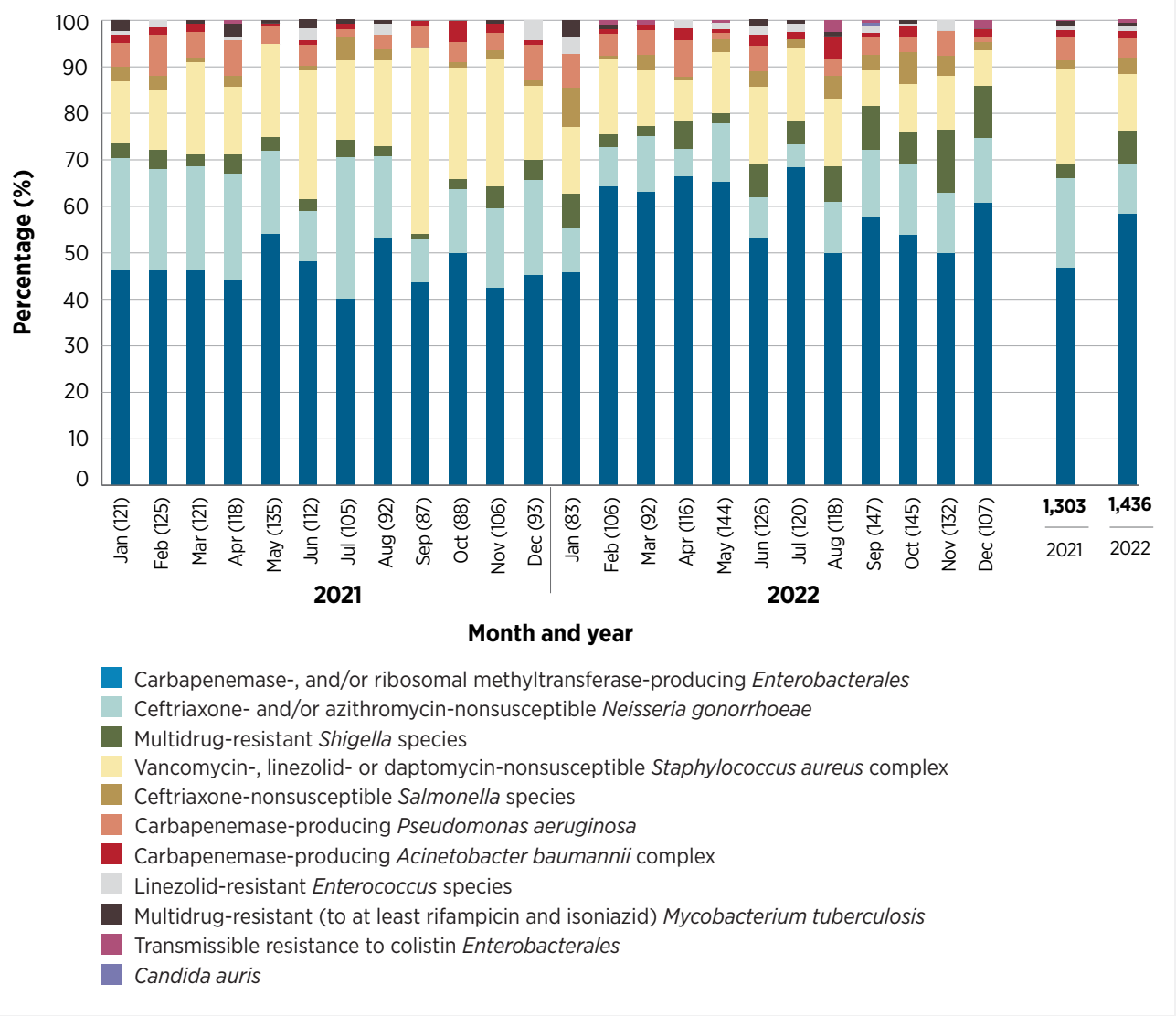
continues

Table 5.2: *continued*

Critical antimicrobial resistance	NSW		Vic		Qld		SA		WA		Tas		NT		ACT		Total		Relative change (%)*
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	
Carbapenemase-producing *Acinetobacter baumannii* complex	8	5†	3	8†	2	4†	0	1†	4	1†	0	0†	0	4†	0	0†	17	23 ■	35.3
Linezolid-nonsusceptible *Enterococcus* species	3	5†	0	3†	0	2†	4	1†	5	4†	0	1†	0	0†	1	1†	13	17 ■	30.8
Multidrug-resistant *Mycobacterium tuberculosis*	5	1†	5	5†	2	2†	1	0†	0	0†	0	0†	0	0†	0	1†	13	9 ■	–30.8
Transmissible resistance to colistin *Enterobacterales*§	0	0†	0	1†	0	0†	0	0†	0	0†	0	0†	0	0†	0	0†	0	1†	n/a
Candida auris	0	1†	1	1†	0	2†	0	3†	0	1†	0	0†	0	1†	0	0†	1	9†	n/a
Total	**537**	**458**	**239**	**386**	**330**	**331**	**51**	**84**	**111**	**130**	**8**	**10**	**4**	**9†**	**23**	**28**	**1,303**	**1,436**	**10.2**
Relative change (%)*		–14.7		61.5		0.3		64.7		17.1		25.0		n/a		21.7		10.2	

n/a = not applicable
* Relative change is the absolute change between 2021 and 2022, expressed as a percentage of the 2021 base
† Insufficient numbers (<10 over both years)
§ For this report, transmissible resistance to colistin refers to the presence of *mcr* genes other than *mcr-9*. This variant is not associated with a colistin-resistant phenotype but is typically found on HI2 plasmids which may carry bla_{IMP-4}
Notes:
1. A change in the proportion of each CAR in the state or territory total in 2021 compared with 2022 (Fisher's exact test $P < 0.05$) is indicated against the 2022 total: ▲ significant increase; ▼ significant decrease; ■ no significant difference.
2.There were no reports of *S. pyogenes* with penicillin-reduced susceptibility.
Source: CARAlert (as at 31 January 2023)

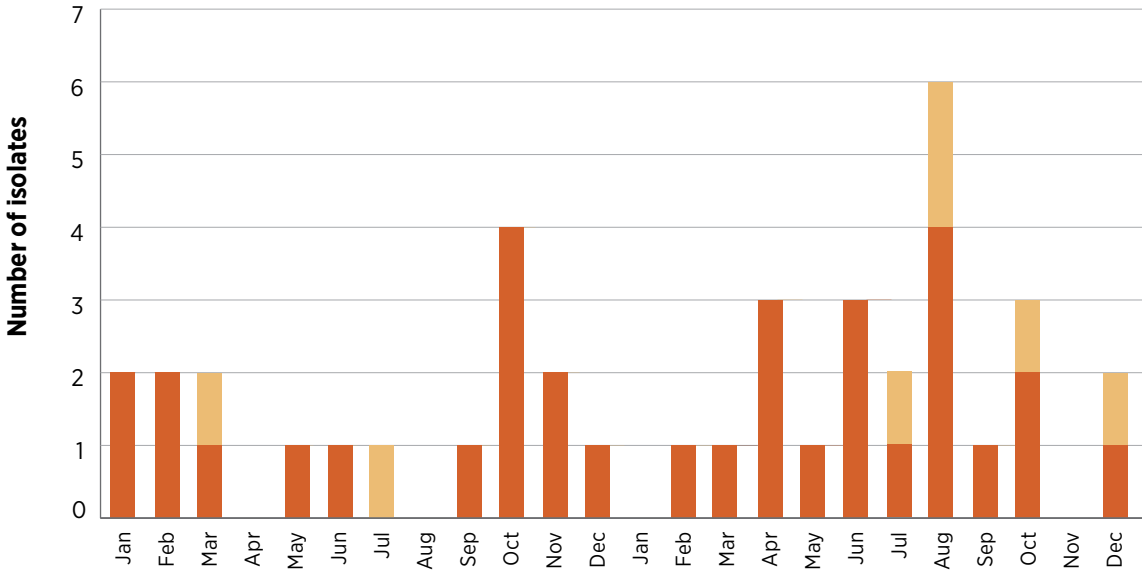
Figure 5.1: Critical antimicrobial resistances, by month of collection, 2021–2022



Note: Numbers of isolates are in brackets.
Source: CARAlert (as at 31 January 2023)

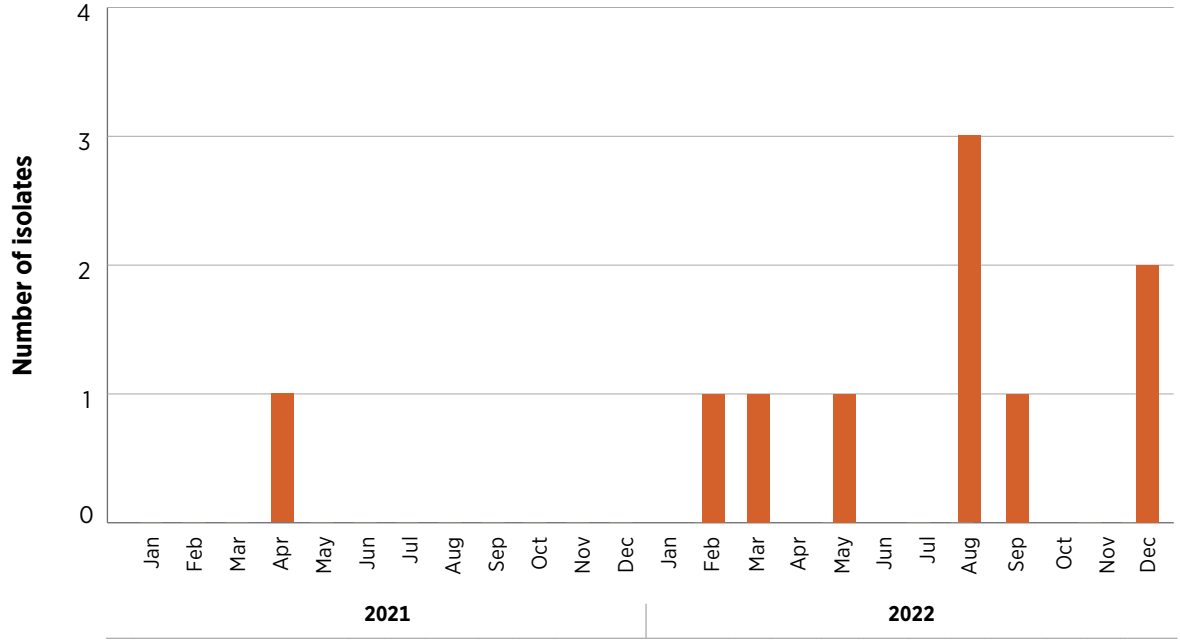
Figure 5.2: Critical antimicrobial resistances by organism, critical resistance and collection month, 2021–2022

***Acinetobacter baumannii* complex – carbapenemase-producing**



	Jan 2021	Feb 2021	Mar 2021	Apr 2021	May 2021	Jun 2021	Jul 2021	Aug 2021	Sep 2021	Oct 2021	Nov 2021	Dec 2021	Jan 2022	Feb 2022	Mar 2022	Apr 2022	May 2022	Jun 2022	Jul 2022	Aug 2022	Sep 2022	Oct 2022	Nov 2022	Dec 2022
Carbapenemase and ribosomal methyltransferase (*n* = 7)	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2	0	1	0	1
Carbapenemase (*n* = 33)	2	2	1	0	1	1	0	0	1	4	2	1	0	1	1	3	1	3	1	4	1	2	0	1

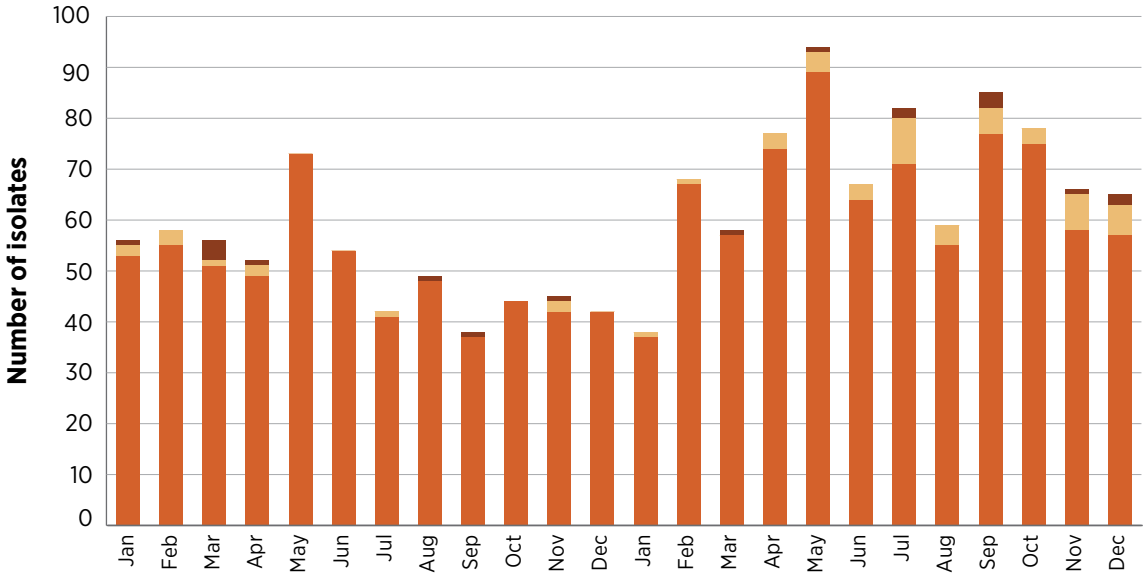
Candida auris



continues

Figure 5.2: *continued*

***Enterobacterales* – carbapenemase-producing and/or ribosomal methyltransferase-producing**



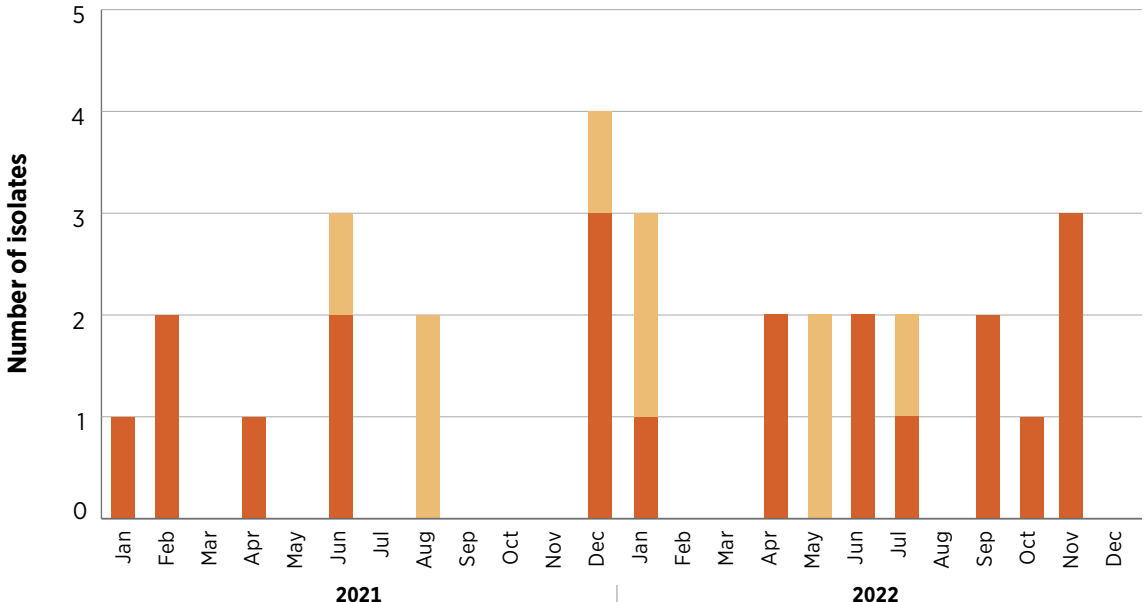
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ribosomal methyltransferase (*n* = 19)	1	0	4	1	0	0	0	1	1	0	1	0	0	0	1	0	1	0	2	0	3	0	1	2
Carbapenemase and ribosomal methyltransferase (*n* = 57)	2	3	1	2	0	0	1	0	0	0	2	0	1	1	0	3	4	3	9	4	5	3	7	6
Carbapenemase (*n* = 1,370)	53	55	51	49	73	54	41	48	37	44	42	42	37	67	57	74	89	64	71	55	77	75	58	57
Total	**56**	**58**	**56**	**52**	**73**	**54**	**42**	**49**	**38**	**44**	**45**	**42**	**38**	**68**	**58**	**77**	**94**	**67**	**82**	**59**	**85**	**78**	**66**	**65**

Note: One carbapenemase-producing *Klebsiella pneumoniae* also harboured *mcr-1.1* (Victoria, September 2022).

continues

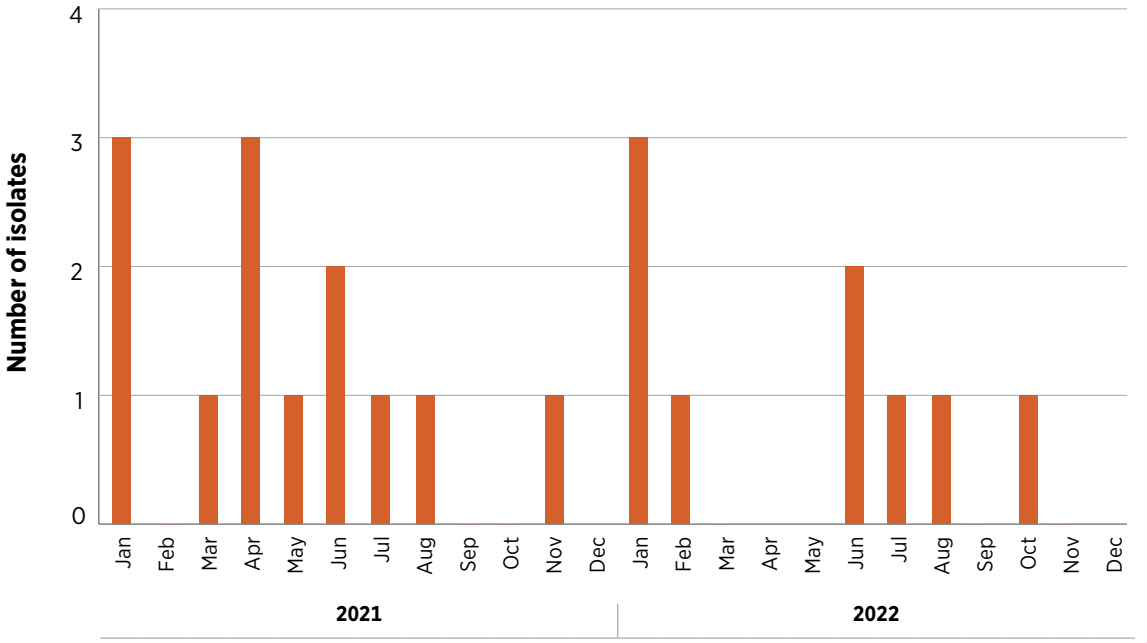
Figure 5.2: *continued*

Enterococcus species – linezolid-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
Enterococcus faecium (*n* = 9)	0	0	0	0	0	1	0	2	0	0	0	1	2	0	0	0	2	0	1	0	0	0	0	0
Enterococcus faecalis (*n* = 21)	1	2	0	1	0	2	0	0	0	0	0	3	1	0	0	2	0	2	1	0	2	1	3	0
Total	**1**	**2**	**0**	**1**	**0**	**3**	**0**	**2**	**0**	**0**	**0**	**4**	**3**	**0**	**0**	**2**	**2**	**2**	**2**	**0**	**2**	**1**	**3**	**0**

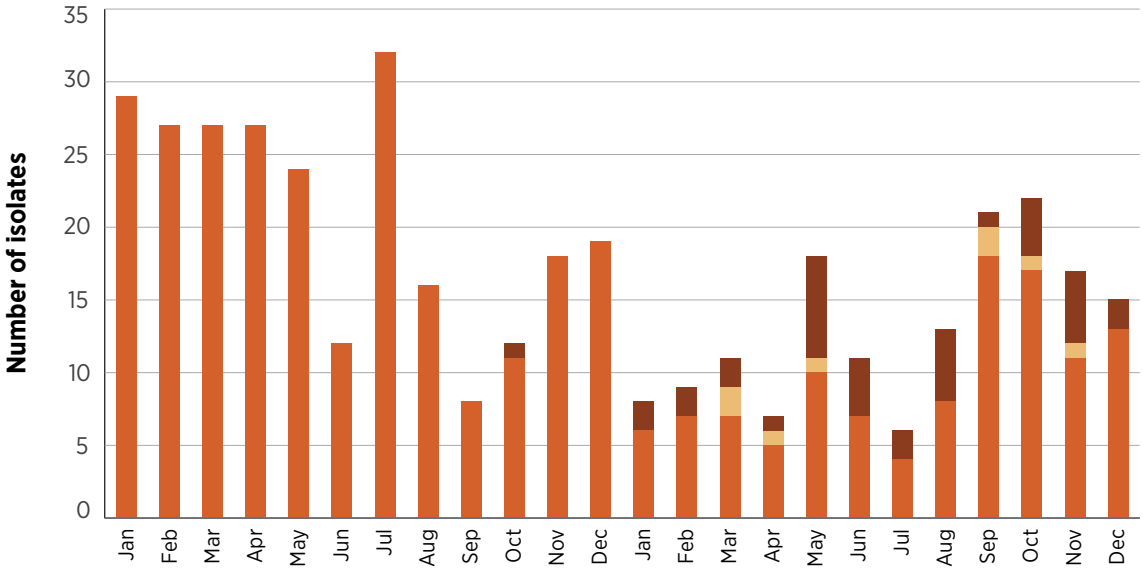
Mycobacterium tuberculosis – multidrug-resistant



continues

Figure 5.2: *continued*

***Neisseria gonorrhoeae* – ceftriaxone-nonsusceptible and/or azithromycin-nonsusceptible**



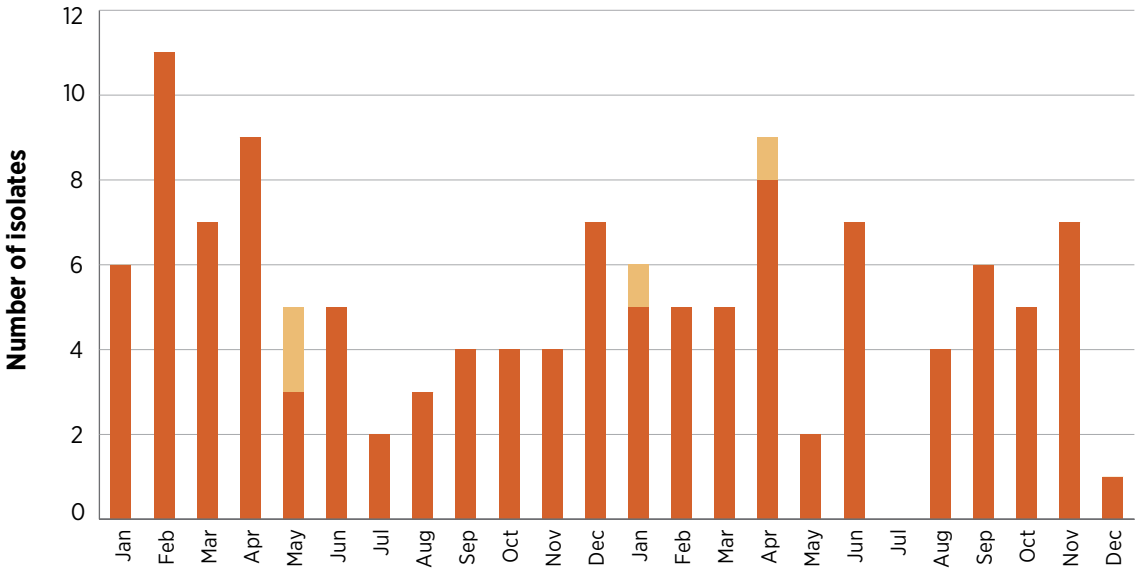
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ceftriaxone non-susceptible (*n* = 38)	0	0	0	0	0	0	0	0	0	1	0	0	2	2	2	1	7	4	2	5	1	4	5	2
Azithromycin-nonsusceptible (HLR, MIC ≥ 256 mg/L) (*n* = 8)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	0	0	0	2	1	1	0
Azithromycin-nonsusceptible (LLR, MIC < 256 mg/L) (*n* = 363)	29	27	27	27	24	12	32	16	8	11	18	19	6	7	7	5	10	7	4	8	18	17	11	13
Total	**29**	**27**	**27**	**27**	**24**	**12**	**32**	**16**	**8**	**12**	**18**	**19**	**8**	**9**	**11**	**7**	**18**	**11**	**6**	**13**	**21**	**22**	**17**	**15**

HLR = high-level resistance; LLR = low-level resistance; MIC = minimum inhibitory concentration

continues

Figure 5.2: *continued*

***Pseudomonas aeruginosa* – carbapenemase-producing**

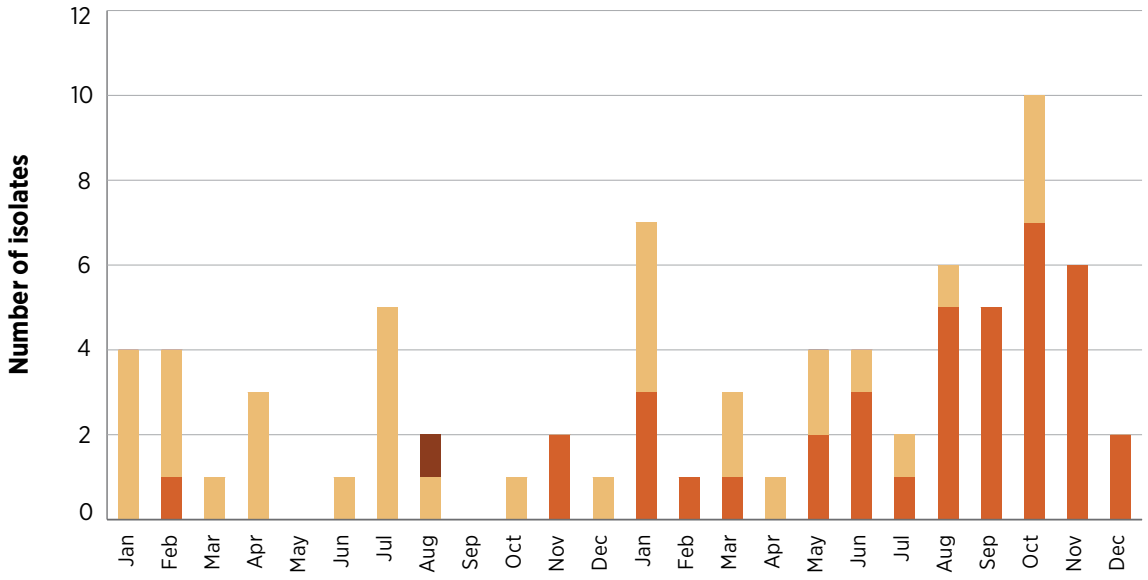


	Jan 2021	Feb 2021	Mar 2021	Apr 2021	May 2021	Jun 2021	Jul 2021	Aug 2021	Sep 2021	Oct 2021	Nov 2021	Dec 2021	Jan 2022	Feb 2022	Mar 2022	Apr 2022	May 2022	Jun 2022	Jul 2022	Aug 2022	Sep 2022	Oct 2022	Nov 2022	Dec 2022
Carbapenemase and ribosomal methyltransferase (*n* = 4)	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Carbapenemase (*n* = 120)	6	11	7	9	3	5	2	3	4	4	4	7	5	5	5	8	2	7	0	4	6	5	7	1
Total	**6**	**11**	**7**	**9**	**5**	**5**	**2**	**3**	**4**	**4**	**4**	**7**	**6**	**5**	**5**	**9**	**2**	**7**	**0**	**4**	**6**	**5**	**7**	**1**

continues

Figure 5.2: *continued*

***Salmonella* species – ceftriaxone-nonsusceptible**



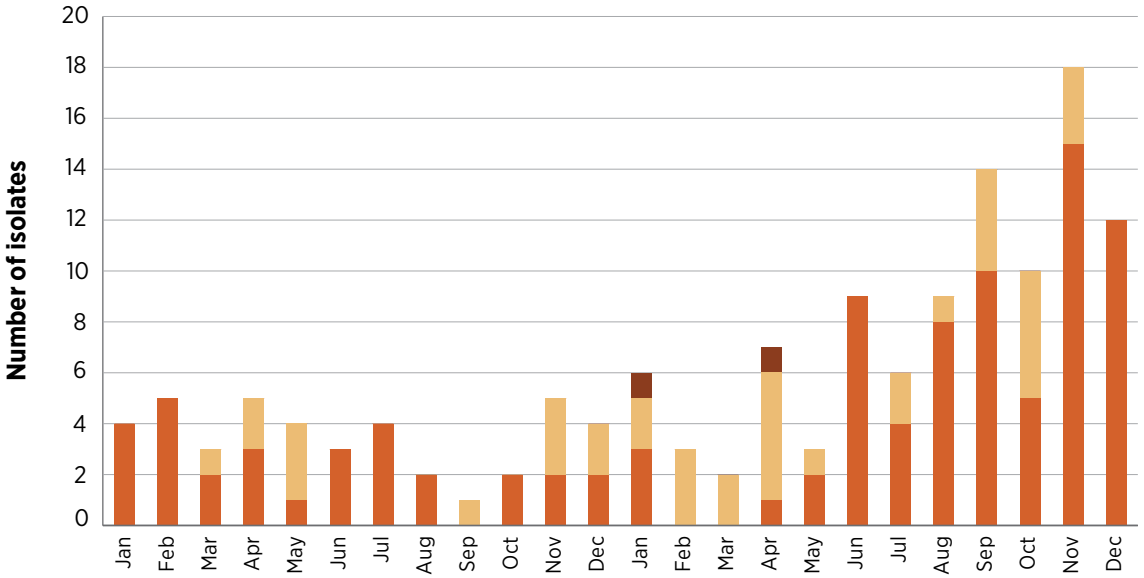
	2021												2022											
AmpC, ESBL (*n* = 1)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AmpC (*n* = 35)	4	3	1	3	0	1	5	1	0	1	0	1	4	0	2	1	2	1	1	1	0	3	0	0
ESBL (*n* = 39)	0	1	0	0	0	0	0	0	0	0	2	0	3	1	1	0	2	3	1	5	5	7	6	2
Total	**4**	**4**	**1**	**3**	**0**	**1**	**5**	**2**	**0**	**1**	**2**	**1**	**7**	**1**	**3**	**1**	**4**	**4**	**2**	**6**	**5**	**10**	**6**	**2**

ESBL = extended-spectrum β-lactamase

continues

Figure 5.2: *continued*

***Shigella* species – multidrug-resistant**

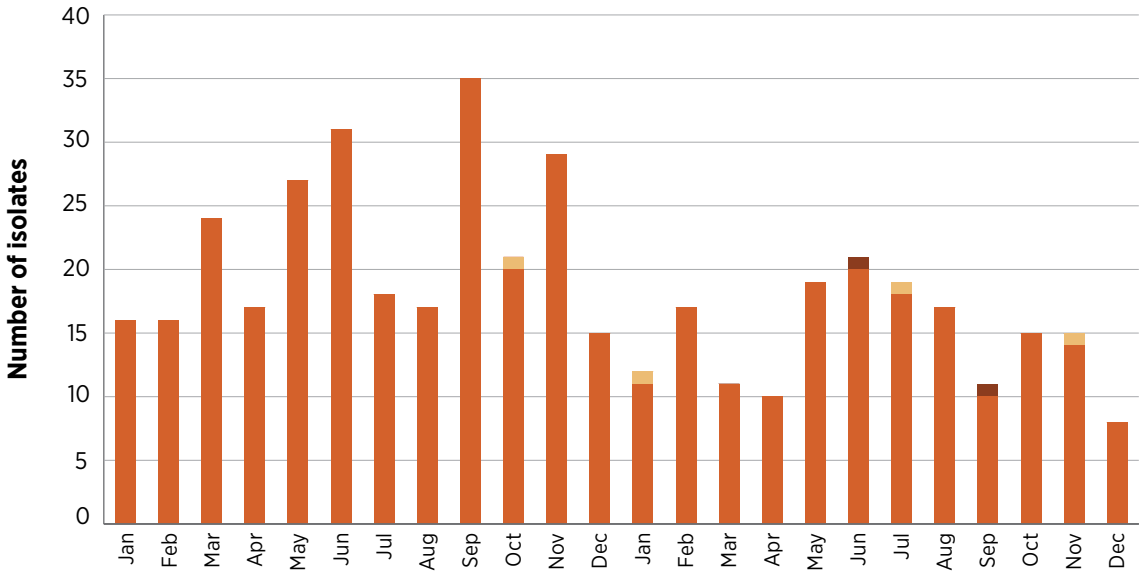


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Shigella boydii (*n* = 2)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Shigella flexneri (*n* = 40)	0	0	1	2	3	0	0	0	1	0	3	2	2	3	2	5	1	0	2	1	4	5	3	0
Shigella sonnei (*n* = 99)	4	5	2	3	1	3	4	2	0	2	2	2	3	0	0	1	2	9	4	8	10	5	15	12
Total	**4**	**5**	**3**	**5**	**4**	**3**	**4**	**2**	**1**	**2**	**5**	**4**	**6**	**3**	**2**	**7**	**3**	**9**	**6**	**9**	**14**	**10**	**18**	**12**

continues

Figure 5.2: *continued*

***Staphylococcus aureus* – daptomycin, linezolid- or vancomycin-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
Daptomycin and vancomycin (*n* = 2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
Linezolid (*n* = 4)	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	1	0
Daptomycin (*n* = 435)	16	16	24	17	27	31	18	17	35	20	29	15	11	17	11	10	19	20	18	17	10	15	14	8
Total	**16**	**16**	**24**	**17**	**27**	**31**	**18**	**17**	**35**	**21**	**29**	**15**	**12**	**17**	**11**	**10**	**19**	**21**	**19**	**17**	**11**	**15**	**15**	**8**

Note: No *S. argenteus* or *S. schweitzeri* were reported.
Source: CARAlert (as at 31 January 2023)

Critical antimicrobial resistances by state and territory

The majority of CARs (85% in 2021; 82% in 2022) were collected from patients from the most populous states: New South Wales (NSW) 32–41% (537/1,303 in 2021; 459/1,429 in 2022), Victoria 18–27% (239/1,303 in 2021; 379/1,429 in 2022) and Queensland 23–25% (330/1,303 in 2021; 331/1,429 in 2022). There were 10 or fewer reports per year from Tasmania and the Northern Territory (NT), and fewer than 30 reports per year from the ACT (Figure 5.3). There were no reports from overseas residents in 2021 or 2022.

The number of CARs reported from NSW declined in 2022 (*n* = 458) compared with 2021 (*n* = 537) (Table 5.2). There was an increase in the number of reports from all other states and territories, most notably Victoria (*n* = 239 in 2021; *n* = 379 in 2022) and South Australia (SA) (*n* = 51 in 2021; *n* = 83 in 2022).

All states and territories reported CPE. The proportion of CPE of all reported CARs varied by state and territory and by year. Compared with 2021, reports of CPE as a proportion of all CARs increased in NSW in 2022 (45% in 2021; 66% in 2022) and in Queensland (49% in 2021; 70% in 2022). Where there were more than 10 CARs reported per year, Western Australia (WA) had the lowest proportion of CPE for both years (28% in 2021; 30% in 2022). No CPE were reported from Tasmania in 2021.

All states and territories reported ceftriaxone- and/or azithromycin-nonsusceptible *N. gonorrhoeae*. Although there was an overall 37% decrease in the number of reports of this CAR in 2022 compared with 2021 (*n* = 251 in 2021; *n* = 158 in 2022), the decrease was only in NSW (*n* = 167 in 2021; *n* = 39 in 2022, down 77%); and there was an increase in reports from Queensland (*n* = 13 in 2021; *n* = 33 in 2022, up 154%).

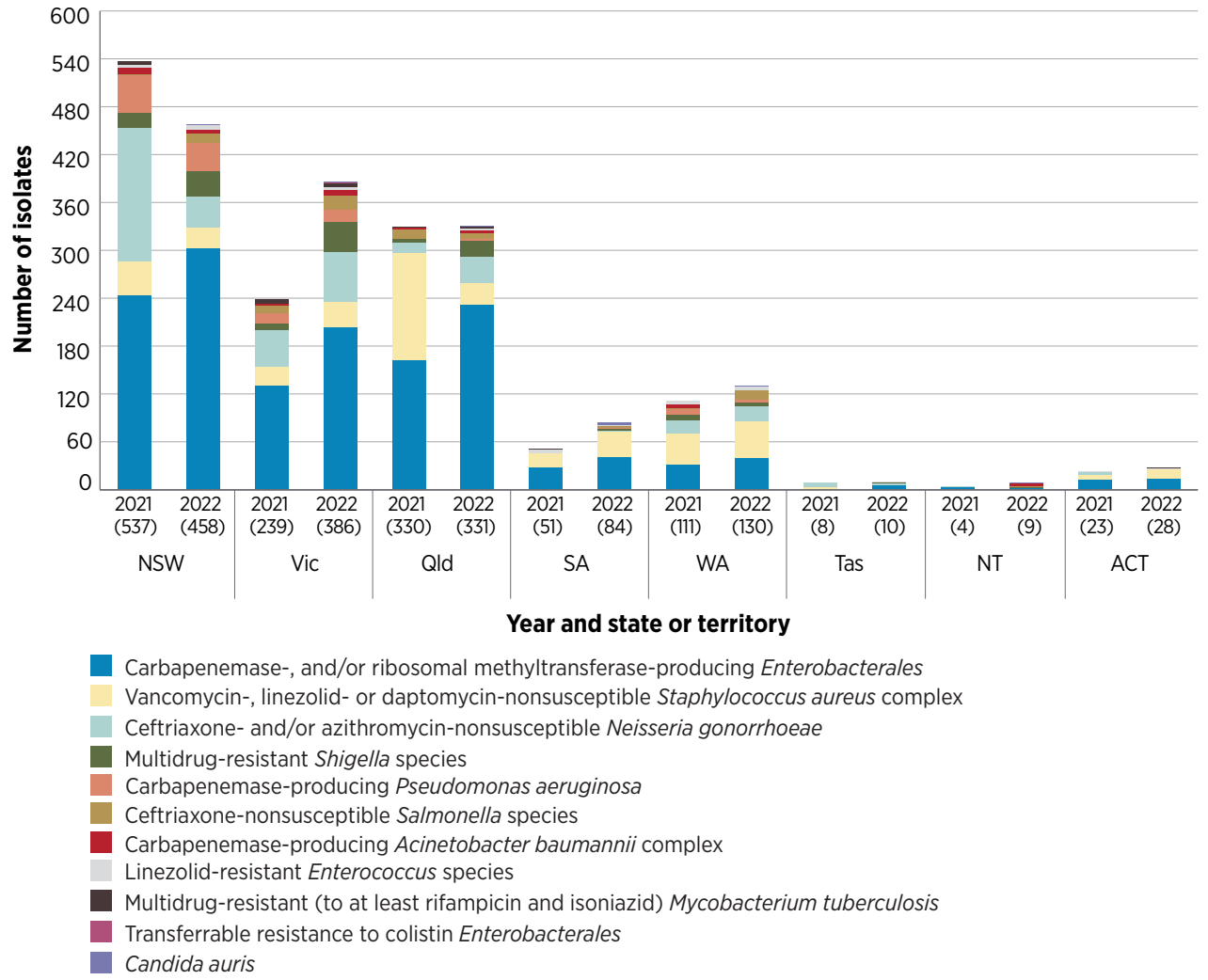
All states and territories reported MDR *Shigella* species. There was a seven-fold decrease in reports in 2021 (*n* = 42) compared with 2020 (*n* = 299), notably from NSW (*n* = 170 in 2020; *n* = 19 in 2021). However, in 2022, there were marked increases in reports from Victoria (*n* = 9 in 2021; *n* = 37 in 2022), Queensland (*n* = 5 in 2021; *n* = 20 in 2021) and NSW (*n* = 32 in 2022).

All states and territories except the NT reported daptomycin-nonsusceptible *S. aureus*. Linezolid-nonsusceptible *S. aureus* was reported from NSW (*n* = 2) and Victoria (*n* = 2). In 2022, there were two reports of daptomycin- and vancomycin-nonsusceptible *S. aureus*, one each from NSW and Victoria.

All states and territories except Tasmania and the ACT reported *C. auris*.

Enterobacterales with transmissible resistance to colistin (*mcr-1.1*) was only reported from Victoria (*n* = 2); and one isolate also harboured a carbapenemase gene ($bla_{\text{OXA-48}}$).

Figure 5.3: Critical antimicrobial resistances, by patient's state or territory of residence, 2021–2022



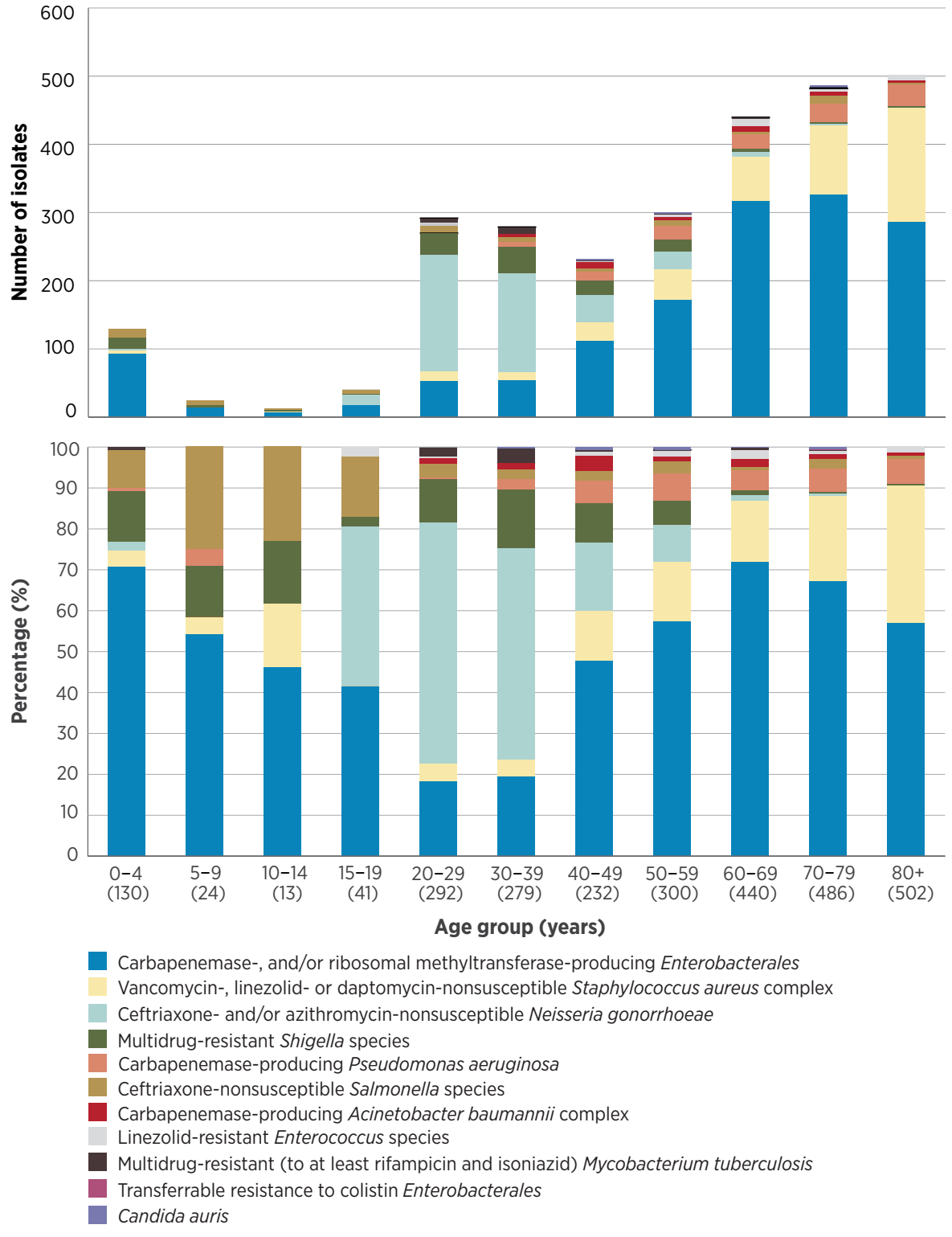
Note: Numbers of isolates are in brackets.
Source: CARAlert (as at 31 January 2023)

Critical antimicrobial resistances age group distribution

CARs were isolated from patients of all ages, and the median age range was 60–69 years (Figure 5.4). A total of 76% (460/609 in 2021; 640/837 in 2022) of CPE were isolated from people aged 50 years and older. Almost all (97–98%) ceftriaxone- and/or azithromycin-nonsusceptible *N. gonorrhoeae* was reported in people aged 15–59 years. The majority (77–81%) of MDR *Shigella* species were reported in people aged 20–59 years.

Only 5.6–6.6% (73/1,303 in 2021; 94/1,429 in 2022) of all CARs were reported in children aged under 15 years. In this age group, CPE, MDR *Shigella* species and ceftriaxone-nonsusceptible *Salmonella* species made up the majority of reports in 2021 (90%) and in 2022 (93%). In the 0–4-year age group, CPE was the most frequently reported CAR (92 reports in two years), followed by MDR *Shigella* species (n = 16) and ceftriaxone-nonsusceptible *Salmonella* species (n = 12).

Figure 5.4: Critical antimicrobial resistances, by age group, 2021–2022



Note: Numbers of isolates in each age group are in brackets.
Source: CARAlert (as at 31 January 2023)

Critical antimicrobial resistances by specimen type

The majority of all CARs were from clinical specimens (947/1,303; 73% in 2021, and 915/1,429; 64% in 2022). These were urine, wound, blood and other (such as genital, faecal or respiratory) specimens that were collected for diagnostic purposes rather than for screening (Figure 5.5).

Of CPE isolates:

- Approximately half (53%) were from clinical specimens (320/609 in 2021; 443/837 in 2022)
- 61–63% of clinical specimens were from urine (201/320 in 2021; 266/433 in 2022)
- 7–9% of clinical specimens were from blood cultures (29/320 in 2021; 29/433 in 2022).

Urine specimens

Urine is an important specimen for certain CARs, such as CPE, because the urinary tract is a common site of infection (Figure 5.5).

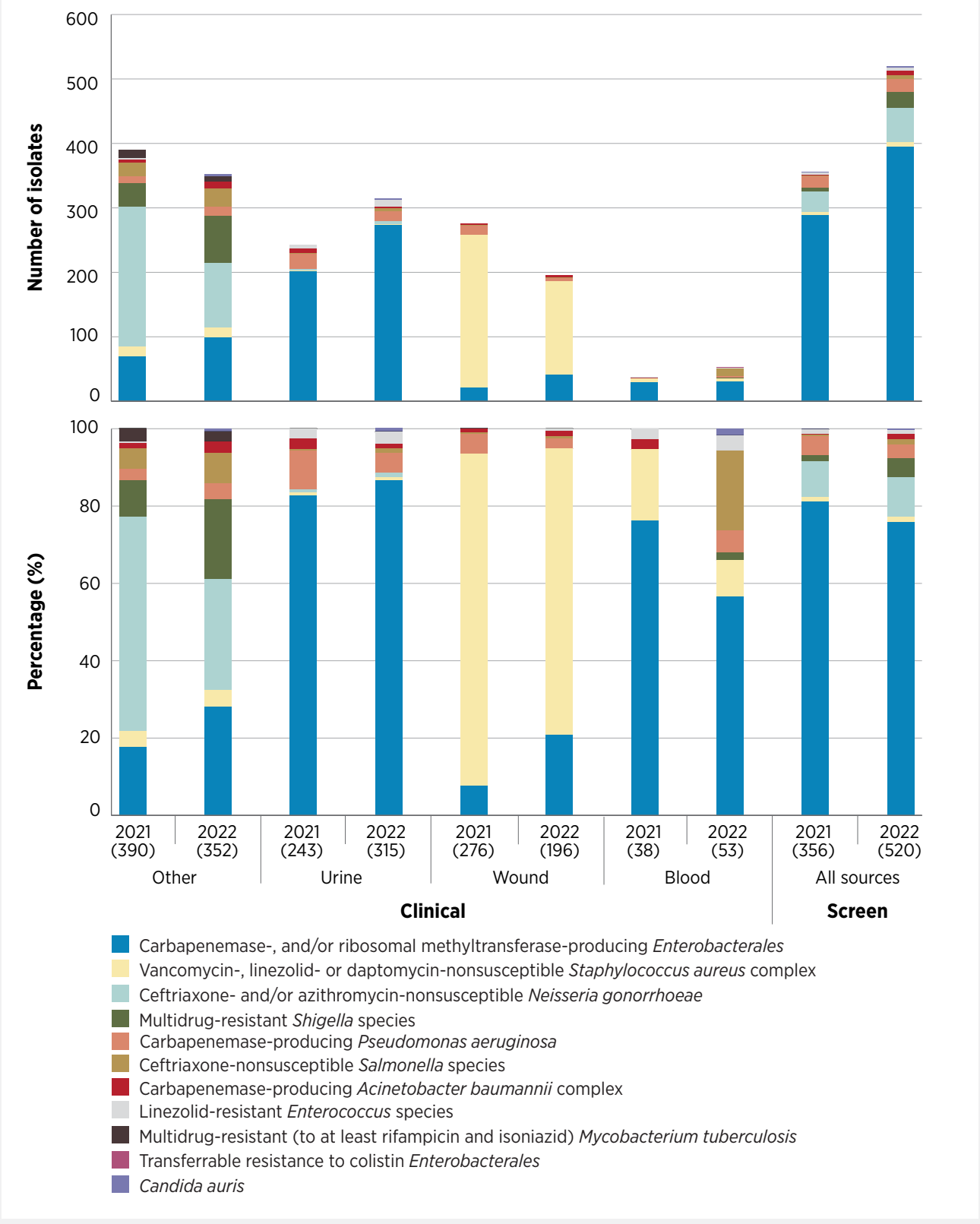
Blood culture specimens

Of blood culture specimens, CPE comprised the majority (55–66%) of all CARs from 2021–2022, highlighting the clinical spectrum of CPE infections compared with other CARs.

Seven other CARs were also reported from blood cultures in 2021 and 2022: ceftriaxone-nonsusceptible *Salmonella* species (*n* = 0 in 2021; *n* = 11 in 2022), daptomycin-nonsusceptible *S. aureus* (*n* = 7 in 2021; *n* = 5 in 2022), carbapenemase-producing *P. aeruginosa* (*n* = 0 in 2021; *n* = 3 in 2022), linezolid-nonsusceptible *Enterococcus* species (*E. faecium*: *n* = 1 in 2021, *n* = 1 in 2022; *E. faecalis*: *n* = 1 in 2022), carbapenemase-producing *Acinetobacter baumannii* (*n* = 0 in 2021; *n* = 1 in 2021), MDR *S. flexneri* (*n* = 0 in 2021; *n* = 1 in 2022) and *C. auris* (*n* = 0 in 2021; *n* = 1 in 2022).

CPE comprised 57–66% of all CARs isolated from blood specimens, highlighting the more serious clinical spectrum of CPE infections compared with other CARs.

Figure 5.5: Critical antimicrobial resistances, by specimen type, 2021–2022



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 2023)

Critical antimicrobial resistances by setting

Where the setting was known, a substantial majority of CARs (737/967; 76% in 2021, and 954/1,129; 84% in 2022) were detected in either hospitalised patients or hospital outpatients.

CPE accounted for 61–72% of those CARs that are typically healthcare-associated. Where the setting was known, 5–7% of CPE reports were from community settings and 1–3% were from aged care homes (Figure 5.6).

For pathogens normally associated with community infections, just over two-thirds of reports were ceftriaxone- and/or azithromycin-nonsusceptible *N. gonorrhoeae* (251/306; 82% in 2021, and 158/266; 59% in 2022) or MDR *Shigella* species (42/306; 14% in 2021, and 99/266; 37% in 2022).

Almost all reports from aged care homes were daptomycin-nonsusceptible *S. aureus* (46–51%) or CPE (49–50%).

Figure 5.6: Critical antimicrobial resistances, by setting, 2021–2022

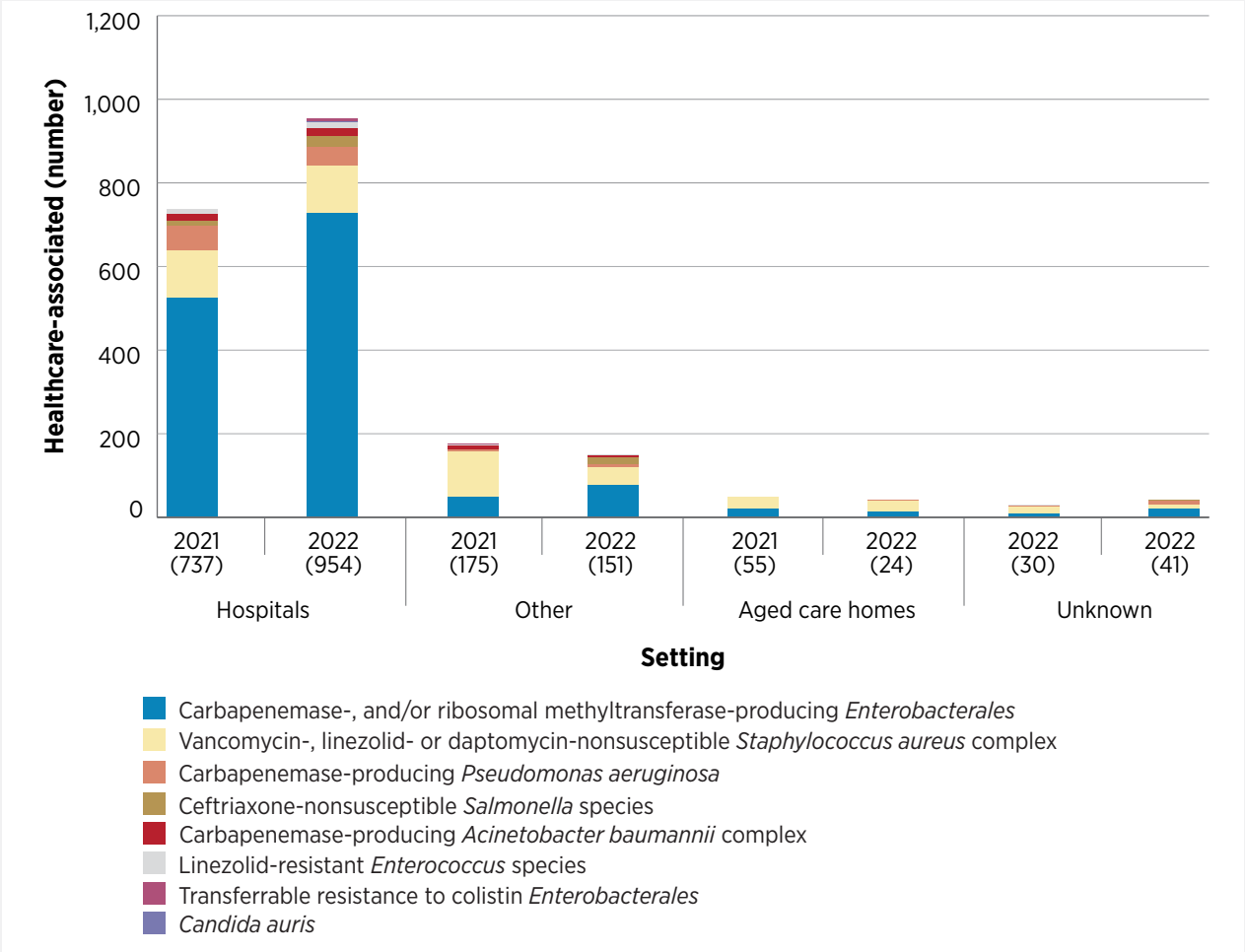


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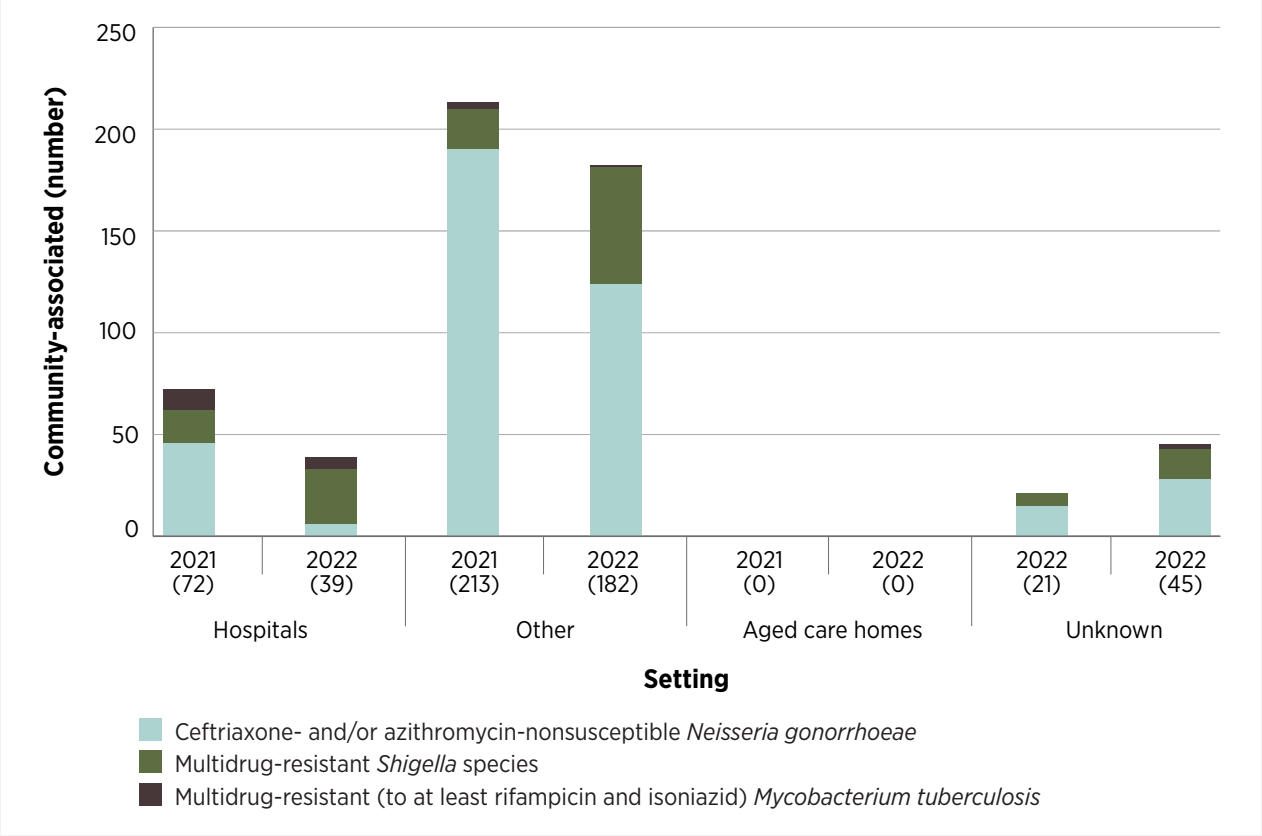
Figure 5.6: continued



Notes:
1. 'Other' refers to community, that is non-hospital and non-aged care home.
2. Numbers of isolates are in brackets.
Source: CARAlert (as at 31 January 2023)

5.3 Critical antimicrobial resistances by species

CARAlert identified confirmed CARs in the following species in 2021–2022.

5.3.1 *Acinetobacter baumannii* complex

A. baumannii complex is a group of environmental organisms that have caused prolonged outbreaks in hospital settings, such as intensive care and severe burn units. *A. baumannii* infections are commonly associated with patients with compromised physical barriers and immunity, including ventilator-associated pneumonia and severe burn infections.

Forty carbapenemase-producing *A. baumannii* isolates were reported across 2021 (*n* = 17) and 2022 (*n* = 23) from six states and territories, with no reports from Tasmania or the ACT (Table 5.3). Several genes that code for carbapenemase resistance have been identified in the *A. baumannii* complex. Three carbapenemase genes (OXA-23-like, NDM and OXA-24/40-like) were reported. Almost all (38/40; 95%) contained OXA-23-like, either alone (*n* = 25) or in combination with NDM (*n* = 6) or NDM alone (*n* = 7). The $bla_{\text{NDM-1}}$ (*n* = 8) and $bla_{\text{NDM-5}}$ (*n* = 2) were the only NDM gene variants reported. Seven carbapenemase-producing *A. baumannii* also harboured a ribosomal methyltransferase gene, *armA*, which encodes for resistance to aminoglycoside antimicrobials.

Table 5.3: *Acinetobacter baumannii* carbapenemase types, by state and territory, 2021–2022

Carbapenemase type	Year	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
OXA-23-like	Total	11	5	3	0	2	0	4	0	25
	2021	7	1	1	0	2	0	0	0	11
	2022	4	4	2	0	0	0	4	0	14
NDM	Total	1	2	2	0	2	0	0	0	7
	2021	0	1	1	0	1	0	0	0	3
	2022	1	1	1	0	1	0	0	0	4
NDM, OXA-23-like	Total	1	4	0	1	0	0	0	0	6
	2021	1	1	0	0	0	0	0	0	2
	2022	0	3	0	1	0	0	0	0	4
OXA-24/40-like	Total	0	0	1	0	1	0	0	0	2
	2021	0	0	0	0	1	0	0	0	1
	2022	0	0	1	0	0	0	0	0	1

Source: CARAlert (as at 31 January 2023)

5.3.2 *Candida auris*

C. auris can cause invasive fungal infections, be passed from person to person, and persist in the environment. Its severity, communicability, propensity to cause outbreaks and drug resistance make the correct identification of *C. auris* crucial to treating patients and preventing infections. However, this is challenging because traditional phenotypic methods may misidentify *C. auris*. There were 10 *C. auris* reported (*n* = 1 in 2021; *n* = 9 in 2022) from all states and territories except the ACT and Tasmania.

5.3.3 *Enterobacterales*

Enterobacterales commonly cause urinary tract, biliary tract and other intra-abdominal infections, and bloodstream infections.

Carbapenemase-producing

Eight carbapenemase gene types were reported throughout Australia during 2021 and 2022. There were notable regional differences in the distribution of the top five carbapenemase types (Table 5.4). Of these, three carbapenemase types (IMP, NDM and OXA-48-like), either produced alone or in combination, accounted for 97% of all the carbapenemase-producing *Enterobacterales* isolates, in both 2021 and 2022.

IMP-types increased by 14% in 2022 (*n* = 438) compared with 2021 (*n* = 383), although there was a slight decrease in reports from WA. Fewer than five IMP-producing *Enterobacterale*s were reported from SA and the NT, and fewer than 10 were reported from the ACT from 2021 to 2022. IMP-types accounted for 72–77% of all CPE reported from Queensland. The vast majority of isolates (218/227; 96% in 2021, and 278/280; 99% in 2022) harboured either *bla*$_{\text{IMP-4}}$ (*n* = 332) or IMP-4-like (*n* = 164) genes. Other variants reported were *bla*$_{\text{IMP-59}}$ (*n* = 6), *bla*$_{\text{IMP-26}}$ (*n* = 1), *bla*$_{\text{IMP-27}}$ (*n* = 1), *bla*$_{\text{IMP-38}}$ (*n* = 1), and *bla*$_{\text{IMP-1}}$ (*n* = 1).

NDM-types, either alone or in combination, were found in all states and territories, although fewer than five per year were reported from Tasmania, the NT and the ACT. There was an 87% increase in reports of NDM types in 2022 (*n* = 294) compared with 2021 (*n* = 157). In SA, NDM-types accounted for just over two-thirds (17/26; 65% in 2021, and 31/41; 76% in 2022) of all CPE reported.

Six different genes were identified in the isolates sequenced (105/157; 67% in 2021, and 193/294; 66% in 2022), which were: *bla*$_{\text{NDM-5}}$ (147/298; 49%), *bla*$_{\text{NDM-1}}$ (84/298; 28%), *bla*$_{\text{NDM-7}}$ (55/298; 18%), *bla*$_{\text{NDM-4}}$ (10/298; 3%), *bla*$_{\text{NDM-18}}$ (1/298) and *bla*$_{\text{NDM-19}}$ (1/298).

Reports of OXA-48-like CPE increased by 88% in 2022 compared with 2021. More than 62% (106/170) of the isolates with OXA-48-like types were sequenced. Six genes were reported; the most common was *bla*$_{\text{OXA-181}}$ (48/106; 45%), followed by *bla*$_{\text{OXA-48}}$ (31/106; 29%), *bla*$_{\text{OXA-232}}$ (16/106; 15%), *bla*$_{\text{OXA-484}}$ (8/106; 8%), *bla*$_{\text{OXA-244}}$ (2/106) and *bla*$_{\text{OXA-922}}$ (1/106).

Of reports of KPC types, 70% were from Victoria (16/23), and most of them were reported in 2022 (*n* = 10); followed by reports from Queensland (*n* = 2), SA (*n* = 2), WA (*n* = 2) and NSW (*n* = 1). Just over three-quarters of the isolates were sequenced (18/23; 78%) and almost all were *bla*$_{\text{KPC-2}}$ (14/18, 78%). Two other variants were reported, *bla*$_{\text{KPC-3}}$ (3/18, 17%) and *bla*$_{\text{KPC-33}}$ (*n* = 1).

IMI types were reported from NSW (*n* = 5), Victoria (*n* = 3), Queensland (*n* = 2) and SA (*n* = 1). All sequenced isolates (*n* = 5) harboured *bla*$_{\text{IMI-1}}$.

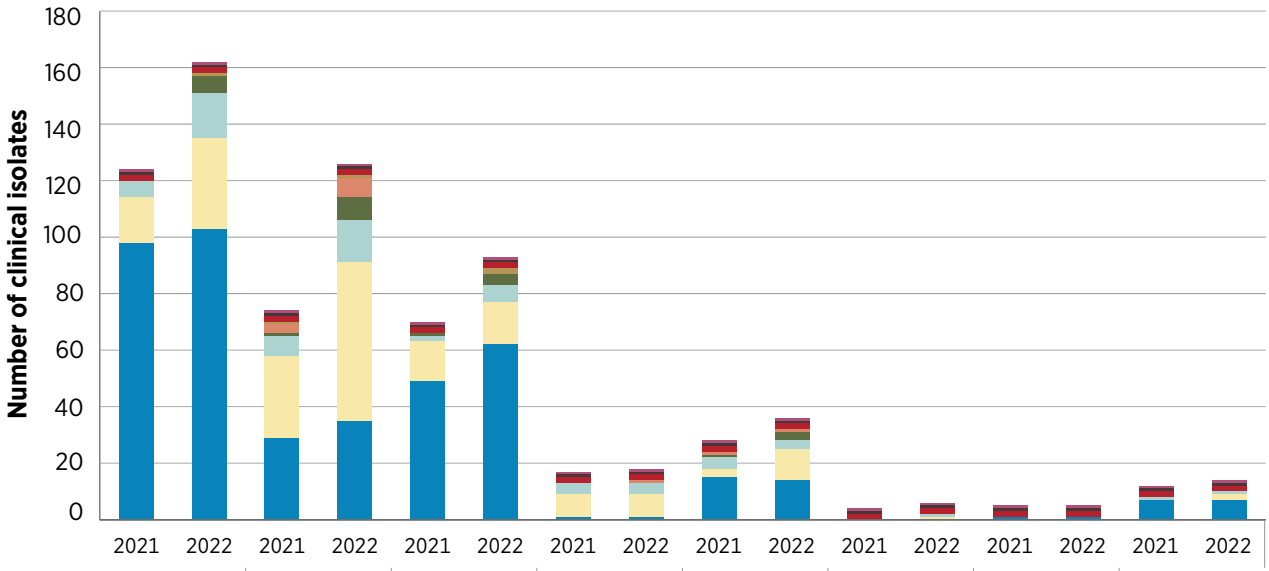
Co-production of carbapenemase was reported at low levels (19/600; 3.2% in 2021, and 42/827; 5.1% in 2022). The co-produced genes in 2021–2022 were NDM+OXA-48-like (*n* = 43), IMP+NDM (*n* = 10) and IMP+OXA-48-like (*n* = 8).

Table 5.4: Top five carbapenemase types, *Enterobacterales*, by state and territory, 2021–2022

Carbapenemase type	Year	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
IMP	Total	374	99	291	4	32	0	3	18	821
	2021	182	47	124	3	17	0	1	9	383
	2022	192	52	167	1	15	0	2	9	438
NDM	Total	123	171	78	48	21	4	2	4	451
	2021	46	59	27	17	6	0	2	0	157
	2022	77	112	51	31	15	4	0	4	294
OXA-48-like	Total	61	50	28	13	14	1	0	3	170
	2021	22	13	11	6	5	0	0	2	59
	2022	39	37	17	7	9	1	0	1	111
KPC	Total	1	16	2	2	2	0	0	0	23
	2021	1	6	1	0	1	0	0	0	9
	2022	0	10	1	2	1	0	0	0	14
IMI	Total	5	3	2	1	0	0	0	0	11
	2021	0	2	0	1	0	0	0	0	3
	2022	5	1	2	0	0	0	0	0	8

Note: Number reported by state and territory includes genes detected alone or in combination with another type.
Source: CARAlert (as at 31 January 2023)

Figure 5.7: *Enterobacterales*, carbapenemase types from clinical isolates, by state or territory, 2021–2022



	NSW		Vic		Qld		SA		WA		Tas		NT		ACT	
Clinical, *n*	124	162	75	124	66	89	13	14	24	32	0	2	1	1	8	9
Screen, *n*	119	136	53	75	95	143	13	27	4	5	0	3	2	1	3	4
Screen, %*	49.0	45.6	41.4	37.7	59.0	61.6	50.0	65.9	14.3	13.5	nd	nd	nd	nd	27.3	30.8
Total	**243**	**298**	**128**	**199**	**161**	**232**	**26**	**41**	**28**	**37**	**0**	**5**	**3**	**2**	**11**	**13**

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 2023)

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 28 species (12 genera) of *Enterobacterales*. IMP types alone accounted for 52–62% (370/600 in 2021; 433/827 in 2022) of all carbapenemases; they were found in 25 different species (Figure 5.8). *Enterobacter cloacae* complex accounted for 45% (167/370 in 2021; 193/433 in 2022) of all IMP types and 23–28% (167/600 in 2021; 193/827 in 2022) of all CPE. NDM carbapenemase types were found mainly in *Escherichia coli* (40–56%), and OXA-48-like types in *E. coli* (34–47%) and *Klebsiella pneumoniae* (42–47%).

Figure 5.8: Carbapenemase-producing *Enterobacterales*, by species and type, 2021–2022

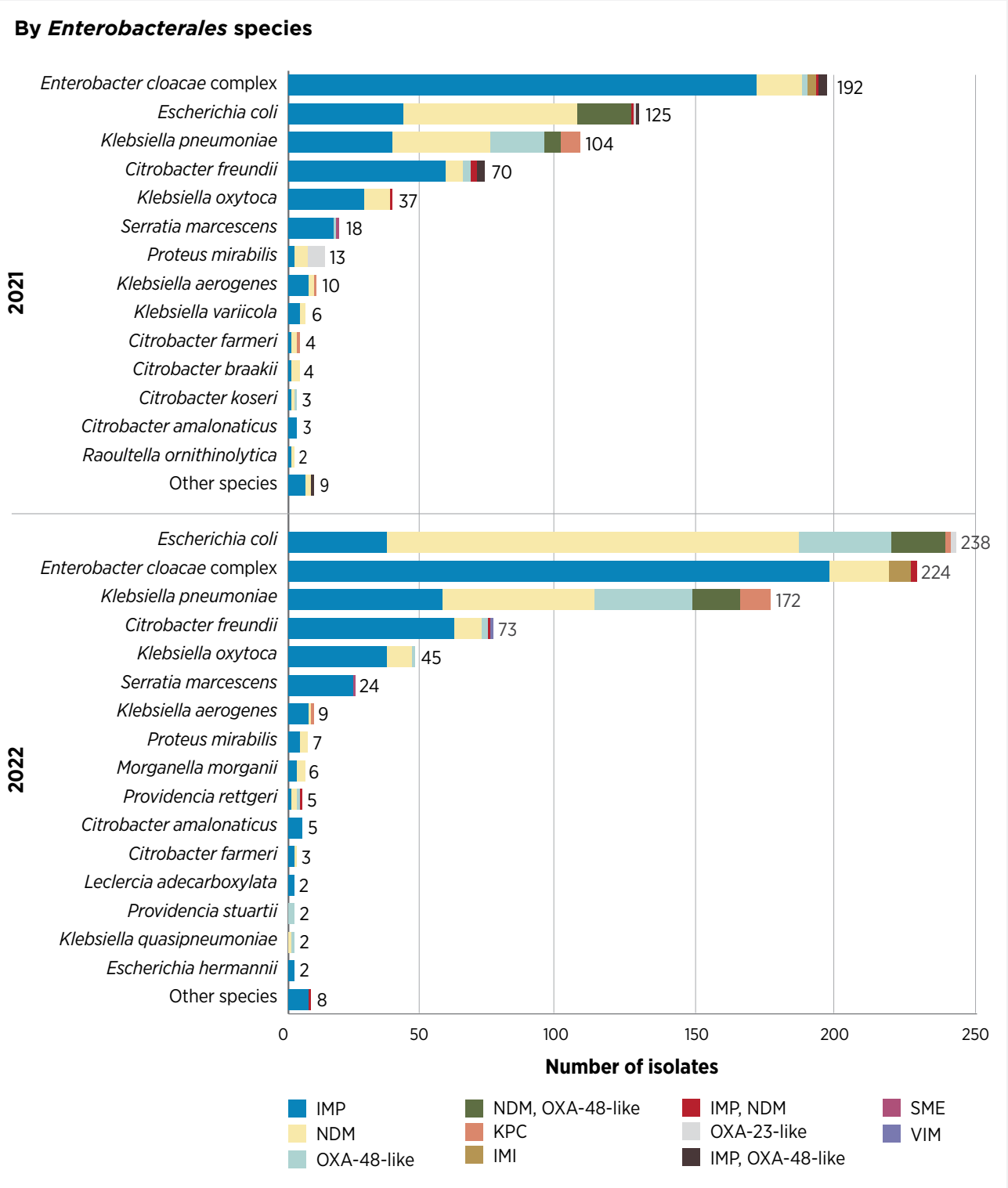


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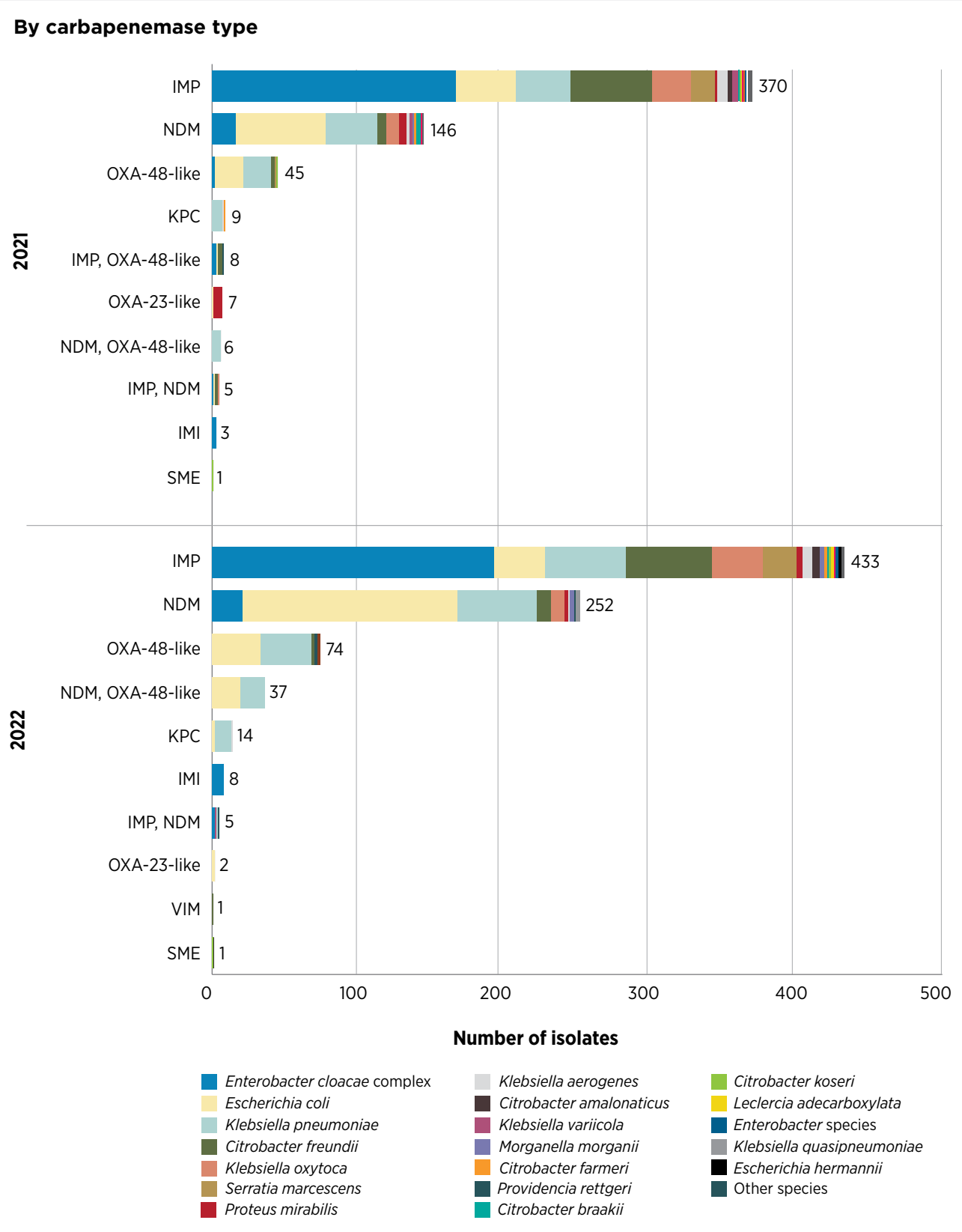
Figure 5.8: *continued*



Source: CARAlert (as at 31 January 2023)

Ribosomal methyltransferases (RMT)

Four RMT genes were detected in 76 isolates of *Enterobacterales*, representing six species. Of these, 75% (57/76) also had a carbapenemase. The RMTs were mostly found among *K. pneumoniae* (43/76; 57%) and *E. coli* (27/76; 36%), either alone: *rmtB* (*n* = 41; 54%), *armA* (*n* = 19; 25%), *rmtF* (*n* = 11; 14%) and *rmtC* (*n* = 3; 4%); or co-produced in two isolates: *armA+rmtF* (*n* = 1) and *rmtB+rmtF* (*n* = 1).

Plasmid-mediated resistance to colistin

Transmissible resistance to colistin is conferred by *mcr* genes located on plasmids. In 2022, two *K. pneumoniae* isolates with *mcr-1.1* were reported in Victoria. One isolate also harboured $bla_{\text{OXA-48}}$. In 2021, *mcr* genes were not reported.

5.3.4 *Enterococcus* species

Enterococcus species commonly cause urinary tract, biliary tract and other intra-abdominal infections, and bloodstream infections. Resistance in enterococci, similar to some CPE and other *Enterobacterales*, is transmitted in hospital environments from patients' bowel flora. This CAR, like CPE, has the potential to become a significant public health problem if it is not prevented and controlled. Australia has a very high reported rate of vancomycin-resistant *E. faecium* compared with European countries.[2] The number of reports of linezolid-nonsusceptible *Enterococcus* species remained stable in 2021 (*n* = 13) and 2022 (*n* = 17). There were only four reports of this CAR in 2017.

5.3.5 *Mycobacterium tuberculosis*

The number of tuberculosis notifications peaked at 1,619 in 2020, and then declined to 1,477 in 2021 and further to 1,305 in 2022.[3] Reports of MDR *Mycobacterium tuberculosis* also declined since 2020 (*n* = 18), with 13 reports in 2021 and 9 in 2022. Reports of MDR *M. tuberculosis* for 2022 may not yet be complete.

5.3.6 *Neisseria gonorrhoeae*

N. gonorrhoeae causes gonorrhoea, which is largely sexually transmitted and most commonly manifests as urethritis in men and cervicitis in women. Treatment strategies globally are reliant on ceftriaxone. In Australia, ceftriaxone with adjunctive azithromycin has been a first-line treatment recommendation since 2014. Sporadic reports of *N. gonorrhoeae* isolates with raised minimum inhibitory concentration (MIC) values to ceftriaxone (decreased susceptibility) have been reported sporadically in Australia, mostly associated with overseas travel or contact, as reported by the Australian Gonococcal Surveillance Programme (AGSP).[4] In 2021, almost all (250/251; >99%) of the CAR types associated with *N. gonorrhoeae* were azithromycin-nonsusceptible (low-level resistance [LLR], MIC <256 mg/L); and there was one isolate (from WA) that was ceftriaxone-nonsusceptible.

In 2022, 72% (113/158) were azithromycin-nonsusceptible (LLR); 23% (37/158) were ceftriaxone-nonsusceptible (MIC ≥0.125 mg/L) (NSW, *n* = 27; Victoria, *n* = 7; WA, *n* = 2; Queensland, *n* = 1); and 5% (8/158) were azithromycin-nonsusceptible (high-level resistance [HLR], MIC ≥256 mg/L) (NSW, *n* = 3; Queensland, *n* = 4; WA, *n* = 1).

5.3.7 *Pseudomonas aeruginosa*

P. aeruginosa infections primarily affect hospitalised or immunocompromised patients. Patients with catheters or drains are considered at high risk for carbapenemase transmission. All states and territories except Tasmania, the NT and the ACT reported carbapenemase-producing *P. aeruginosa* in 2021 and 2022. Two-thirds of the isolates were from NSW (82/124; 66%). Four carbapenemase types (GES, VIM, NDM and IMP) were reported. Of these, 82% (102/124) contained GES (*n* = 82; 66%) or VIM (*n* = 20; 16%), either alone (*n* = 19) or in combination

with IMP (*n* = 1). Other types reported include NDM (*n* = 16) and IMP alone (*n* = 6).

5.3.8 *Salmonella* species

Salmonella species are important causes of bacterial gastroenteritis. Most cases are acquired through food-borne transmission.

Most ceftriaxone-nonsusceptible *Salmonella* species (MIC >1 mg/L) were reported in Victoria (26/75; 35%), followed by Queensland (19/75; 25%), NSW (14/75; 19%) and WA (13/75; 17%). There were no reports of this CAR from Tasmania or the ACT in 2021 and 2022. The reported ceftriaxone-nonsusceptible *Salmonella* species were ESBL-producing (39/75; 52%), pAmpC (35/75; 47%) or both ESBL and pAmpC (1/75). In 2021, pAmpC dominated reports (19/24; 79%), which were mostly from Queensland (*n* = 10) and NSW (*n* = 9). In 2022, ESBL types were dominant (36/51; 71%) from all states and territories except Queensland, where pAmpC types continued to be more prevalent. Where the variant was reported, the ESBLs were predominantly CTX-M types (33/35; 94%) and pAmpC were all CMY (31/32; 97%).

In 2021, almost all ceftriaxone-nonsusceptible *Salmonella* reports were from non-typhoidal species (23/24; 96%). In 2022, one-quarter of reports were from typhoidal species (13/51; 25%) from NSW (*n* = 6), Victoria (*n* = 5) and WA (*n* = 2). All of the typhoidal species reported in 2022 harboured CTX-M genes.

5.3.9 *Shigella* species

Shigella species infections are commonly food-borne or sexually transmitted. Based on ceftriaxone susceptibility, MDR isolates are reported as having an ESBL or pAmpC phenotype.

MDR *Shigella* species increased rapidly from 2018 due to a prolonged clonal outbreak of *S. sonnei* with $bla_{\text{CTX-M-27}}$ associated with men who have sex with men. There were two large outbreaks across two states, with a peak in numbers in April 2019 (75% from Victoria) and another in January 2020 (61% from NSW). There was a sharp fall in the monthly number of reports of this CAR from April 2020 onwards, continuing throughout 2021 to reach the lowest level since CARAlert began. This fall coincided with the introduction of COVID-19 restrictions throughout Australia. However, as borders re-opened, the number of reports of ESBL-producing *S. sonnei* has again increased from 17 in 2021 to 62 in 2022. Just over one-third of ceftriaxone-nonsusceptible *S. sonnei* in 2022 (21/56, 38%) harboured $bla_{\text{CTX-M-15}}$.

The majority of MDR *S. flexneri* were ceftriaxone-susceptible (5/12; 42% in 2021, and 19/28;68% in 2022). However, low levels of both ESBL (CTX-M, 4/12 in 2021 and 6/28 in 2022) and pAmpC (bla_{DHA}, 3/12 in 2021, 3/28 in 2022) types were detected.

5.3.10 *Staphylococcus aureus*

S. aureus is a common pathogen that causes a wide variety of infections of varying severity. It is often associated with skin and soft tissue infections. Almost all (435/441; 99%) CARs reported for *S. aureus* were daptomycin-nonsusceptible. There is considerable variation in reporting of phenotypic tests, and data are difficult to interpret without sequencing.

Four linezolid-nonsusceptible isolates were confirmed, one in 2021 (from Queensland) and three in 2022 (*n* = 2, NSW; *n* = 1, Queensland). Two daptomycin- and vancomycin-nonsusceptible *S. aureus* isolates were reported in 2022, from one patient residing in NSW and another from Victoria.

References

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Chapter 6

Focus areas

Focus areas

Key findings

Antifungal drug susceptibility for common *Candida* group species and *Aspergillus fumigatus* complex

- Antifungal resistance among common *Candida* species and *Aspergillus fumigatus* complex remains uncommon.
- However, small numbers of *Candida* group isolates, particularly *Nakaseomyces (Candida) glabratus*, were anidulafungin- and micafungin-resistant. Four *N. glabratus* isolates (0.6%) that were echinocandin-resistant or had intermediate susceptibility were also co-resistant to azoles.
- Azole resistance among *C. tropicalis* and *N. glabratus* may be emergent (both approximately 8%).
- Voriconazole resistance among *A. fumigatus* complex was uncommon (<5%).

International comparisons of antimicrobial use

- Australian hospital antimicrobial use is estimated to be nearly three times that of the European country with the lowest use, the Netherlands, and considerably higher than Canada, which has a comparable healthcare system.
- Australia ranks seventh highest compared with European countries, the United Kingdom and Canada in its use of antimicrobials in the community.

International comparisons of antimicrobial resistance in bacteria

- Australia's rates of fluoroquinolone resistance in *Escherichia coli* and *Klebsiella pneumoniae* remain very low compared with most European countries.
- Australia's rates of resistance to third-generation cephalosporins were lower than European rates.
- Australia's rates of resistance in key gram-positive pathogens such as *Staphylococcus aureus* were moderate to high compared with European countries.
- Australia's rates of vancomycin resistance in *Enterococcus faecium* remain higher than in more than 20 European countries, but are slowly reducing.

continues

This chapter includes analyses of antifungal susceptibility data, and an update on international comparisons of antimicrobial resistance (AMR) and antimicrobial use (AU).

6.1 In vitro susceptibility to antifungal agents for common *Candida* group species and *Aspergillus fumigatus* complex: 2020–2022

Fungal microorganisms, like bacteria, can cause serious and even life-threatening infections, especially in immunocompromised people or those with serious underlying diseases. Treatments for these infections can be compromised or even rendered ineffective by AMR. Emerging AMR among *Candida* pathogens and *Aspergillus* species, which are the major causes of invasive fungal infections, is particularly concerning and has led to the increasing incorporation of in vitro antifungal susceptibility testing (AFST) to guide clinical decisions.[1,2] In recognition of their significance, the World Health Organization (WHO) has highlighted the need for increased awareness of fungi and their susceptibility profiles.[3]

In AURA 2023, Australian data on the susceptibility of selected fungal species to antifungal agents from 2020–2022 are included for the first time since the inception of the Antimicrobial Use and Resistance in Australia Surveillance System (AURA). Expanding the scope of surveillance of AMR is an aim of Australia's National AMR Strategy.[4]

For fungal pathogens, susceptibility testing to antifungal agents is important to determine effective therapy in clinical settings. It is based on the availability of categorical endpoints, namely clinical breakpoints (CBPs) or epidemiological cut-off values (ECOFFs). The Clinical Laboratory Standards Institute (CLSI) and European Committee on Antimicrobial Susceptibility Testing (EUCAST) have developed antifungal susceptibility testing, CBPs and ECOFFs for certain fungal species – although, because of methodological differences, CBPs and ECOFFs often do not align. The minimum inhibitory (or effective) concentration (MIC or MEC) is the lowest concentration of an antimicrobial at which fungal (or bacterial) growth is completely (or substantially) inhibited. The ECOFF is the MIC or MEC that separates fungal populations into those with and without acquired (mutational) resistance based on their phenotypes, by differentiating isolates as wild type (with no acquired resistance) or non-wild type (with acquired resistance). CBPs distinguish between 'susceptible' and 'resistant' isolates based on evidence from pharmacological studies and clinical outcome data to inform drug selection for antifungal treatment.

This chapter provides a summary of the susceptibilities of common *Candida* species (*C. albicans, Nakaseomyces* [previously *Candida*] *glabratus*, *C. tropicalis*, *C. parapsilosis*, *Pichia kudriavzevii* [previously *C. krusei*]) and *A. fumigatus* complex. AFST was performed using Sensititre® YeastOne™ YO10 or AUSNMRC1 (TREK Diagnostics, Cleveland, OH) in two laboratories (SA Pathology, and Institute of Clinical Pathology and Medical Research, NSW Health Pathology). Hence, this is based on CLSI methodology. Large numbers of isolates were tested (Table 6.1), representing those at these two centres as well as those referred from public and private laboratories in other Australian jurisdictions, except Western Australia. MIC values are presented for the following antifungals: amphotericin B, anidulafungin, micafungin, 5-flucytosine, fluconazole, itraconazole, voriconazole, posaconazole and isavuconazole. Anidulafungin and micafungin values are presented as MECs for *A. fumigatus* complex. MICs and MECs were interpreted against CLSI CBPs or, where there are none, ECOFFs.[5–7]

Table 6.1 includes data on *Candida* and *A. fumigatus* complex where CBPs, ECOFFs or both are established for a fungus-drug combination. For each fungus-drug combination, the proportions of resistant (non-wild type) isolates are displayed; where there are CBPs as well as ECOFFs, the proportion that was non-wild type is also shown, as for epidemiological (and statistical) purposes, this is of interest and may signal the need for more regular surveillance and reporting. Table 6.3 includes data on these fungi where there are neither CBPs nor ECOFFs (for 5-flucytosine and isavuconazole).

Key findings

All *Candida* group isolates tested were defined species and all *A. fumigatus* isolates were *A. fumigatus* complex, a collection of species within the complex found in clinical specimens which often are not easily distinguished in routine laboratory testing.[8]

Amphotericin B

For most isolates of the *Candida* group, amphotericin B had good activity, although 16% (38/238) of *C. parapsilosis* isolates were non-wild type (range 2–4 mg/L), which was not evident in a 2014–2015 national Australian survey.[9] For the *A. fumigatus* complex, 15.1% were non-wild type for amphotericin B.

Echinocandin

Echinocandin resistance was uncommon (<2% overall), occurring only in a single *Candida* group isolate. However, it is possible that both echinocandin resistance and echinocandin–azole co-resistance could be emerging in *N. glabratus*. In the 2014–2015 survey, only one *N. glabratus* isolate was echinocandin-resistant[9], with no resistance across drug classes. In 2020–2022, eight isolates were anidulafungin- (MIC 1–2 mg/L) and micafungin- (MIC 0.5–4 mg/L) resistant, and four (0.6%) also demonstrated the echinocandin–azole co-resistance/non-wild type phenotype.

Fluconazole

For fluconazole, resistance rates were low and varied among species: 2.9% for *C. albicans*, 3.4% for *C. parapsilosis*, 8% for *C. tropicalis* and 8.6% for *N. glabratus*. Although fluconazole resistance was less than 10% for common *Candida* species, there may be a small increase compared with 2014–2015.[9] The proportion of non-wild type isolates was three to five times higher than those assigned as resistant. *P. kudriavzevii* is a poor target for fluconazole, and hence this agent should not be used to treat infections caused by this species.

Other azoles

Isavuconazole demonstrated good activity against common *Candida* group species, especially *C. albicans*, and including *P. kudriavzevii*.

Resistance to the other azoles was uncommon (1–3%) amongst *C. albicans* and *C. parapsilosis*, while 6% of *C. tropicalis* were voriconazole-resistant and 44% were non-wild type to posaconazole. In *P. kudriavzevii*, 9% of isolates were non-wild type to voriconazole. This finding supports the need for active surveillance of these species.

Similarly, there was a relatively high proportion of non-wild type *N. glabratus* isolates for itraconazole (17.5%), posaconazole (13.1%) and voriconazole (27.7%).

For the *A. fumigatus* complex, 21 (4.3%) isolates were voriconazole-resistant and 16 (4.5%) were non-wild type for isavuconazole (Table 6.1). The azole (voriconazole) resistance rate remains stable at under 10%, supporting the appropriateness of voriconazole remaining as first-line therapy for invasive aspergillosis pending the results of drug susceptibility testing.[10]

Table 6.1: Antifungal resistance and non-wild type isolates for *Candida* group species, Australia, 2020–2022 combined

		MIC (or MEC) (mg/L)						
		Interpretive categories					ECOFF	
Fungus and antifungal agent	Isolates, *n*	Susceptible	Intermediate	Susceptible-dose dependent	Resistant	Resistant, % (*n*)	ECOFF (mg/L)	Non-wild-type, % (*n*)
Candida albicans								
Amphotericin B	629	–*	–*	–*	–*	–*	2	0.0 (0)
Fluconazole	629	≤2	–*	4	≥8	2.9 (18)	0.5	10.7 (67)
Itraconazole	629	–*	–*	–*	–*	–*	–†	–†
Voriconazole	629	≤0.12	0.25–0.5	–*	≥1	1.6 (10)	0.03	3.0 (19)
Posaconazole	629	–*	–*	–*	–*	–*	0.06	4.0 (25)
Anidulafungin	629	≤0.25	0.5	–*	≥1	0.2 (1)	0.12	0.2 (1)
Micafungin	629	≤0.25	0.5	–*	≥1	0.2 (1)	0.03	0.6 (4)
Nakaseomyces (*Candida*) *glabratus*								
Amphotericin B	643	–*	–*	–*	–*	–*	2	0.0 (0)
Fluconazole	643	–*	–*	≤32	≥64	8.6 (55)	8	29.0 (186)
Itraconazole	643	–*	–*	–*	–*	–*	4	17.5 (11)
Voriconazole	643	–*	–*	–*	–*	–*	0.25	27.7 (178)
Posaconazole	643	–*	–*	–*	–*	–*	1.0	13.1 (84)
Anidulafungin	643	≤0.25	0.25	–*	≥0.5	1.2 (8)	0.25	1.6 (10)
Micafungin	643	≤0.06	0.12	–*	≥0.25	1.2 (8)	0.03	2.1 (14)
Candida tropicalis								
Amphotericin B	100	–*	–*	–*	–*	–*	2.0	0.0 (0)
Fluconazole	100	≤2	–*	4	≥8	8.0 (8)	1.0	53.0 (53)
Itraconazole	100	–*	–*	–*	–*	–*	0.5	2.0 (2)
Voriconazole	100	≤0.12	0.25-0.5	–*	≥1.0	6.0 (6)	0.12	31.0 (31)
Posaconazole	100	–*	–*	–*	–*	–*	0.12	44.0 (44)

continues

Table 6.1: *continued*

Fungus and antifungal agent	Isolates, *n*	MIC (or MEC) (mg/L)						
		Interpretive categories					ECOFF	
		Susceptible	Intermediate	Susceptible-dose dependent	Resistant	Resistant, % (*n*)	ECOFF (mg/L)	Non-wild-type, % (*n*)
Candida tropicalis (*continued*)								
Anidulafungin	100	≤0.25	0.5	–*	≥1.0	1.0 (1)	0.12	10.0 (10)
Micafungin	100	≤0.25	0.5	–*	≥1.0	1.0 (1)	0.06	2.0 (2)
Candida parapsilosis								
Amphotericin B	238	–*	–*	–*	–*	–*	1.0	16.0 (38)
Fluconazole	238	≤2.0	–*	4	≥8.0	3.4 (8)	2.0	0.0 (0)
Itraconazole	238	–*	–*	–*	–*	–*	0.5	0.8 (2)
Voriconazole	238	≤0.12	0.25–0.5	–*	≥1.0	2.5 (6)	–†	–†
Posaconazole	238	–*	–*	–*	–*	–*	0.25	4.6 (11)
Anidulafungin	238	≤2.0	4.0	–*	≥8.0	0.4 (1)	4.0	0.4 (1)
Micafungin	238	≤2.0	4.0	–*	≥8.0	0.4 (1)	2.0	0.4 (1)
Pichia kudriavzevii (*Candida krusei*)								
Amphotericin B	88	–*	–*	–*	–*	–*	2.0	2.2. (2)
Fluconazole§	88	–*	–*	–*	–*	–*	–†	–†
Itraconazole	88	–*	–*	–*	–*	–*	1.0	0.0 (0)
Voriconazole	88	≤0.5	1.0	–*	≥2.0	0.0 (0)	0.5	9.1 (8)
Posaconazole	88	–*	–*	–*	–*	–*	0.5	1.1 (1)
Anidulafungin	88	≤0.25	0.5	–*	≥1.0	0.0 (0)	0.25	0.0 (0)
Micafungin	88	≤0.25	0.5	–*	≥1.0	0.0 (0)	–†	–†

ECOFF = epidemiological cut-off value; MEC = minimum effective concentration; MIC = minimum inhibitory concentration
* No clinical breakpoints
† No ECOFFs
§ *P. kudriavzevii* is a poor target for fluconazole; hence it is not possible to establish clinical breakpoints or ECOFFs for this drug-fungus combination
Sources: National Mycology Reference Centre, SA Pathology; Clinical Mycology Reference Laboratory, Institute of Clinical Pathology and Medical Research, NSW Health Pathology

Table 6.2: Antifungal resistance and non-wild type isolates for *Aspergillus fumigatus* complex, Australia, 2020–2022 combined

		MIC (or MEC) (mg/L)						
		Interpretive categories					ECOFF	
Fungus and antifungal agent	Isolates, *n*	Susceptible	Intermediate	Susceptible-dose dependent	Resistant	Resistant, % (*n*)	ECOFF (mg/L)	Non-wild-type, % (*n*)
Aspergillus fumigatus complex								
Amphotericin B	490	–*	–*	–*	–*	–*	2.0	15.1 (74)
Itraconazole	490	–*	–*	–*	–*	–*	1.0	0.8 (4)
Voriconazole	490	≤0.5	1.0	–*	≥2.0	4.3 (21)	1.0	11.6 (57)
Posaconazole	490	–*	–*	–*	–*	–*	–†	–†
Isavuconazole	358	–*	–*	–*	–*	–*	1.0	4.5 (16)
Anidulafungin	490	–*	–*	–*	–*	–§	–§	–†
Micafungin	490	–*	–*	–*	–*	–§	–§	–†

ECOFF = epidemiological cut-off value; MEC = minimum effective concentration; MIC = minimum inhibitory concentration
* No clinical breakpoints
† No ECOFFs
§ For *A. fumigatus* complex, a single strain had an anidulafungin MEC of 4 mg/L and 0.5 mg/L for micafungin; the MEC_{90} was 0.016 mg/L for anidulafungin and 0.008 mg/L for micafungin
Sources: National Mycology Reference Centre, SA Pathology; Clinical Mycology Reference Laboratory, Institute of Clinical Pathology and Medical Research, NSW Health Pathology

Table 6.3: Susceptibility results for 5-flucytosine and isavuconazole for *Candida* species lacking clinical breakpoints or epidemiological cut-off values, Australia, 2020–2022 combined

Antifungal agents and fungus tested	Isolates, *n*	MIC_{50} (mg/L)	MIC_{90} (mg/L)	Range (mg/L)
5-flucytosine				
Candida albicans	629	0.06	0.12	≤0.06–≥64
Nakaseomyces (*Candida*) *glabratus*	626	0.06	0.06	≤0.06–≥64
Candida parapsilosis	238	0.25	0.25	≤0.06–2
Candida tropicalis	100	0.06	0.12	≤0.06–≥64
Pichia kudriavzevii (*Candida krusei*)	88	8.0	16.0	0.03–≥64
Isavuconazole				
Candida albicans	386	0.008	0.03*	≤0.008–≥8
Nakaseomyces (*Candida*) *glabratus*	396	0.12	0.5	≤0.008–≥8
Candida parapsilosis	151	0.016	0.25	≤0.008–4.0
Candida tropicalis	72	0.12	0.5	0.03–≥8
Pichia kudriavzevii (*Candida krusei*)	59	0.25	0.5	0.03–2.0
Aspergillus fumigatus complex	358	0.5	1.0	0.008–≥8

MIC = minimum inhibitory concentration
* The MIC_{90} was >2 dilutions above the MIC_{50} and acquired mechanisms of resistance are likely to be present in ≥10% of isolates
Sources: National Mycology Reference Centre, SA Pathology; Clinical Mycology Reference Laboratory, Institute of Clinical Pathology and Medical Research, NSW Health Pathology

Table 6.3 shows the MIC_{50} and MIC_{90} values, and range of MICs, for 5-flucytosine and isavuconazole according to species. Overall, 5-flucytosine demonstrated good activity against the *Candida* group tested, with the exception of *P. kudriavzevii* where the MIC_{50} and MIC_{90} values were ≥8mg/L. For *N. glabratus*, although there are a small number of isolates with high MICs, MICs for this species were generally low to very low.

Candida auris

C. auris is a species of particular worldwide concern due to its high frequency of multi-drug resistance in some regions, coupled with its propensity to cause serious invasive infections in compromised hosts and to result in case clusters. For these reasons, it is included in the National Alert System for Critical Antimicrobial Resistances (CARAlert). Currently, it remains a rare cause of infection in Australia and so only five *C. auris* isolates were available to be tested. MIC ranges were 1–4 mg/L for amphotericin B, 0.06–1 mg/L for itraconazole, 0.03–≥8mg/L for voriconazole, 0.03–0.5 mg/L for posaconazole and 0.03–2 mg/L for isavuconazole. MIC ranges for anidulafungin and micafungin were 0.12–0.5 mg/L (CLSI ECOFF 1.0 mg/L) and 0.12–0.25 mg/L (CLSI ECOFF 0.5 mg/L), respectively. MICs for fluconazole were ≥256 mg/L.

Although there are no CPBs established by either CLSI or EUCAST, the US Centers for Disease Control and Prevention has provided the following 'tentative breakpoints':

amphotericin B ≥2 mg/L; both anidulafungin and micafungin ≥4 mg/L; and fluconazole ≥32 mg/L (summarised in the Australasian Society for Infectious Diseases guidelines for *C. auris* management).[11,12] Hence all five isolates may be regarded as fluconazole-'resistant'. Cross 'resistance' to other azoles has been described, and one of the five isolates tested here had a voriconazole MIC of ≥8 mg/L. However, isolates with high fluconazole MICs may have low MICs to the other triazoles.[10] Correlation between these tentative breakpoints and clinical outcomes remains unknown. For the present, given that most Australian *C. auris* isolates are associated with travel, susceptibility testing of all isolates is warranted, with a high index of suspicion for drug resistance.

Conclusions

Antifungal resistance among common *Candida* group species and *A. fumigatus* complex remains uncommon; however:

- Azole resistance in *C. tropicalis* and *N. glabratus* (~8%) may be increasing in 2020–2022 compared with 2014–2015
- Small numbers of *Candida* isolates, particularly *N. glabratus*, were anidulafungin- and micafungin-resistant; for *N. glabratus*, four (0.6%) isolates that were echinocandin-resistant or had intermediate susceptibility were also co-resistant to azoles
- The proportion of voriconazole-resistant *A. fumigatus* complex isolates was less than 5%.

The ongoing surveillance of antifungal resistance is essential, and the correlation of non-wild type MICs with clinical outcomes warrants further investigation.

Although antifungal resistance amongst common *Candida* group species and *A. fumigatus* complex remains uncommon, ongoing surveillance of antifungal resistance is essential, and the correlation of non-wild type isolates with clinical outcomes warrants further investigation.

6.2 International comparisons of antimicrobial use by setting

Analysis of international AU data by setting (hospital and community use) is of interest to identify opportunities for improvement in Australia.

Hospital use

In 2021, systemic AU (on a defined daily dose [DDD] per 1,000 people per day basis) was estimated by the Australian Commission on Safety and Quality in Health Care (the Commission) to be higher in Australian hospitals than in any European country (Figure 6.1), Scotland[14], and Canada.[15]

However, it should be noted that the Australian figures are based on the extrapolation of data collected in the National Antimicrobial Utilisation Surveillance Program (NAUSP), which is biased towards larger hospitals. It is plausible that AU is higher in larger hospitals than the national average because of greater patient complexity (see Figure 3.7, Chapter 3). It is estimated that NAUSP participation captured data from around 43% of nationally occupied bed days in 2021.

Nevertheless, Australian AU is nearly three times that of the European country with the lowest AU – the Netherlands – and is considerably higher than the AU in Canada, suggesting that use was comparatively high, despite the caveat noted above.

> Australian antimicrobial use in hospitals is nearly three times that of the European country with the lowest antimicrobial use – the Netherlands – and is considerably higher than Canada.

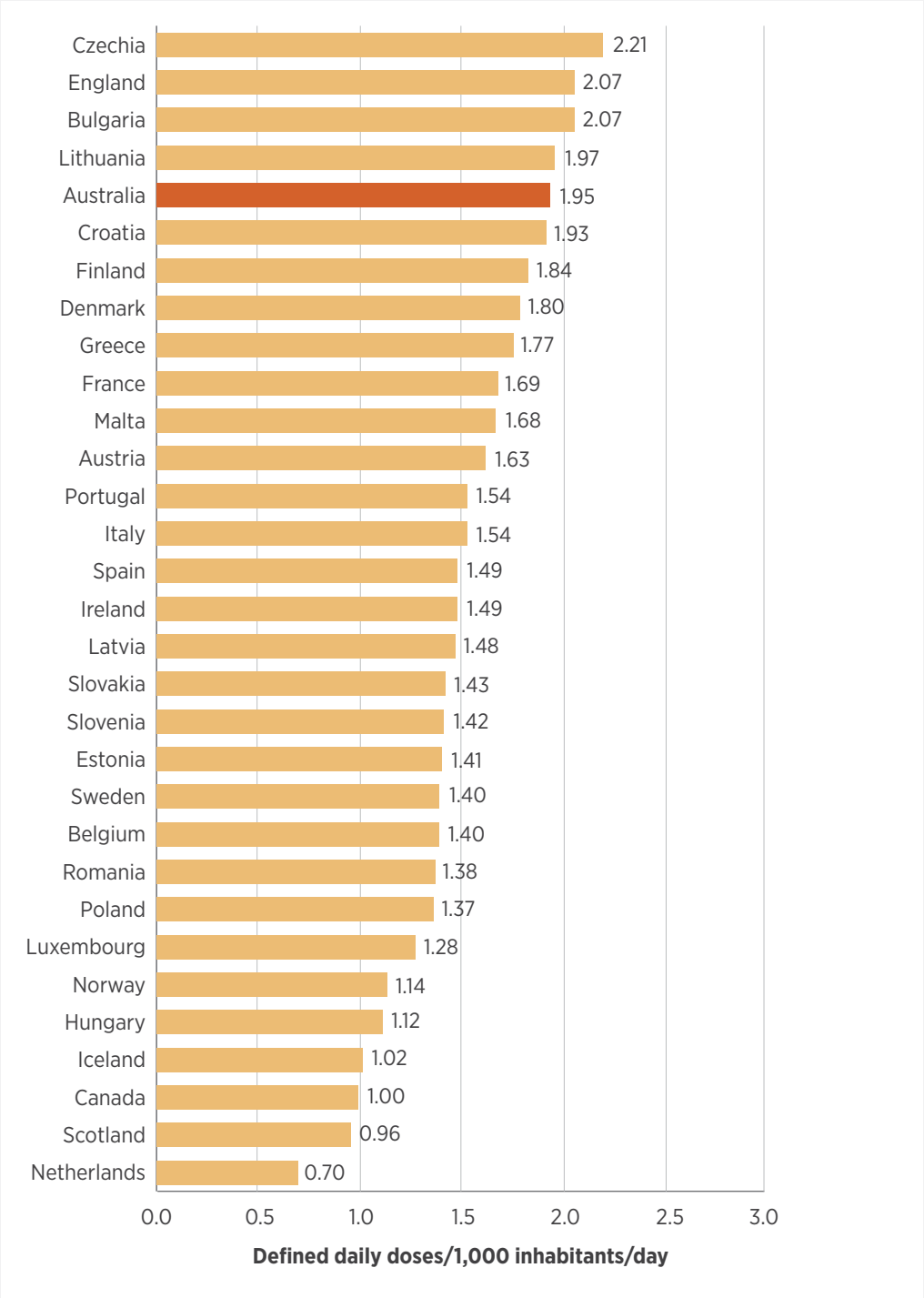
Community use

With the onset of the COVID-19 pandemic, antimicrobial community use dropped substantially by over 23% from 22.9 defined daily doses per 1,000 inhabitants per day (DID) in 2019 to 17.6 DID in 2020. Community use of antimicrobials in Australia in 2021 remained lower (17.5 DID), similar to 2020 levels, but was still high compared with most European countries, including England[13] and Scotland[14], and Canada[15] (Figure 6.2).

Of the 31 comparator countries, community AU, on a DID basis, was higher in only six European countries. There has been a downward trend of AU in Australia since 2015, but in association with the COVID-19 pandemic, there was a further major reduction that was sustained throughout 2020 and 2021. This is similar to patterns observed in Europe.[16,17]

> Australian antimicrobial use per person in the community was higher in only six of the comparative European countries.

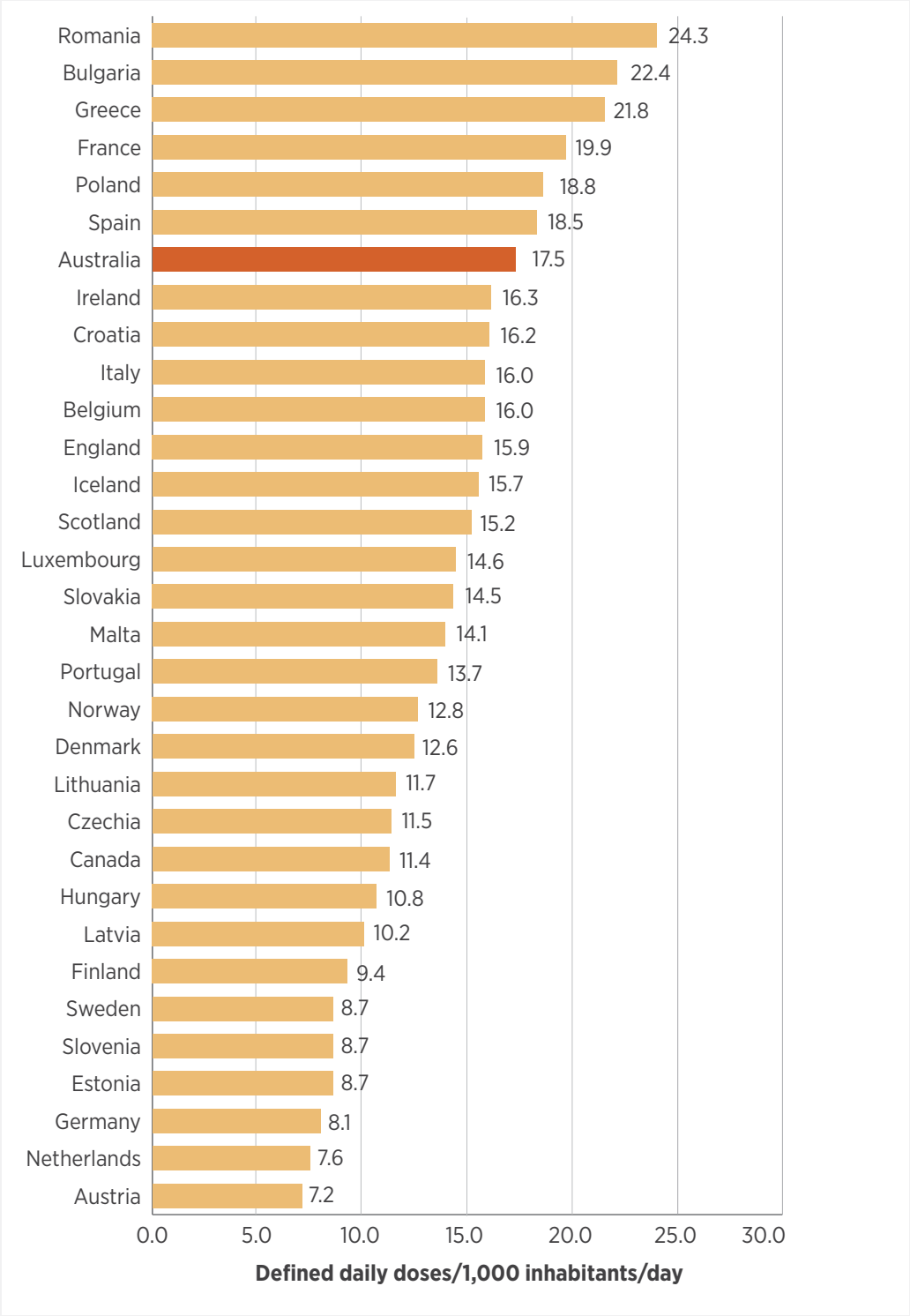
Figure 6.1: Hospital antimicrobial use in Australia*, European countries, England, Scotland and Canada, 2021



* Estimate calculated by the Commission based on the number of occupied bed days covered by NAUSP, and excludes sub-acute use and use in emergency departments and operating theatres. NAUSP data for Australia were extrapolated to a national estimate by the Commission by dividing the total number of patient days (less same day patient days) published by the Australian Institute of Health and Welfare for 2021 by the total number of occupied bed days recorded by NAUSP contributors

Sources: NAUSP (Australia); ESAC-Net (Europe)[17]; ESPAUR 2021–2022 (England), SONAAR 2021 (Scotland), CARSS 2022 (Canada)[13–15]

Figure 6.2: Community antimicrobial use in Australia, European countries, England, Scotland, and Canada, 2021



Sources: PBS and RPBS (Australia); ESAC-Net (Europe); ESPAUR 2021–2022 (England), SONAAR 2021 (Scotland), CARSS 2022 (Canada)

International scalability of the National Antimicrobial Prescribing Survey program: a case study

Background

The National Antimicrobial Prescribing Survey (NAPS) is an important program for the implementation of the objectives of Australia's National AMR Strategy.[4] The NAPS enables the assessment of the quality of AU across healthcare facilities nationally, with the goal of facilitating the appropriate and judicious use of antimicrobials. Over the years, the NAPS program has expanded internationally and has been successfully piloted in Canada, New Zealand, the United Kingdom, Fiji, Vietnam, Malaysia, Bhutan, Nepal, Pakistan, Papua New Guinea and Timor-Leste. The successful adoption of the NAPS program across multiple countries with varied healthcare systems and levels of antimicrobial stewardship (AMS) program maturity has consistently demonstrated its adaptability and transferability.

Method

When a new country adopts the NAPS, the NAPS program team works closely with the in-country coordinator to determine if any country-specific amendments are required to the data fields or supporting resources, while carefully maintaining the fundamental intent and structure of the survey content or definitions.

Before the NAPS can be piloted internationally, several information technology configurations are required, including creating a dedicated data entry portal for each country to allow for the registration of participating hospitals and auditors.[18] Technical changes are made to the NAPS database to enable a country-specific view of the survey, including minor modifications to reflect the local context and healthcare system. These may include wording changes for the appropriateness assessment (to ensure local understanding), the addition of antimicrobials available within the national or local antimicrobial formulary, additional routes of administration, frequencies and units, new classifications for auditors and facility types, and the modification and/or addition of indications for AU.

To address the issue of multiple time zones, the NAPS support team develops in-application training videos and eLearning modules to support an in-country 'train the trainer' approach.[18] To support implementation, further discussions with the in-country coordinator are held to explore any contextual difficulties or enablers specific to that country. This is then combined with in-depth training of local champions to manage and coordinate the program in their country and support the local participants.

A novel component of the NAPS program is the Universal Indications List, which has been maintained by the Royal Melbourne Hospital Guidance Group. This standardised approach to indications supports its adoption across many countries.

Results

The majority of international participants have piloted the Hospital NAPS module, with Malaysia and the United Kingdom also piloting the Surgical NAPS and Pakistan piloting the Quality Improvement NAPS. All have adopted the module content in its entirety, and in English, with only very minor changes. As most countries do not have a national guideline,

minor wording changes have been made to the Appropriateness Assessment matrix to accommodate this.

Portuguese adoption

Recently there have been discussions with Portugal to pilot the NAPS, and the program team is working through the process of translating the Hospital NAPS into Portuguese. This process will involve linguistic validation and inter-rater reliability testing to ensure that the module content has been consistently and accurately translated.

Malaysian adoption

The Malaysian NAPS Working Group has recently published findings of an analysis from their NAPS program across two tertiary hospitals, the University Malaya Medical Centre (UMMC) and the Hospital Canselor Tuanku Muhriz (HCTM).[19] The analysis was conducted on a total of 260 patients who were prescribed 372 antimicrobial prescriptions. Prescription appropriateness was 60.1% at UMMC and 67% at HCTM, and was similar to guideline compliance: 60.0% at UMMC and 61.5% at HCTM. Amoxicillin–clavulanic acid was the most commonly prescribed antimicrobial (UMMC, 16.9%; HCTM, 11.9%).

Canadian adoption

The Hospital NAPS was introduced to Canada by the Sinai Health-University Health Network Antimicrobial Stewardship Program (SH-UHN ASP) in 2018 after the recognition that the NAPS would not only meet their needs but remove barriers that had prevented the implementation of a national auditing program.[18] There was widespread interest in the pilot from 38 participating hospitals representing the provinces of British Columbia, Alberta, Ontario, Quebec, New Brunswick, Prince Edward Island and Nova Scotia, which collectively constitute over 90% of Canada's population.[20] The overall appropriateness of AU was 73.7%, ranging from 53.1% to 80.8%.[20]

Summary

The NAPS has already demonstrated successful international pilots. Further work is needed to ensure the feasibility, implementation and acceptability of the NAPS programs' novel measure of antimicrobial appropriateness as a key metric to support AMS programs globally.

6.3 International comparisons of antimicrobial resistance rates

Australia's AMR rates can be compared with those of European countries because Europe is the main 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[21,22], and the WHO Central Asian and European Surveillance of Antimicrobial Resistance (CAESAR) network[23], as all these surveillance systems review resistance in bacterial pathogens isolated from blood cultures.

Rates of resistance to fluoroquinolones in *E. coli* and *K. pneumoniae* (represented by resistance to ciprofloxacin) remain low in Australia compared with most European countries (Figures 6.3 and 6.4). From 2015 to 2019, fluoroquinolone resistance in Australia increased substantially to 16.0% for *E. coli* and 10.2% for *K. pneumoniae*. In 2021, these rates declined for the first time to 12.3% and 7.2%, respectively.

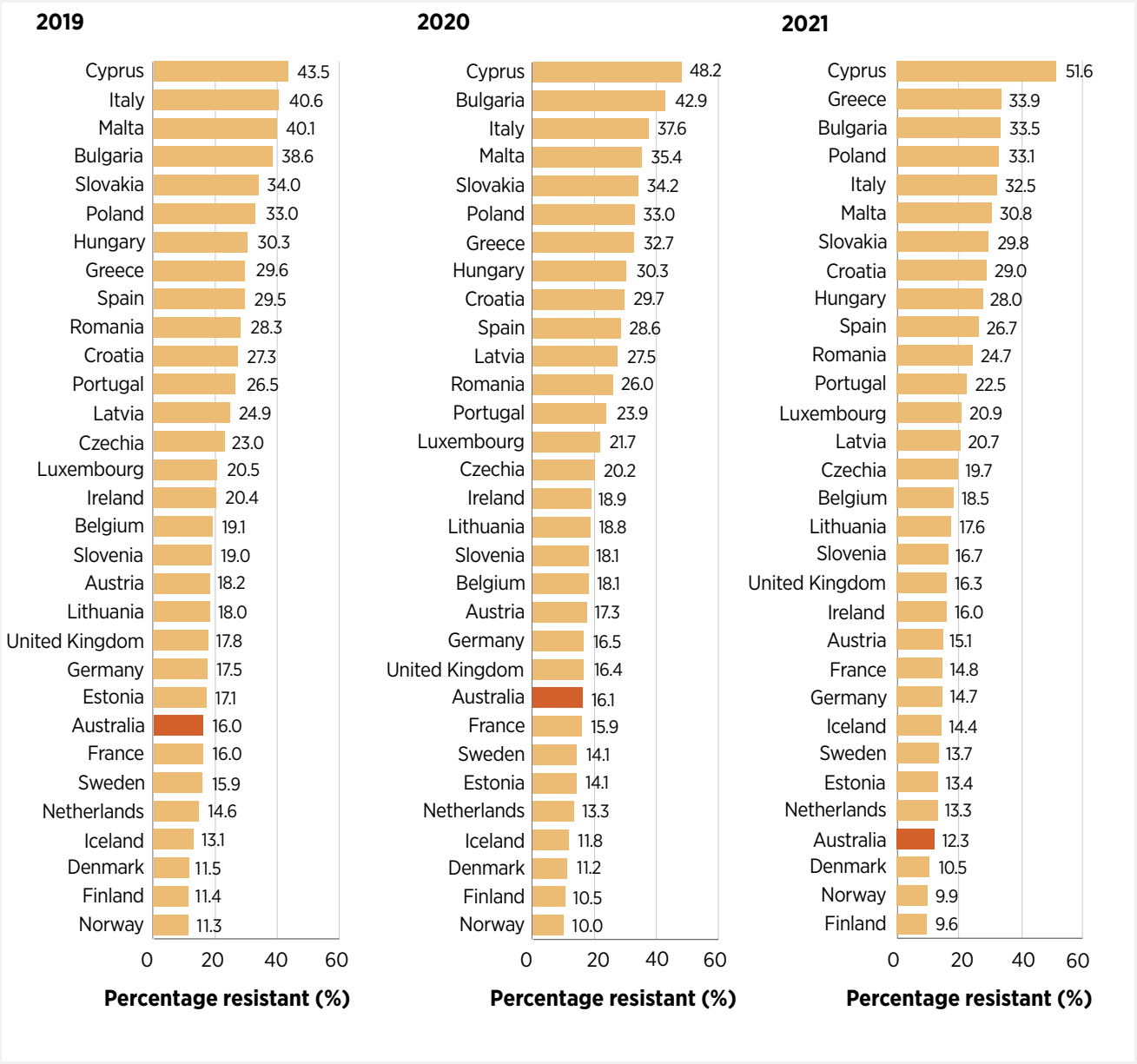
In Australia, there was an increasing trend in third-generation cephalosporin resistance from 2015 to 2019[24] in these two species, which stabilised in 2020 and 2021. Almost three-quarters of European countries had either decreasing trends or no change. Australia now ranks around the middle of European rates of resistance to third-generation cephalosporins in *E. coli* (Figure 6.5). It slowly rose in rank over the previous decade to 2019. Third-generation cephalosporin resistance in *K. pneumoniae* remains low by comparison with European countries (Figure 6.6).

Resistance to piperacillin–tazobactam in *Pseudomonas aeruginosa* was moderate, but lower than the European Union and European Economic Area average (Figure 6.7). There was little change in the resistance rate from 2017 to 2021.

Australia's methicillin resistance rate remained steady from 2017 to 2021, while just over one-third of European countries showed decreasing trends. Australia ranked eleventh in the rate of resistance to methicillin in *S. aureus* in 2020 and 2021 (Figure 6.8).

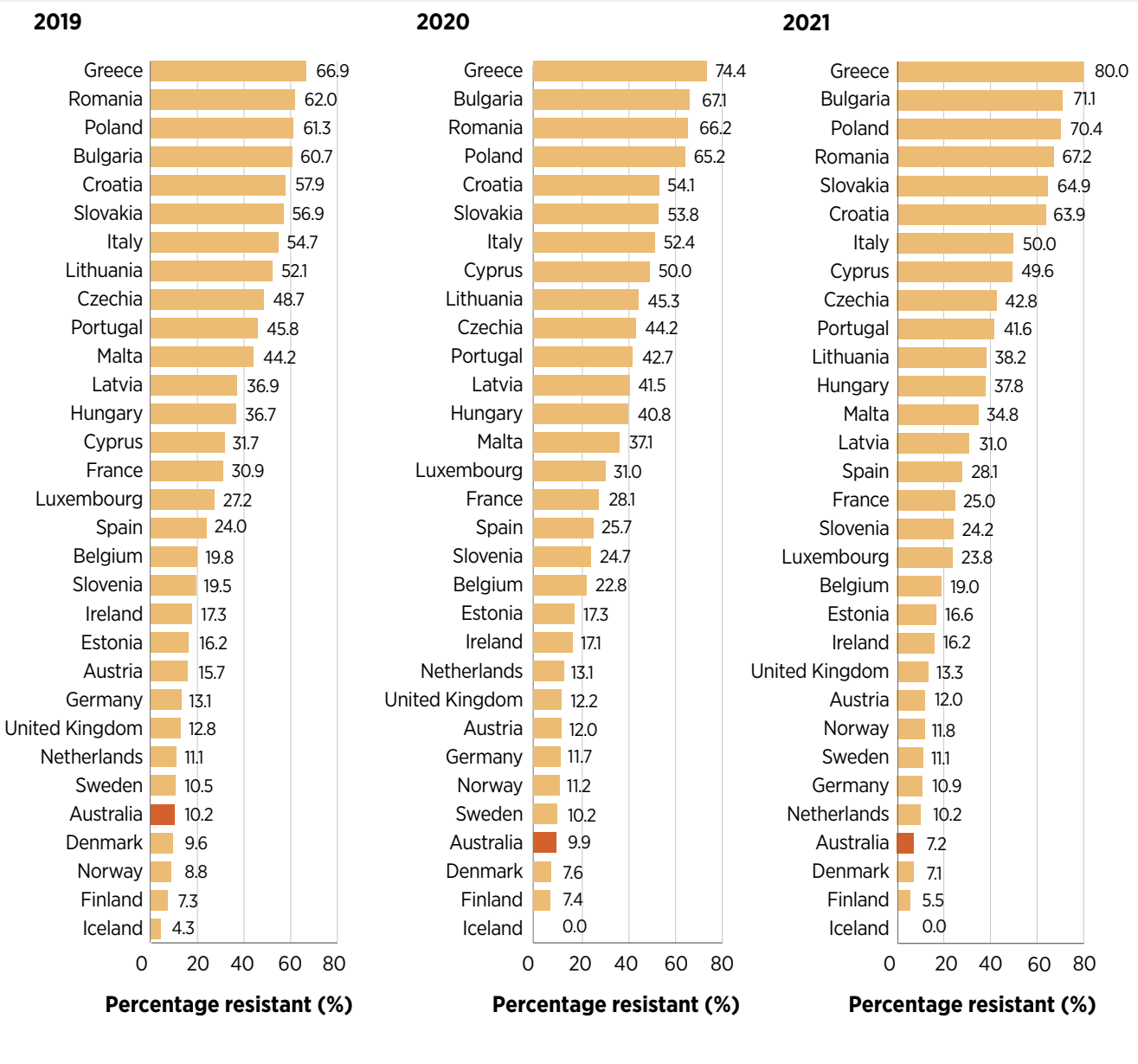
In 2017, Australia ranked first in its rates of resistance to vancomycin in *E. faecium* compared to all European countries. Resistance rates in Australia declined from 2015 to 2021, and its rank dropped to the fourth highest in 2019 and the eighth highest in 2021. In contrast, just under one-half of European countries had increasing trends. Australia currently ranks in the top third in the rate of resistance to vancomycin in *E. faecium* compared with European countries (Figure 6.9).

Figure 6.3: *Escherichia coli* rates of resistance to fluoroquinolones* in Australia, European countries and the United Kingdom, 2019–2021



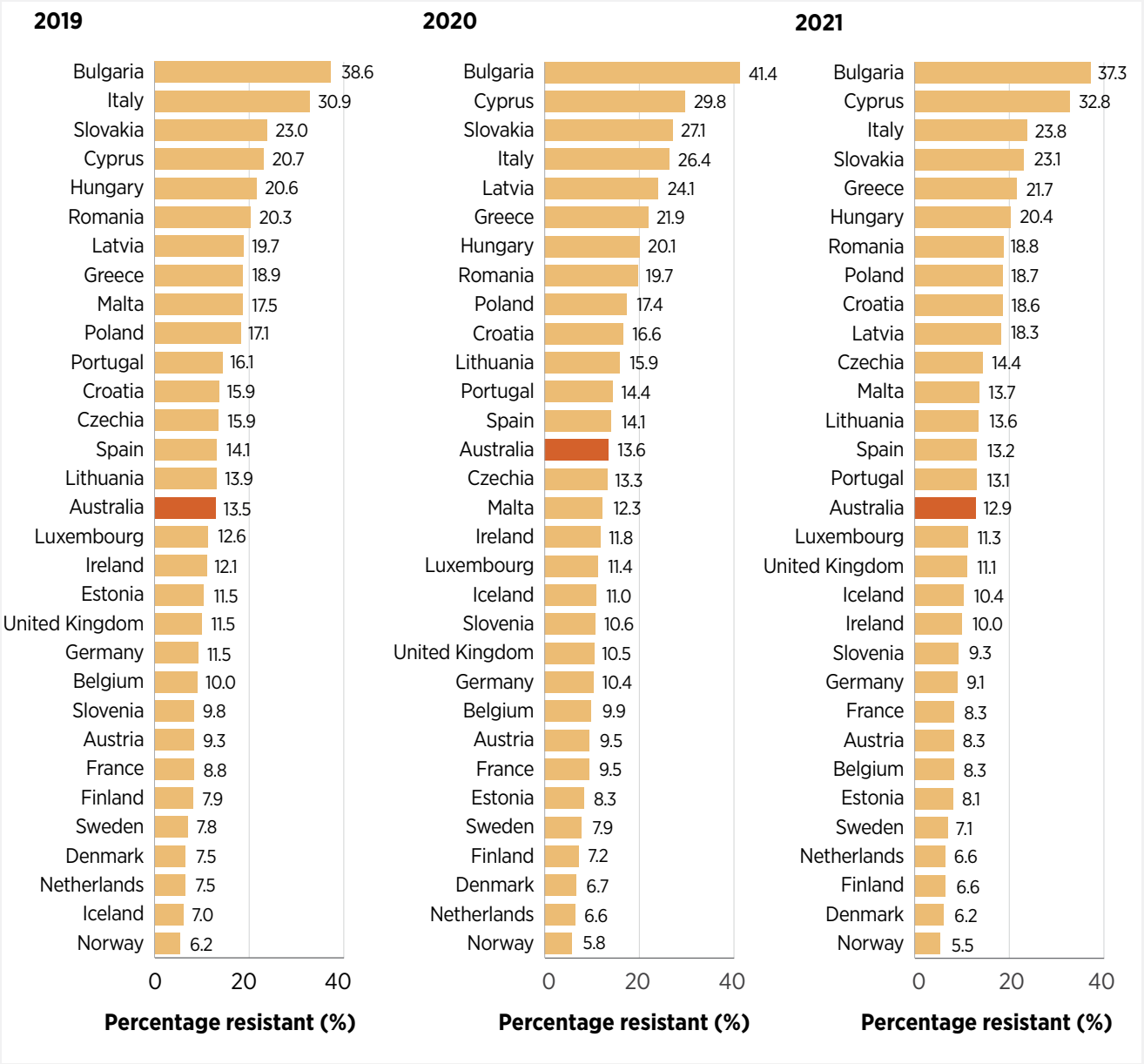
* Represented by resistance to ciprofloxacin
Note: European Union and European Economic Area countries' population-weighted mean percentages.
Sources: AGAR (Australia); CAESAR (United Kingdom); EARS-Net (Europe)

Figure 6.4: *Klebsiella pneumoniae* rates of resistance to fluoroquinolones* in Australia, European countries and the United Kingdom, 2019–2021



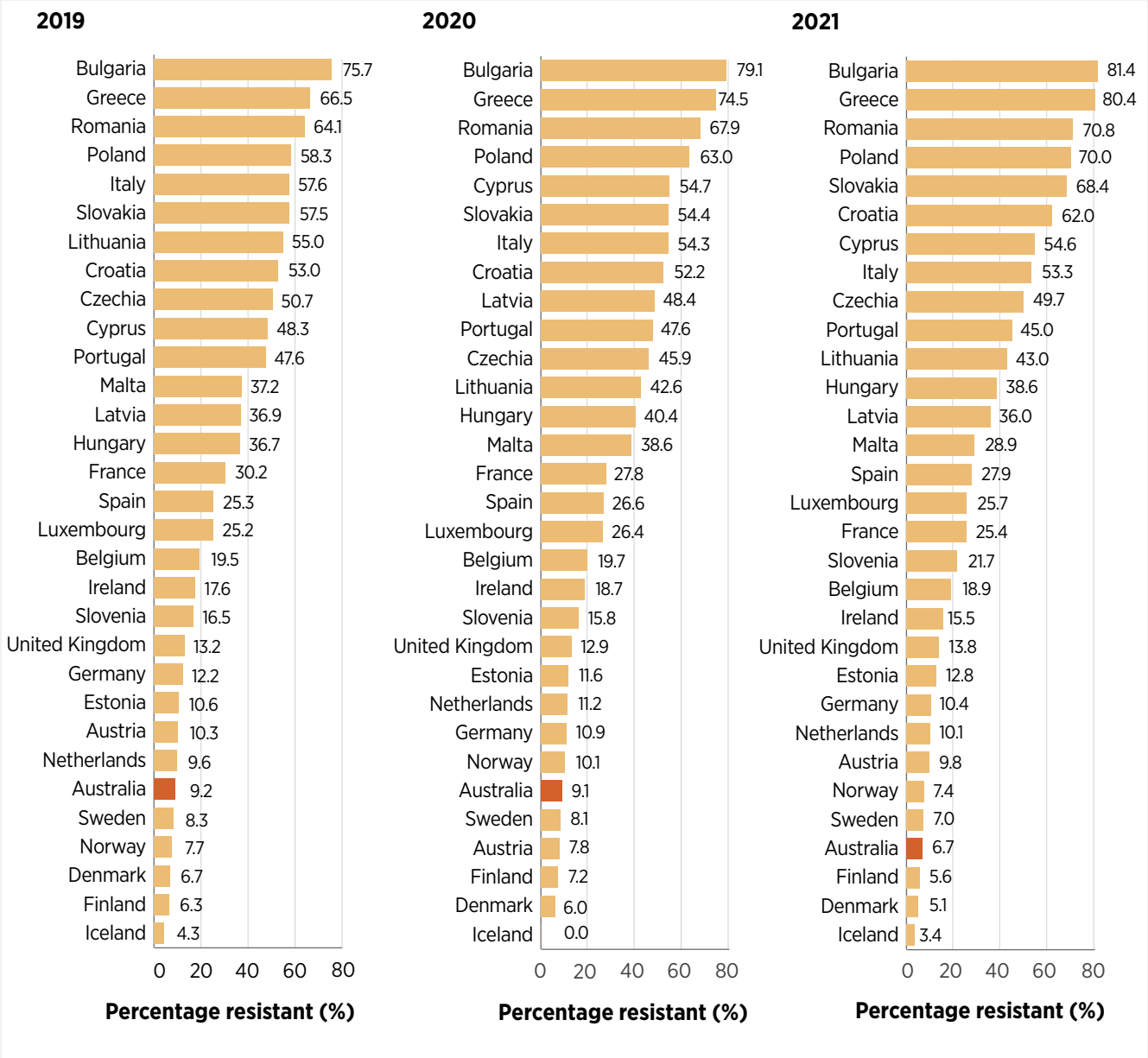
* Represented by resistance to ciprofloxacin
Note: European Union and European Economic Area countries' population-weighted mean percentages.
Sources: AGAR (Australia); CAESAR (United Kingdom); EARS-Net (Europe)

Figure 6.5: *Escherichia coli* rates of resistance to third-generation cephalosporins in Australia, European countries and the United Kingdom, 2019–2021



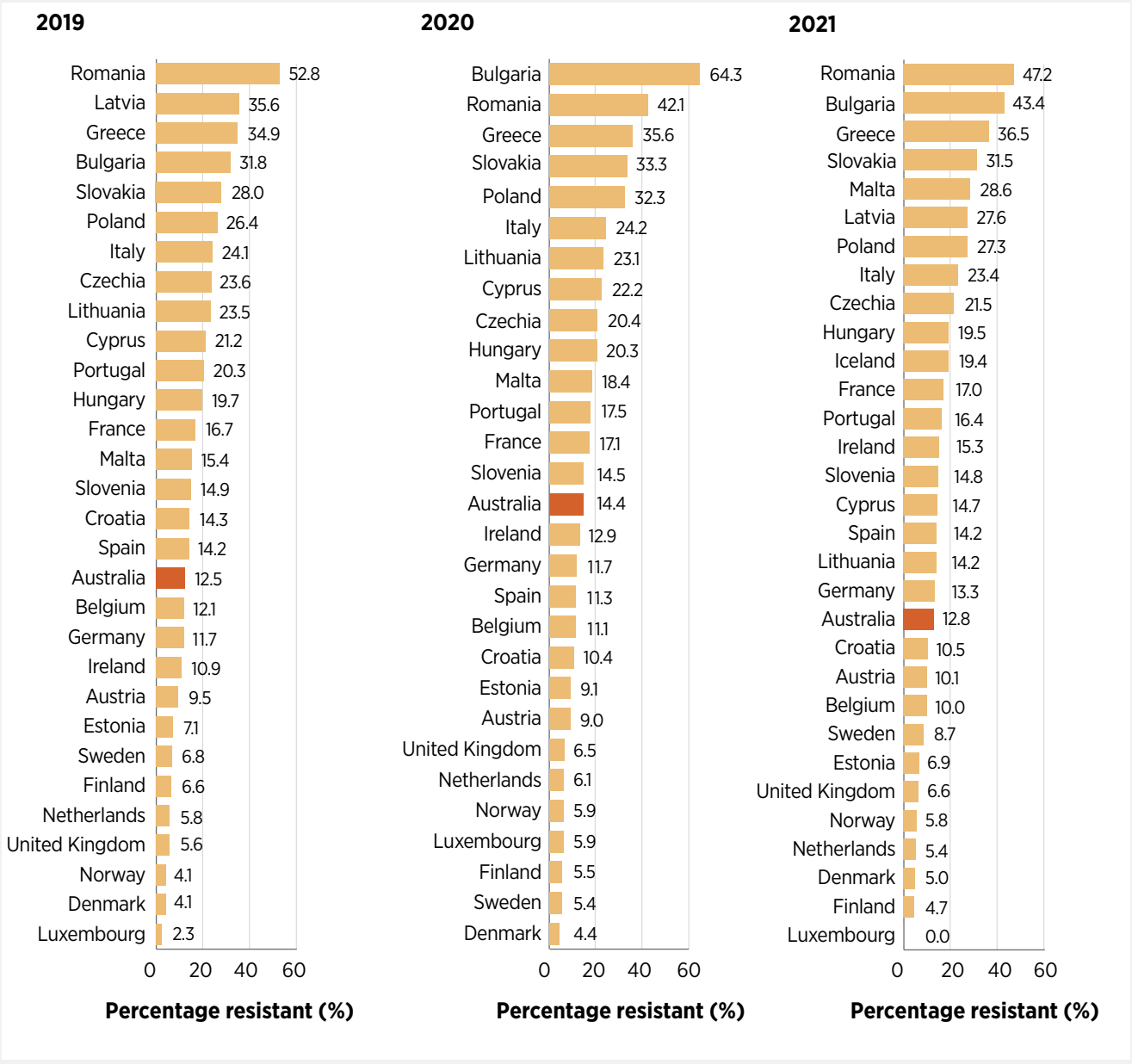
Note: European Union and European Economic Area countries' population-weighted mean percentages.
Sources: AGAR (Australia); CAESAR (United Kingdom); EARS-Net (Europe)

Figure 6.6: *Klebsiella pneumoniae* rates of resistance to third-generation cephalosporins in Australia, European countries and the United Kingdom, 2019–2021



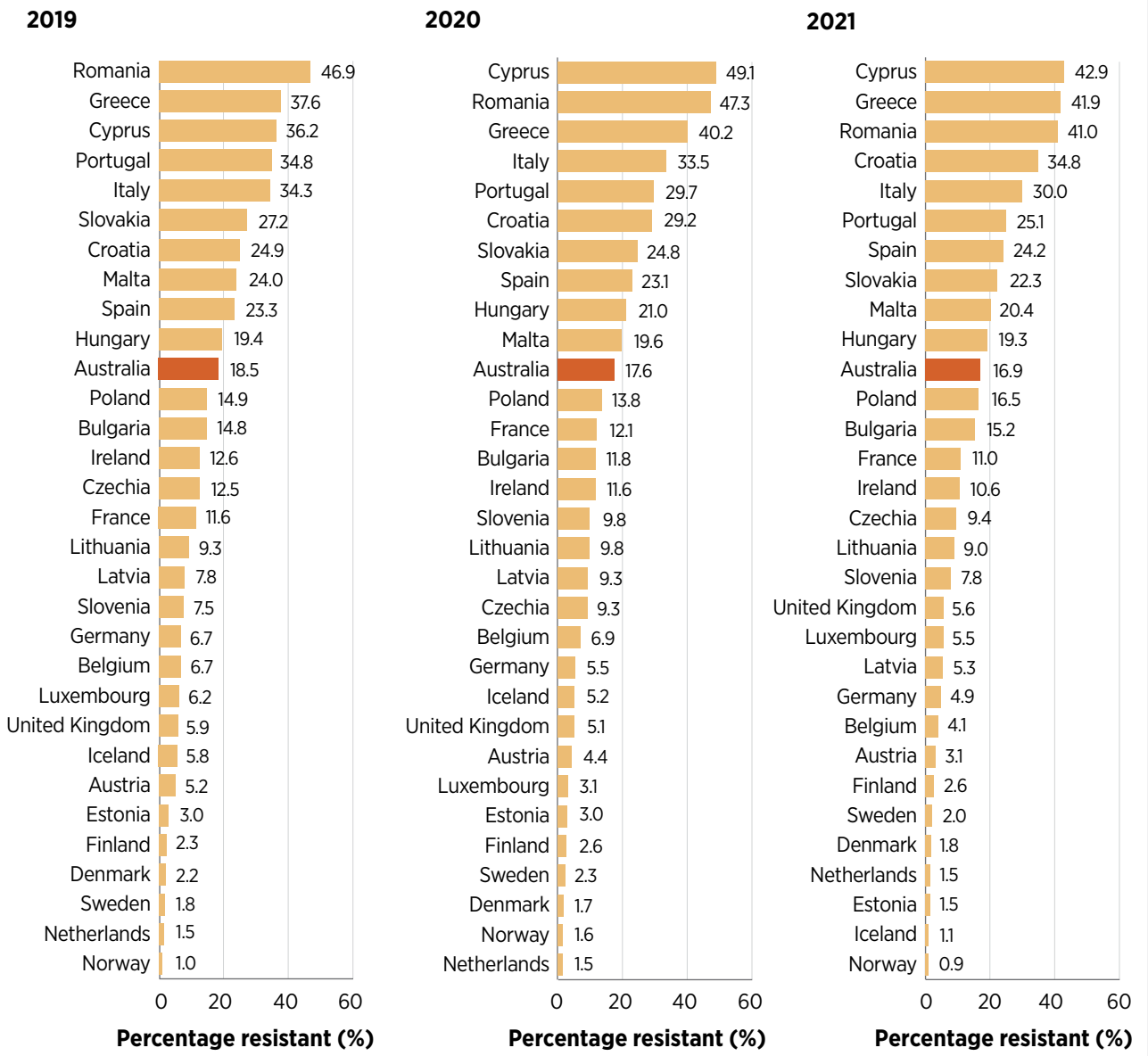
Note: European Union and European Economic Area countries' population-weighted mean percentages.
Sources: AGAR (Australia); CAESAR (United Kingdom); EARS-Net (Europe)

Figure 6.7: *Pseudomonas aeruginosa* rates of resistance to piperacillin–tazobactam in Australia, European countries and the United Kingdom, 2019–2021



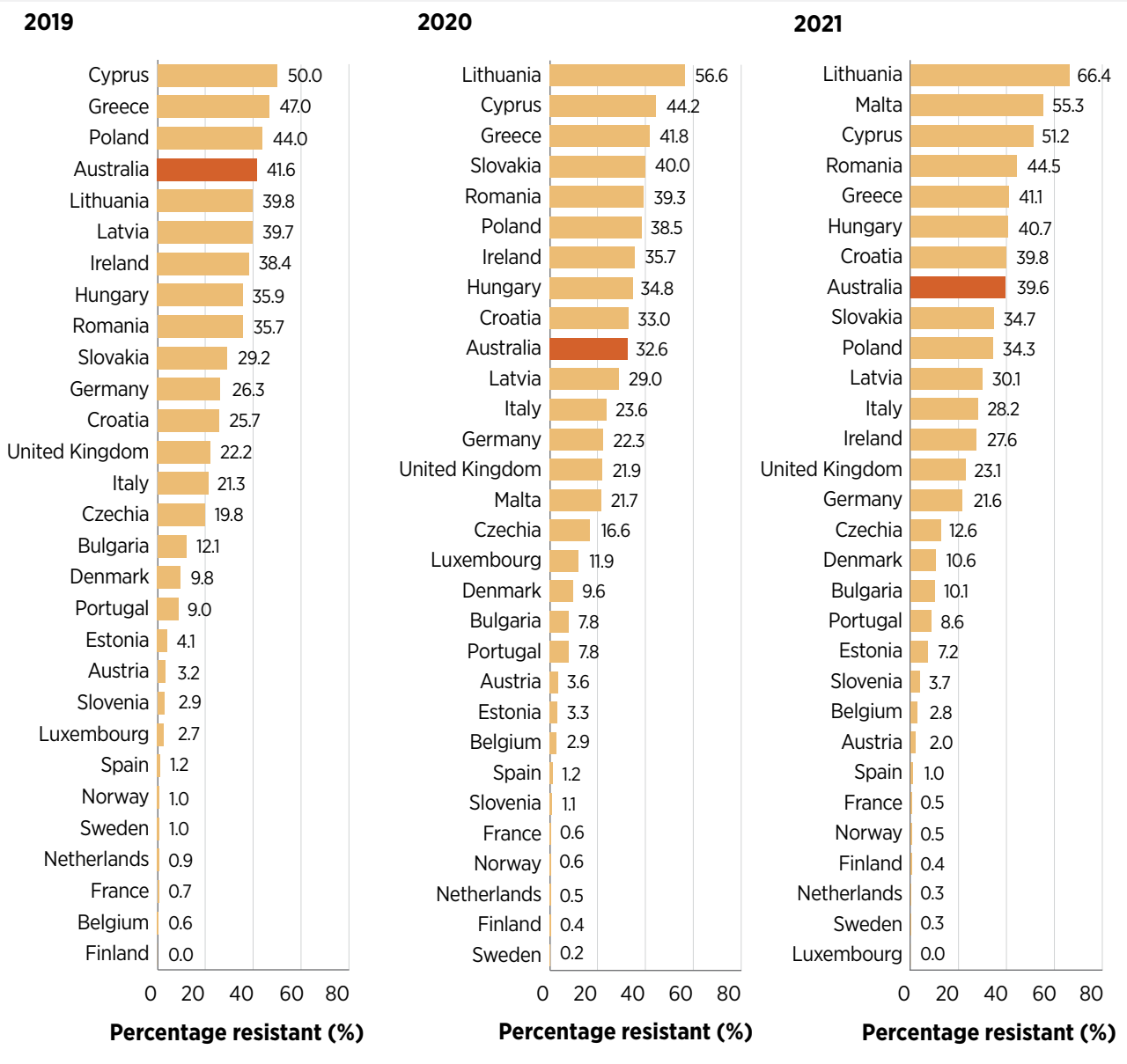
Note: European Union and European Economic Area countries' population-weighted mean percentages.
Sources: AGAR (Australia); CAESAR (United Kingdom); EARS-Net (Europe)

Figure 6.8: *Staphylococcus aureus* rates of resistance to methicillin in Australia, European countries and the United Kingdom, 2019–2021



Note: European Union and European Economic Area countries' population-weighted mean percentages.
Sources: AGAR (Australia); CAESAR (United Kingdom); EARS-Net (Europe)

Figure 6.9: *Enterococcus faecium* rates of resistance to vancomycin in Australia, European countries and the United Kingdom, 2019–2021



Note: European Union and European Economic Area countries' population-weighted mean percentages.
Sources: AGAR (Australia); CAESAR (United Kingdom); EARS-Net (Europe)

Enterobacterales: fluoroquinolones and third-generation cephalosporins

Although Australia's rates of fluoroquinolone resistance in *E. coli* and *K. pneumoniae* remain low compared with most European countries, Figures 6.3 and 6.4 show that resistance reduced from 2019 to 2021. Resistance rates to third-generation cephalosporins in these two species remain lower than European averages (Figures 6.5 and 6.6).

Australia's restricted access to fluoroquinolones in both the community and hospitals is thought to have kept rates of resistance to these antimicrobials low, ensuring their ongoing treatment efficacy for 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[25], but rose to eighth lowest in 2019.[24] Since then, rates have reduced and in 2021, only three countries had lower rates than Australia. It is possible that COVID-19 restrictions have indirectly affected fluoroquinolone resistance rates, due to the drop in community use of antimicrobials in 2020 and 2021 and less international travel.

> For fluoroquinolone-resistant *E. coli*, Australia ranked fourth lowest compared with European countries in 2021, and has declined since 2019, perhaps as a consequence of reduced community use of antimicrobials in 2020 and 2021 and less international travel.

Rates of resistance to third-generation cephalosporins remained fairly low in Australia for some time. However, rates have been increasing slowly, reaching 13.6% in *E. coli* in 2018[24], and stabilising since then. This rate is close to the median rate of European countries.

In contrast, rates in *K. pneumoniae* have been consistently lower than most European countries and have been gradually declining since 2018 to 6.7% in 2021. This antimicrobial class is restricted in the community but is still widely used in hospitals – often unnecessarily, as the NAPS has shown (see Chapter 3).

> Rates of resistance in *E. coli* to third-generation cephalosporins have remained fairly low in Australia for some time, but have been slowly increasing.

Pseudomonas aeruginosa: piperacillin–tazobactam

As with other gram-negative pathogens, Australian resistance rates to piperacillin–tazobactam in *P. aeruginosa* are lower than the European averages (Figure 6.7). Because *P. aeruginosa* is a species with a largely environmental (rather than human) reservoir, differences between countries reflect environmental factors and infection prevention and control standards and practices.

Staphylococcus aureus: methicillin

Australia ranks in the top half of countries for methicillin-resistant *S. aureus* (MRSA) rates (Figure 6.8). Overall, MRSA resistance rates have changed very little in Australia in 2020 and 2021. However, there has been a:

- Continuing decline in the prevalence of the multidrug-resistant 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.[26,27]

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 the transfer of HA-MRSA clones into the community.[28] In Australia, CA-MRSA and HA-MRSA have a similar prevalence.

Enterococcus faecium: vancomycin

Australia had higher rates of resistance to vancomycin in *E. faecium* than 22 European countries in 2021 (Figure 6.9), even though rates in Australia have been slowly declining in recent years, as described in Chapter 4.

In contrast to the resistance rates for *E. coli* and *K. pneumoniae*, rates for *S. aureus* and *E. faecium* are less favourable. Australia ranks in the top half of countries for MRSA rates, and had higher rates of resistance to vancomycin in *E. faecium* than more than 20 European countries in 2021, despite rates slowly declining in recent years.

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Chapter 7

Conclusions and priorities for action

Conclusions and priorities for action

This chapter provides an overview of the key issues identified from analyses of data for the *Fifth Australian report on antimicrobial use and resistance in human health* (AURA 2023), and the priorities for the prevention and control of antimicrobial resistance (AMR) and for the improvement of appropriateness of antimicrobial use (AU).

7.1 Antimicrobial use and appropriateness

Acute care

National Antimicrobial Utilisation Surveillance Program (NAUSP) data show that the volume of AU in Australian hospitals is substantially higher than in comparable European countries and Canada.

NAUSP data analyses undertaken using the Priority Antibacterial List[1] demonstrate the practical benefits of stratifying antibacterials based on the evidence for their use as first-line therapy and their potential to contribute to the development of AMR. Further, these and other analyses of NAUSP data enable Australian hospitals to benchmark and monitor their AU against other similar hospitals and over time.

The 2021 Hospital National Antimicrobial Prescribing Survey (Hospital NAPS) data show that notable improvements in the appropriateness of antimicrobial prescribing within hospitals have been achieved. This progress is evident through a positive trend in the documentation of indications for prescribing. While overall levels of appropriateness of prescribing have remained stable since 2015, the appropriateness of prescribing for public hospitals has improved. These improvements could be explained by the development and implementation of the antimicrobial stewardship (AMS) programs in these settings. Nevertheless, as there has been no change since 2015, further improvement is needed.

Action area: Reducing variations in the volume of antimicrobial use in public hospitals between states and territories and in private hospitals

Analyses of NAUSP data identified ongoing variations between states and territories in the volume of use of different categories of antibacterials. NAUSP data also revealed a concerning proportion of use of antibacterials with a high selection potential for AMR, particularly in private hospitals.

- This highlights the opportunity for states and territories, and the private sector, to develop local AMS strategies and targets for the use of antimicrobials that are recommended as first-line treatment for common infections, which have a lower selection potential for AMR.

Action area: Improving appropriateness of private hospital antimicrobial prescribing

Compared to public hospitals, appropriateness of prescribing remains lower in private hospitals. However, there was an observed improvement in the 2021 NAPS data compared with 2020 in the large private hospital peer groups. In addition, it is

concerning that there was a large proportion of usage in private hospitals of antibacterials that have high selection potential for AMR.

- Identifying opportunities to support improvement in the appropriateness of prescribing in private hospitals is important.

Action area: Improving the appropriateness of prescribing for chronic obstructive pulmonary disease

Chronic obstructive pulmonary disease (COPD), surgical prophylaxis and acute cholecystitis continue to be the indications with the highest rates of inappropriate prescribing in Australian hospitals.

There is significant variation in health care for COPD in Australia. The *Fourth Australian Atlas of Healthcare Variation*[2] identified an almost 18-fold variation in the hospitalisation rates for COPD between local areas. The rate for Aboriginal and Torres Strait Islander peoples was 4.8 times higher than the rate for other Australians.

- The Australian Commission on Safety and Quality in Health Care (the Commission) is developing a COPD Clinical Care Standard, which is expected to be published in 2024. The aim of this Standard is to reduce hospitalisation rates and improve overall outcomes for people with COPD by supporting best practices in the diagnosis, assessment and management of COPD. The Standard will address aspects of care relating to the judicious use of antibacterials for COPD exacerbations, in line with current best-practice guidelines.
- The Commission will collaborate with the Lung Foundation Australia and the Thoracic Society of Australia and New Zealand to promote appropriate prescribing and adherence to national guidelines, including *Therapeutic Guidelines: Antibiotic*[3] and *The COPD-X Plan: Australian and New Zealand guidelines for the management of chronic obstructive pulmonary disease.*[4]

Action area: Quality improvement actions for surgical procedures with high volume and high inappropriatenes

The 2021 Surgical NAPS identified continued inappropriate use of surgical prophylaxis in contributor hospitals, consistent with previous surveys.

- Results highlight the need for health service organisations that are undertaking quality improvement actions to prioritise areas of high-volume surgical procedures with high rates of inappropriate antimicrobial prescribing. The key areas for improvement are the timing for procedural prescribing and duration of post-procedural prescribing. This latter issue mainly involves use for more than 24 hours.

For many procedures, there is no evidence that prophylactic AU is beneficial in reducing post-operative infections, either procedurally or post-procedurally; accordingly, it is not recommended by the relevant guidelines.[3] There are very few procedures or clinical situations for which the available evidence supports surgical antimicrobial prophylaxis beyond a single pre-operative dose.[3] In these situations, the total duration of antimicrobial prophylaxis should not exceed 24 hours.[3]

Unnecessary surgical antimicrobial prophylaxis has been shown to harm patients with adverse effects such as renal failure and drug-related toxicities, and likely contributes to the development of AMR.[5] Reducing inappropriate surgical antimicrobial prophylaxis balances the unintended harms of AU with the benefits of evidence-based care.

The clinical care standard for emergency laparotomy, which the Commission is developing, will include a quality statement on the appropriate use of antimicrobials for this procedure.

Community: primary care

Action area: Sustaining improvements in volume and appropriateness of primary care prescribing

The declining volume of antimicrobial prescribing in primary care since 2015 is encouraging, particularly because there was a large drop in Pharmaceutical Benefits Scheme (PBS) and Repatriation Pharmaceutical Benefits Scheme (RPBS) prescriptions during the COVID-19 pandemic. Despite an increase in the number of prescriptions supplied in 2022 compared to 2021, rates still remained well below those observed prior to the pandemic.

These results likely reflect changes in the practices of primary care prescribers over time in response to AMS messaging and evidence-based prescribing guidance.[6] Results are also likely the outcome of strong, system-wide public health messaging and actions to encourage effective infection prevention and control, reduce infection rates and support appropriate antimicrobial prescribing, in conjunction with restricting the number of repeats supplied.[7] As a result of COVID-19, public health actions included messaging related to working and learning from home, wearing a mask, staying home when experiencing symptoms of respiratory illness, and encouraging hand hygiene and physical distancing.

Increases in AU observed towards the end of 2021 and in 2022 suggest that there is further opportunity to support primary care providers and build on the encouraging decrease in the volume of antimicrobial prescribing in the community. This may include reinforcing messaging for consumers that antibacterials are not required for the treatment of viral respiratory infections, providing information about the role of antimicrobials in AMR, explaining the impact of antimicrobials on beneficial as well as harmful bacteria, and raising awareness of the impact of AU on the development of chronic disease in children and adults.[8–11]

- The Commission will continue to work with primary care clinicians and professional bodies to develop targeted strategies to sustain improvements in the appropriateness of prescribing, especially for upper respiratory tract infections.
- The Commission will continue to inform consumers of the role of antimicrobials in AMR, and will also develop messages about the effects of AU on beneficial and harmful bacteria and the potential for AU to increase the risk of development of chronic conditions in children and adults.[8–11]

The lack of reporting or monitoring mechanisms available for private or non-PBS and non-RPBS prescriptions, with the exception of data from the MedicineInsight program, is an important gap in the surveillance of AU in Australia. The expansion of prescribing rights to a range of practitioners for whom prescriptions will not be subsidised under the PBS or the RPBS will add to the volume of private prescriptions and difficulties in measuring the volume of AU.

- In collaboration with the Australian Government Department of Health and Aged Care (the Department), the Commission will explore opportunities to further analyse and enhance the availability of data on antimicrobials prescribed and dispensed privately, to provide a more complete picture of AU in Australia.

The National Safety and Quality Primary and Community Healthcare Standards (the Primary and Community Healthcare Standards)[12] were published in late 2021. These standards include dedicated actions for preventing and controlling infections and AMS. The Commission has developed a range of resources to support the implementation

of AMS strategies in primary and community healthcare settings and the delivery of safe care through appropriate antimicrobial prescribing and use.[13] Similar resources on infection prevention and control are in development.

Community-onset *Clostridioides difficile* infection (CDI) is a larger health concern in Australia than was previously recognised. Despite the decline in community AU, the rate of community-onset CDI increased from 2020 to 2021. This aligned with an increase in total CDI diagnoses from 2020 to 2021 – greater than the number observed in 2019 – following a decline from 2019 to 2020. This increase, in the context of reduced community AU, suggests that there are mechanisms other than antimicrobial treatment responsible for the acquisition of CDI, such as food or the environment.[14] HealthPathways are important tools for providing clinical management information for primary and community care providers during patient consultations.[15]

- Promoting the inclusion of HealthPathways, which provide information on the diagnosis and management of CDI, will support general practitioners (GPs) and other primary healthcare clinicians to contribute to reducing the burden of community-onset CDI.

Community: residential aged care

The 2021 Aged Care NAPS revealed continued AU that is not consistent with guidelines. Minimal improvement was observed for the facilities that consistently participated in Aged Care NAPS over time, indicating that there are opportunities to support the use of surveillance data for quality improvement.

These findings support the results of previous surveys that highlighted elevated levels of PRN ('as needed') prescriptions, particularly for topical antimicrobials. Additionally, the data highlight the prescribing of antimicrobials for prophylaxis of conditions that can be effectively prevented through hydration management and better infection prevention and control practices such as hand hygiene.

The use of topical antifungals in aged care provides limited benefits and increases the risk of AMR. Moreover, it potentially delays wound healing and is an unnecessary expense for the resident. Improved management of antifungal therapy should be an important focus for aged care AMS programs.

Action area: Support improved appropriateness of prescribing in residential aged care

There are continued high levels of inappropriate AU in aged care homes. Future analyses of PBS and RPBS data will include dispensing of antimicrobials for aged care home residents, which will contribute to additional information to support the development of improvement strategies for this setting.

The Commission will continue to:

- Collaborate with the Aged Care Quality and Safety Commission, aged care providers and GPs to promote antimicrobial prescribing for residents of aged care services consistent with the Aged Care Quality Standards.[16]
- Use data on AU and AMR, in conjunction with data on healthcare-associated complications and potentially preventable hospitalisations, to develop strategies to prevent and control urinary tract infections, cellulitis and other infections that may affect older people and require treatment with antimicrobials.

7.2 Antimicrobial resistance

Acute care

Action area: Continue to monitor carbapenemase-producing *Enterobacterales* and promote effective prevention and control strategies

Carbapenemase-producing *Enterobacterales* (CPE) are the critical antimicrobial resistance (CAR) most frequently reported to the National Alert System for Critical Antimicrobial Resistances (CARAlert), which means that they continue to be a concern for patient safety. Typically a healthcare-associated infection, reports of CPE increased in hospitals between 2021 and 2022. CPE continues to be dominated by those of the IMP type, found most often in the *Enterobacter cloacae* complex.

Bacteria that produce carbapenemase enzymes are almost always resistant to other important antibiotic classes, such as other β-lactams, β-lactamase inhibitor combinations, fluoroquinolones and aminoglycosides. This means that effective treatment options for infections may be very limited, and lengths of stay for hospital admissions may increase.

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 are likely to require increased infection prevention and control and surveillance resources in affected hospitals over short periods of time. In the absence of timely prevention and control actions, the impact of outbreaks on other aspects of hospital work and patient flows may be substantial.

The ongoing variation between states and territories in CPE as a proportion of all CARs reported to CARAlert and the frequency of CPE reporting highlights the need for local decisions about containment priorities and screening practices.

- The Commission will continue to work with the states and territories to promote the consistency of screening, infection prevention and control practices, and outbreak responses to improve CPE containment. The *Recommendations for the control of carbapenemase-producing* Enterobacterales *(CPE): A guide for acute care health service organisations*[17] and relevant local guidance continue to provide a framework for responding to CPE. These and other AMR 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 (NSQHS) Standards[18] and the Primary and Community Healthcare Standards.[12]

Action area: Continuing to monitor antifungal use and emerging antifungal resistance

NAUSP data revealed annually increasing systemic antifungal usage in Australian hospitals since reporting commenced in 2017. Elevated antifungal use increases the risk of resistance, particularly to the azole class of antifungals. It is important to monitor emerging resistance and consider the global context, despite data supporting low antifungal resistance in Australia. The World Health Organization (WHO) has highlighted the need for greater awareness of fungi and their susceptibility profiles.[19]

Antifungal therapy may be increasing because of the complexity of cancer chemotherapy and use of immunosuppression. Usage may be associated with the corresponding heightened risk of invasive fungal disease in these patient groups. Prioritising the surveillance of antifungal use is an important issue for AMS programs, particularly given the vulnerability of these at-risk populations.

While resistance is rarely detected in common *Candida* group species and *Aspergillus fumigatus* complex, the ongoing surveillance of antifungal use and resistance is essential. The correlation of non-wild type isolates with clinical outcomes also warrants further investigation.

Community: primary care

Action area: Continuing to monitor declining *Escherichia coli* resistance

The Australian Group on Antimicrobial Resistance (AGAR) data showed that the percentage of resistance in *Escherichia coli* in blood culture isolates in 2021 was similar to 2020 for all antimicrobial agents tested, except for ciprofloxacin, for which a marked decrease in resistance was observed. From 2020 to 2021, ciprofloxacin resistance in *E. coli* declined in all states and territories except Tasmania. While rates across states and territories varied, the most notable decline occurred in New South Wales and Victoria. This followed a steady increase in *E. coli* resistance to fluoroquinolones from 2013 to 2020.

The onset of episodes of *E. coli* bloodstream infections overwhelmingly occurred in the community in 2020 and 2021. While the reduction in *E. coli* resistance is not directly attributed to the broader reduction in community AU observed at this time, it is reasonable to speculate that there is a relationship between these two factors and the reduction in international travel during the COVID-19 response.

Action area: Promoting surveillance and containment of antimicrobial resistance in multidrug-resistant *Shigella* species and in *Neisseria gonorrhoeae*

CARAlert data revealed a sharp decrease in reports of multidrug-resistant (MDR) *Shigella* species from April 2020. The number of reports in 2021 fell to levels reported in 2017, coinciding with the COVID-19 restrictions in Australia. The increase in reports in 2022 may reflect the re-opening of international borders and eased COVID-19 restrictions across Australia.

Increases in reports of MDR *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 oral antimicrobial options are limited and intravenous antimicrobials may be required to treat MDR infections. There may also be resource implications for the health system because of increased testing, hospital admissions and transmission in the community.

In Australia, the recommended treatment for *Neisseria gonorrhoeae* is ceftriaxone in conjunction with azithromycin. This protocol was introduced in Australia in 2014 to limit further development of resistance to ceftriaxone.[20]

The low background rate of azithromycin-nonsusceptible *N. gonorrhoeae* (low-level resistance) in Australia is well established. However, the clinical implications of low-level resistance are not clear. Reports to CARAlert declined slightly during 2019 and 2020, in the context of 34,244 notifications of gonococcal infection nationally in 2019 and 29,516 notifications in 2020. There were 26,861 notifications in 2021 and 33,746 notifications in 2022.[21]

In 2022, 72% of all *N. gonorrhoeae* CARAlert reports were azithromycin-nonsusceptible (low-level resistance [LLR], minimum inhibitory concentration [MIC] <256 mg/L), 23% were ceftriaxone-nonsusceptible (MIC ≥0.125 mg/L) and 5% were azithromycin-nonsusceptible (high-level, MIC >256 mg/L). Reports of azithromycin-nonsusceptible *N. gonorrhoeae* (LLR) declined by almost 55% from 2021 to 2022, while reports of ceftriaxone-nonsusceptible *N. gonorrhoeae* increased sharply during the same period. Many of the ceftriaxone-nonsusceptible and azithromycin-nonsusceptible (high-level resistance) isolates were associated with travel, as reported by the Australian Gonococcal Surveillance Programme (AGSP).[22]

Global concerns about the effectiveness of currently recommended treatments remain, with overseas reports from a number of countries documenting *N. gonorrhoeae* strains with resistance to ceftriaxone.[23–26] Continuing low numbers of reports of ceftriaxone-nonsusceptibility, and the resumption of usual social interaction and international travel following the easing of COVID-19 restrictions from late 2021, indicate that ongoing monitoring of resistance to azithromycin and ceftriaxone is required because of the importance of emerging changes in susceptibility for treatment guidelines. This is also important because the use of antimicrobials such as azithromycin is associated with increased resistance in other organisms as well.[27]

- Maintaining effective surveillance of AMR in *Shigella* species and *N. gonorrhoeae*, continuing public health messaging to highlight the risk of sexual transmission of these organisms (particularly in men who have sex with men), and continuing programs for the prevention and control of these infections and implementation of outbreak response strategies are essential to minimise the spread of difficult-to-treat or even untreatable shigellosis[28] and gonorrhoea.

Action area: Supporting the review of prescribing guidance in light of current and emerging resistances

Resistance rates in some common pathogens are at levels at which prescribing practices should be reviewed.

- The Commission will continue to work with developers of prescribing guidelines, including Therapeutic Guidelines Limited, to inform guidelines and promote these findings through clear communications with prescribers.

Community: residential aged care

Action area: Supporting infection prevention and control in aged care

CARAlert revealed a decrease in the number of CARs reported from aged care homes from 2021 to 2022. The overall number of reports was very low, and *Staphylococcus aureus* and CPE were the most commonly reported.

Australian Passive AMR Surveillance (APAS) data showed that the rates of resistance in *Enterobacterales* in aged care homes were as high as, or higher than, rates in hospitals. High rates of methicillin-resistant *S. aureus* (MRSA) were reported for aged care homes, for which there are high rates of MRSA resistant to ciprofloxacin and erythromycin.

In aged care homes, skin and soft tissue infections are one of the most common reasons for antimicrobial prescriptions.[29] Skin and soft tissue infections are commonly caused by *S. aureus*, which is spread by contact with contaminated surfaces and hands of care workers, visitors and residents. Environmental cleaning and hand hygiene are important prevention and control strategies for *S. aureus.* In group living situations, *S. aureus* may also be inadvertently spread

from person to person, for example by sharing personal items such as bed linen, towels or clothing.

While the overall number of reports of resistances from aged care homes is small, the resistance rates remain very high. This poses a high risk for both infections caused by resistant bacteria and spread of these resistant bacteria, given the vulnerability of the population and their frequent interaction with the acute sector. Vigilance in monitoring AMR, along with enhancement of infection prevention and control and AMS programs, is vital in aged care homes. This is particularly important in the context of a sustained high rate of inappropriate AU in this setting, as revealed by Aged Care NAPS.

- The Commission is developing a standard on Clinical Care as a part of the current review of the Aged Care Quality Standards.[30,31] It aims to protect older people from harm and improve the quality of clinical care for people receiving aged care. The Commission will continue to collaborate with the Aged Care Quality and Safety Commission and aged care providers to support the implementation of infection prevention and control and AMS programs that meet the requirements of the Aged Care Quality Standards.

7.3 Conclusion

AMR remains a substantial risk to patient, community and aged care resident safety in Australia, and there are opportunities across these settings to improve AU – a key factor in the development of AMR.

AMR reduces the number and effectiveness of antimicrobials available to treat infections, increases morbidity and mortality associated with infections caused by MDR organisms, and may limit future capacity to perform medical procedures such as organ transplantation, cancer chemotherapy, diabetes management and major surgery.

The Commission continues to pursue 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 support AMR prevention and control strategies, improvements in AU and appropriateness, and ongoing surveillance of AMR and AU.

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Appendix 1

Data source description

Data source description

This appendix describes the data sources used for this 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 data collection and analysis processes and limitations.

National Antimicrobial Prescribing Survey

The National Antimicrobial Prescribing Survey (NAPS) is administered by the Royal Melbourne Hospital Guidance Group in Melbourne Health, and has been adopted as an important platform to support antimicrobial stewardship (AMS) programs in Australian hospitals and residential aged care homes. The platform has undergone continuous improvement since 2013 and now comprises four modules: the Hospital NAPS, the Surgical NAPS, the Aged Care NAPS and the Quality Improvement NAPS. The National Centre for Antimicrobial Stewardship (NCAS) is funded by the Australian Government Department of Health and Aged Care (the Department) to coordinate, analyse and report on data from the various NAPS modules and to provide data for the Antimicrobial Use and Resistance in Australia Surveillance System (AURA).

The Hospital NAPS module is a voluntary online audit offered annually to all Australian hospitals to assess antimicrobial prescribing practices and appropriateness of prescribing within the hospital. National aggregated and de-identified data from the Hospital NAPS are reported annually by NCAS. Participating hospitals can interrogate their own data and undertake benchmarking using the reporting functionality within the NAPS platform. The preferred methodology for the audit is a hospital-wide point prevalence survey. AURA 2023 includes highlights of analyses of 2020 and 2021 Hospital NAPS data.[1,2]

The Surgical NAPS module is a voluntary online audit that allows facilities to review their use of antimicrobials for surgical procedures, including procedural and post-procedural 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. The Surgical NAPS captures data across the patient's entire surgical episode. It includes existing antimicrobial therapy, procedural and post-procedural antimicrobials, and the duration of antimicrobial prophylaxis. AURA 2023 includes highlights of analyses of 2020 and 2021 Surgical NAPS data.[3,4]

The Aged Care 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 2023 includes highlights of the analyses of 2020 and 2021 Aged Care NAPS data.[5,6]

Participants

The number of facilities participating in the Hospital NAPS, Surgical NAPS and Aged Care 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 classifications. In 2020, 409 hospitals (285 public and 124 private) contributed data. In 2021, 407 hospitals (291 public and 116 private) contributed data.

In 2020, 155 hospitals provided data to Surgical NAPS that were included in the analyses. The 2020 Surgical NAPS analyses included 7,935 surgical episodes, of which 7,477 (94.2%) involved an incisional procedure. In 2021, 181 public and private facilities contributed data for the Surgical NAPS. The 2021 Surgical NAPS analyses included 10,927 surgical episodes, of which 10,150 (92.9%) involved an incisional procedure. In 2020 and 2021, every state contributed data, and a range of hospital peer groups and all remoteness classifications (except 'very remote') were represented.

In 2020, 823 aged care homes submitted Aged Care NAPS data; 689 participated in 2021. In both years, all states, remoteness classifications and organisation types were represented (except the Northern Territory [NT] in 2021). In 2021, three-quarters (75.6%) of participating residential aged care services were located in major cities or inner regional areas, and 385 (55.9%) were operated as not-for-profits. Compared to 2021 to 2020 data, the percentage of participating residential aged care services decreased for most states and territories. Representation within the Aged Care NAPS cohort varied between states and territories, and across remoteness classifications.

Considerations for data interpretation

Issues that need to be considered when interpreting NAPS data include the following:

- Participation in the Hospital NAPS and Surgical NAPS is voluntary, and facilities that choose to participate are not a randomised sample. Nonetheless, there is now a high degree of representativeness of Hospital NAPS participation across many hospital peer groups
- It is strongly recommended that all Australian aged care homes and multi-purpose services participate annually in Aged Care NAPS; participation has been mandatory for aged care facilities operated by the Victorian Government since 2017
- The development of NAPS modules has been iterative, and there have been changes to the data fields and some methodology elements (particularly in the early foundational years), so the results from some data fields are not directly comparable.

Specific considerations for each module are as follows.

Hospital NAPS

The Hospital NAPS includes only patients who are prescribed antimicrobials in the survey; therefore, patients who are not receiving antimicrobials are excluded. It is important to understand that the survey does not describe the prescribing behaviour for an indication in the context of a whole patient population. Therefore, for indications where the usual recommended therapy is no antimicrobial treatment, only those patients receiving antimicrobials are included.

Individual auditors at each facility are responsible for assessing antimicrobial prescribing appropriateness and compliance with guidelines. These assessments involve some degree of interpretation, thus standardised appropriateness definitions

are required to moderate subjectivity. Auditors are supported to conduct their assessments with mandatory eLearning modules, detailed User Guides, a standardised appropriateness assessment matrix and remote expert support.

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 use of the antimicrobials to treat these conditions.

Depending on the impact of COVID-19, local AMS 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 2020 and 2021 Hospital NAPS.

Surgical NAPS

The flexible methodology of the Surgical NAPS means that the 2020 and 2021 results are not directly comparable with each other, nor with any previous Surgical NAPS. Comparisons are limited to those between specific surgical procedure groups within the same year as the cohort of contributors varies each year, along with the proportions of surgical procedure groups represented.

Each contributing hospital decides how to conduct the survey, including which patients or surgical procedure groups are audited. If directed surveys are performed, patient sampling may not be random and auditors may target problem or higher-volume surgical units, thus creating a sampling bias and over-representation of certain surgical procedure groups.

Individual auditors at each participating facility are responsible for assessing compliance with guidelines and the appropriateness of antimicrobial prescribing. These assessments are not completely objective, as they involved some degree of interpretation. Similar to the Hospital NAPS, auditors are supported with a mandatory eLearning module, detailed User Guides, a standardised appropriateness assessment matrix and remote expert support to conduct their assessments.

To maintain strict timelines 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.

Prior to the 2019 data analyses, extensive data cleaning was performed to review incongruous results and ensure data accuracy of the new duration of surgical prophylaxis calculation methodology. The review mainly involved dates being entered incorrectly, resulting in prolonged durations of therapy. The majority of these changes were able to be identified and amended by the NAPS support team following internal review and discussion, with six facilities contacted directly to review and amend their records. This data cleaning process resulted in some survey data moving into alternate audit years, resulting in a decrease in total facility participation in some years as compared to previous Surgical NAPS public reports.

Aged Care NAPS

Data for the period 2016–2021 that were included in the analyses for the 2021 Aged Care NAPS report differed from previous reports. Some data were retrospectively entered and an extensive data cleaning process was undertaken before commencing analysis.

Over time, different cohorts of residential aged care services (aged care homes and multi-purpose services) have participated in the annual Aged Care NAPS. Each year, the overall number of participating services has increased, as new services have participated and some services that previously participated have chosen not to participate.

For the 2021 Aged Care NAPS, a suspected infection was defined as at least one sign and/or symptom of infection on the survey day and/or the two days prior to the survey day. In many cases, the prescriptions audited were prescribed more than three days prior to the survey day. As signs and symptoms are likely to be most significant in the time period just prior to or on commencement of antimicrobial prescriptions, the number of suspected infections defined in the 2021 Aged Care NAPS audit may under-represent the true number of antimicrobial prescriptions where signs and symptoms were present prior to the prescription commencing.

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).[8] Signs and symptoms of infection in older residents may be atypical, so failing to meet the McGeer et al. definitions 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 [UTIs]). 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 residential aged care services compared with acute care services. For some definitions, radiological evidence and the 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 services over time, as opposed to being used to rule in or rule out the clinical need for a prescription.

The survey was mostly conducted on a single day during winter or spring. The results may have varied across different seasons. Certain respiratory infections, for example, are usually more frequent in winter.

The analysis relied on the validity of local assessments. No additional external validation was undertaken.

Content included in AURA 2023 is drawn from reports prepared by Noleen Bennett (Aged Care NAPS), Michael Malloy (Aged Care NAPS), Caroline Chen (Hospital NAPS), Courtney Ierano (Surgical NAPS), Rod James and Karin Thursky. Further information on NAPS can be found on the NAPS website.[9]

National Antimicrobial Utilisation Surveillance Program

The National Antimicrobial Utilisation Surveillance Program (NAUSP) was established by SA Health in 2004 to monitor the consumption of antimicrobials in Australian public and private hospitals. SA Health is funded by the Department to co-ordinate analyses and reports on NAUSP data and to provide data for AURA.

The NAUSP provides a standardised measurement of antimicrobial use in Australian acute public and private hospitals using the metric of World Health Organization (WHO) defined daily doses (DDD) per 1,000 occupied bed days (OBD).[10] Hospitals contribute AU data and hospital activity data to NAUSP on a voluntary basis via an online portal.

The portal has undergone continuous improvement since it was first established. In January 2021, NAUSP underwent a suite of upgrades to capture AU in more hospital settings. It also introduced new denominators that enable benchmarking in settings where OBD do not accurately measure hospital activity, such as operating theatres (OT)/ recovery and emergency departments (ED).

In summary, the changes introduced to NAUSP include:

- Expansion of data definitions to capture all antimicrobials
- Alternate denominators for benchmarking usage in the ED and OT/recovery:
  - ED usage reported relative to ED presentations
  - OT usage reported relative to the number of OT cases or procedures, which enables day-only surgical facilities to participate in NAUSP
- Surveillance of AU in sub-acute settings such as mental health, palliative care, long-term rehabilitation and long-stay aged care wards
- Inclusion of Hospital in the Home (HITH) as a stand-alone location
- Combining intensive care unit and high dependency unit data and categorising them as critical care.

The aggregate usage rate reported by NAUSP includes usage from all acute care settings but excludes usage from subacute settings. From 2021, the aggregate usage rate excludes usage from ED and OT. This means previous reports and longitudinal trends must be interpreted with caution.

Methods

Pharmacy departments of Australian hospitals that participate voluntarily in NAUSP supply and upload monthly AU data via an online portal. These data are based on dispensing and distribution reports for the different clinical departments or wards for inpatient use. Hospital occupancy data are collected on a monthly basis in the form of OBD, theatre cases and ED presentations.

Each contributing hospital is assigned a unique code by NAUSP. Contributor codes allow de-identified comparative usage rates to be reported, enabling hospitals to benchmark their usage against other similarly peered hospitals.

Data development and analysis

Each contributing hospital is responsible for the accuracy of AU data submitted to NAUSP, including compliance with NAUSP data definitions.[11] Alerts are generated automatically during the data submission process if quantities fall outside the usual or expected range. This enables the validation of data at an early stage of data submission.

The NAUSP team performs periodic quality assurance processes to validate the accuracy and integrity of the data uploaded into the online portal managed by SA Health. The NAUSP team notifies contributors if data anomalies are identified or if data resubmission is required.

Antimicrobial surveillance data are reported by NAUSP as a standardised usage density rate on a monthly basis. Usage rates are only calculated for inpatient use, with OBD, OT cases and ED presentations being the denominators used. Consumption data submitted to NAUSP are aggregated into the total number of grams used each month for each individual antimicrobial. As part of the analysis, proprietary drug names and product descriptions extracted by hospital dispensing software are mapped to a standardised list. Antimicrobial usage is then converted from total grams used into the DDD metric. These DDD values are based on the assumed

average maintenance dose per day for the main indication in adults. One limitation of the DDD as a consumption metric is that for some antimicrobials, the DDD does not always reflect the usual daily doses used in Australian clinical practice.

Since the two Australian territories have a small number of hospitals participating in NAUSP, these territories have been grouped with larger states for the purposes of this report. For usage rates reported at a jurisdictional level, hospitals in the NT have been grouped with Queensland, and hospitals in the Australian Capital Territory (ACT) have been grouped with New South Wales (NSW).

Considerations

The AU rates calculated for this report were correct at the time of publication. These data are contingent on the accuracy of the antimicrobial quantities and denominators 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 previously excluded hospitals due to issues regarding data validity.

Usage reflects antimicrobials distributed or dispensed from pharmacy and does not reflect actual antimicrobial consumption at the patient level. Reported usage rates are limited to acute hospital usage only and do not include AU in subacute settings. Outpatient usage and day-only usage are currently not included in NAUSP data.

Antimicrobials currently included in the NAUSP dataset are the most commonly used antibacterials and antifungals in Australian hospitals. Care is required when interpreting NAUSP data where the WHO DDD does not accurately reflect the Australian setting. If the routine doses used in the Australian setting are higher or lower than the WHO-assigned DDD, this may contribute to the usage rates being underestimated or overestimated.

Content included in AURA 2023 is drawn from reports prepared by Erin Connor, Ajmal Dalwai, Nadine Hillock, Vicki McNeil and Alice Teoh. Further information on NAUSP can be found on the SA Health website.[12]

Pharmaceutical Benefits Scheme and Repatriation Pharmaceutical Benefits Scheme

Services Australia collects data on antimicrobial dispensing in the community through the Pharmaceutical Benefits Scheme (PBS) and the Repatriation Pharmaceutical Benefits Scheme (RPBS) in the Medicare pharmacy claims database.

The Department analyses PBS and RPBS data to inform economic analyses and policy development. Comprehensive medicine usage data are required for several purposes, including pharmacosurveillance and targeting, and evaluation of initiatives for the quality use of medicines. These data are also needed by regulatory and financing authorities and the pharmaceutical industry.

Data captured by the PBS and RPBS are extensive. In 2022, 21,848,005 prescriptions were supplied under the PBS and RPBS for all antimicrobials.

Additional data and analysis

As part of the development of AURA 2023, the Commission engaged the University of South Australia to provide a report on the use of antimicrobials in Australia. Data were analysed for all antimicrobial prescriptions supplied under the PBS and the RPBS for 2015–2022.

Services Australia provided an extract of antimicrobial prescriptions supplied under the PBS and the RPBS over an 8-year period. The extract included all antimicrobials listed on the PBS and the RPBS that were dispensed between 1 January 2015 and 31 December 2022. 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 (encrypted, system-generated unique identifier)
- Patient date of birth (MMYYYY)
- Postcode in which the patient resided at the date of supply
- Postcode in which the prescriber's address was located at the date of supply
- Specialty group of the prescriber
- PBS or RPBS item code
- Anatomical Therapeutic Chemical (ATC) code (Level 2)
- Drug name
- Product form and strength
- Quantity of PBS or RPBS item supplied
- Date of prescribing
- Date of supply
- Prescription count
- Type of prescription: original, repeat or authority
- Number of repeats ordered
- Number of previous supplies
- Regulation 49 indicator (previously Regulation 24, which indicates whether all repeats for a PBS or RPBS prescription were supplied at the same time as the original prescription)
- Pharmacy type dispensed (hospital/community).

The antimicrobials included in the analyses presented in this report are shown in Table A1.1. The codes that are additional to J01 antibacterials are included to better reflect antimicrobial exposure in the community and resistance selection pressure – for example, topical fluoroquinolones.

Table A1.1: Antimicrobials included in the analyses of PBS and RPBS data for AURA 2023, 2015–2022

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 antibacterials: 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[13]

The following analyses were undertaken:

- Trends in antimicrobials supplied between 2015 and 2022, defined as:
  - number of prescriptions per 1,000 people at national, state/territory and Statistical Area Level 3 (SA3) (derived from postcode)
  - number of prescriptions per 1,000 people by class of antibacterial for systemic use (J01)
  - DDD per 1,000 people per day at national and state/territory levels
  - DDD per 1,000 people per day by class of antibacterial for systemic use (J01)
- Number of antimicrobials dispensed per 1,000 people by patient age, patient SA3 and state/territory of residence in 2022
- For the top 10 antimicrobials supplied in 2022:
  - most commonly supplied antimicrobials
  - rate of original and repeat dispensing of each antimicrobial
- Rate per 1,000 people of all antimicrobials supplied in winter (June, July and August) 2022, by prescriber SA3, and by state/territory.

For reporting of age-standardised rates, the reference population was the Australian population in mid-2013, for consistency with previous AURA reports. Where population data were used, the mid-year (30 June) estimates for each calendar year were used, as provided by the Australian Bureau of Statistics.

Considerations

Issues that need to be considered when interpreting PBS and RPBS data include the following:

- Data include antimicrobials dispensed through the PBS and the RPBS; therefore, antimicrobials dispensed by some inpatient and outpatient services, some community health services, and Aboriginal and Torres Strait Islander health services may not be captured in this dataset

- Private prescriptions are not included in this dataset
- The data do not indicate the diagnosis or condition of the patient.

Other prescriptions may be dispensed privately or are non-PBS and non-RPBS prescriptions.

The reasons for antimicrobials being dispensed privately may include that the prescriber wishes to prescribe:

- An antimicrobial for a non-subsidised indication or for travel
- A quantity that exceeds the PBS or RPBS limit
- Cost (some antimicrobials cost the patient less if dispensed privately).

In addition, dispensing through the PBS and the RPBS does not necessarily equate to consumption. Antimicrobial consumption can be overestimated because patients may not comply with therapy recommendations.

Content included in AURA 2023 is drawn from reports prepared by Svetla Gadzhanova and Libby Roughead. Further information on the PBS and the RPBS can be found on the PBS and RPBS website.[14]

MedicineInsight program

NPS MedicineWise operated MedicineInsight from 2011 until 31 December 2022. Responsibility for the operation of the MedicineInsight program was transferred to the Australian Commission on Safety and Quality in Health Care (the Commission) from 1 January 2023 as part of the 2022–23 Budget initiative that included the redesign of the Quality Use of Diagnostics, Therapeutics and Pathology Program. The Commission is seeking ethics approval and contributor consent for the continuation of the program. As a result, 2022 MedicineInsight data were not available for analysis and inclusion in AURA 2023.

MedicineInsight collects longitudinal, de-identified clinical data from participating general practices across Australia and relies on the level of completeness and accuracy of those records. Patients are included from the first recording of their clinical data in the participating practices' clinical systems. MedicineInsight data include patient demographic and clinical data entered directly into the system by general practitioners (GPs) and practice staff, which are collected from external sources (for example pathology test results), and system-generated data such as antibacterial start time and date of a patient encounter.

The program was established 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 practices and identify key areas for improvement.

MedicineInsight data provide a unique capacity to monitor community antibacterial prescribing patterns and assess the appropriateness of antibacterial use in the community in Australia. The data can be used to analyse the 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; accordingly, the general practices included are not a randomised sample. It is estimated that there were 8,147 general practices in Australia in 2019.[15] MedicineInsight data are estimated to represent approximately 6% of Australian general practices (see Table A1.2).

Patients are included from the first recording of their clinical data in the participating practices' clinical systems. There are currently two general practice clinical information software systems that can contribute data to MedicineInsight.

Data source and criteria

This report analyses MedicineInsight data from 2015 to 2021, and complements analyses previously reported for the period 2010 to 2019.[17–19] Table A1.3 outlines the data source, type of data analysed, setting, time period and population.

Table A1.2: Number of general practices contributing to MedicineInsight, by state and territory, 2020–2021

State or territory	2020	2021
NSW	176	176
Vic	95	95
Qld	107	108
SA	13	13
WA	59	59
Tas	36	36
NT	8	8
ACT	9	9
Total	503	504

Source: MedicineInsight[16]

Table A1.3: MedicineInsight community antibacterial use data sources

Subject and type of surveillance	Targeted surveillance of antimicrobial use in the community
Data source	MedicineInsight program
Type of data	Appropriateness of prescribing, prescribing patterns
Setting	Australian general practices*†
Coverage	National 2015: 480 general practices; 2,291,604 patients 2016: 493 general practices; 2,413,269 patients 2017: 498 general practices; 2,560,823 patients 2018: 502 general practices; 2,657,445 patients 2019: 502 general practices; 2,726,115 patients 2020: 503 general practices, 2,581,255 patients 2021: 504 general practices; 2,778,848 patients

* Prescribing data can differ from dispensing data, because not all prescriptions are dispensed, and this dataset includes only J01 antibacterials, unlike Pharmaceutical Benefits Scheme (PBS) and Repatriation PBS (RPBS) data; therefore, these data may not correlate completely with PBS and RPBS data

† Data are sourced from medical records and rely on an appropriate level of completeness and accuracy of those records; specialist prescriptions and samples are not included

Source: MedicineInsight[16]

Data were analysed for antimicrobials included in the standard collection of ATC class J01 (antibacterials for systemic use). Additional analyses are included for the seven most frequently prescribed antibacterials, also referred to as high-use antibacterials: amoxicillin, amoxicillin–clavulanic acid, azithromycin, cefalexin, ciprofloxacin, doxycycline and roxithromycin.

MedicineInsight prescribing data differ from PBS and RPBS dispensing data, as not all prescriptions issued by GPs are dispensed. Therefore, MedicineInsight data may not always correlate with PBS and RPBS data. Additionally, MedicineInsight data include only antibacterials that are classed ATC J01. PBS and RPBS data also include ATC code A02, A07, D06, S01, S02 and S03 antimicrobials (Table A1.1).

Both GP visits and the number of patients prescribed an antibacterial are used as denominators in the MedicineInsight data.

Absolute numbers are used within this report to describe patterns in prescribing and do not take into consideration the differences in the number of GP visits in that period. This should be taken into consideration when interpreting results based on absolute numbers. Comparison of prescribing between years is presented as rates where applicable, and not absolute numbers, to account for these differences.

Information about the clinical indication for an antibacterial prescription can be collected from general practice clinical information software in several ways. The most straightforward approach is through the 'Reason for Prescription' 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. Where a reason for prescription was not recorded, the analysis used information recorded on the same day as the antibacterial prescription from other fields – 'Reason for Encounter' and 'Diagnosis'

– to identify the clinical indication(s). For the purposes of this report, appropriateness is assessed by drug choice and indication whereby an appropriate antibacterial is compliant with recommendations in *Therapeutic Guidelines: Antibiotic*.[20]

From March 2020, the Australian Government introduced telehealth items on the Medicare Benefits Scheme (MBS).[21] Data on antibacterial prescribing during telehealth consultations were extracted from patient records of participating MedicineInsight practices.

Data development and analysis

In collaboration with NPS MedicineWise, the Commission performed the following analyses of 2021 data:

1. Monthly rate of GP PBS and RPBS prescriptions for J01 systemic antibacterials (originals and repeats) per 100 GP visits of:
   a. PBS and RPBS
   b. non-PBS and non-RPBS

2. Patterns of antibacterial prescribing among GPs for high-use antibacterials:
   a. proportions of non-PBS and non-RPBS to total prescriptions, originals and repeats
   b. proportions of patients issued a prescription
   c. indications (taken from 'Reason for Prescription', 'Reason for Encounter' and 'Diagnosis') for therapy recorded
   d. repeats prescribed
   e. PBS and RPBS and non-PBS and non-RPBS prescriptions
   f. patient demographics (5-year age group, state or territory, Socio-Economic Indexes for Areas [SEIFA], remoteness)
   g. patients issued a prescription (PBS and RPBS or non-PBS and non-RPBS) (%)
   h. most common indication (%)
   i. patient age group with the highest rate of prescribing (years)
   j. prescriptions (PBS and RPBS or non-PBS and non-RPBS) ordered with repeats (%)
   k. prescriptions ordered as non-subsidised (%)

3. Number and percentage of patients prescribed systemic antibacterials by GPs stratified by:
   a. state or territory
   b. remoteness
   c. SEIFA
   d. age group (5-year age group)

4. Number and percentage of patients prescribed systemic antibacterials by GPs for the following selected conditions:
   a. acute upper respiratory tract infection (URTI), acute bronchitis or bronchiolitis, acute tonsillitis, sinusitis (chronic or acute), acute otitis media/myringitis, community-acquired pneumonia, cystitis or other UTI, influenza-like illness, chronic obstructive pulmonary disease (COPD)

5. Number and percentage of GPs who recorded 'indication' for antibacterial prescription for systemic antibacterials:
   a. by calendar year
   b. by age group (5-year group)

6. Telehealth services' rate of antibacterial prescribing (original prescription only) per 100 telehealth visits versus the rate of antibacterial prescribing per 100 non-telehealth GP visits or per 100 GP visits of any type.

Billing data were used to classify patient-date interactions into one of the following categories using the relevant MBS item numbers (that correspond to a regular face-to-face MBS encounter)[21]:

- Face-to-face
- Telehealth
- Unknown (billing item found but not included in the list of relevant codes)
- Missing (billing item not found).

Prescribing rates were provided in two ways for telehealth analyses[21]:

- Direct Date Match: prescription/encounter and face-to-face or telehealth MBS billing item identified on the same day (direct date match)
- Sensitivity Analysis (+/- 1 Day Match): if no MBS billing item was identified on the same day as the prescription or encounter, rates were calculated by identifying prescriptions or encounters with a face-to-face or telehealth MBS billing item on the same day or on the day before or after the prescription or encounter.

Data definitions

The definitions in Table A1.4 were used for the analyses conducted for this report.

Table A1.4: NPS Medicinewise MedicineInsight data definitions

Term	Definition
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 clinical information system (CIS) that capture the patient's medical history, reason for encounter and reason for prescription. The CIS uses coding systems, such as DOCLE in Medical Director 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 (such as remoteness and SEIFA decile) in the MedicineInsight database based on commonly accepted definitions.
General practice sites	One or more practices that share the same 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.
Indication	Indications for prescribing are described using the 'reason for prescription' field in the first instance.
Patients	Patients who had at least one clinical encounter with a GP in the year of analysis, and were marked as active by the practices, and not recorded as deceased.
Systemic antibacterials	Antibacterial with a J01 ATC code. This excludes antibacterials that act systemically but are part of a different ATC (such as A02BD – 'combinations for eradication of *Helicobacter pylori*').
Telehealth	The remote diagnosis and treatment of patients by means of telecommunications technology.

Considerations

The MedicineInsight program relies on voluntary participation and submission of data from general practices, resulting in non-random sampling, connection, practice involvement and other issues. Therefore, comparisons between different states and territories should be interpreted carefully.

Percentages and other data for 2015–2021 may have changed compared to previous reports as more data have become available.

Volumes of prescriptions are represented as original with repeats, or original only, noting that repeat prescriptions may not have been supplied. General practices that participate in the MedicineInsight program may be more likely to focus on the quality use of medicines in their practice.

Appropriateness has been assessed by drug choice and indication whereby an appropriate antibacterial is compliant with *Therapeutic Guidelines: Antibiotic*[20] recommendations.

Further information on dose, frequency, duration and other prescribing parameters are not considered as they are not captured in these data.

Changes since 2019

NPS MedicineWise made several changes to MedicineInsight after 2019, including to some of the rules and algorithms used for data analysis, to provide a more accurate picture of the appropriateness of prescribing in participating practices.

These include:

- Selecting antibacterials by ATC code, rather than the active ingredient alone. This functionality allows systemic antibacterials to be identified as a group (J01) and as specific antibacterials of interest
- Restricting the patient count to those who attended the GP 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.

Not all MedicineInsight practices have billing software that is compatible with their CIS. Therefore, analyses that require billing data do not include all practices. For the analysis included in this report, 484 practices had compatible billing software out of a potential 503 practices in 2020 and 504 practices in 2021.

Clinical encounters were classified as being face-to-face or telehealth using MBS item numbers recorded in the billing section of the CIS. To support the comparison of antibacterial prescribing rates for face-to-face encounters, the search for MBS items in the MedicineInsight database was restricted to telehealth MBS item numbers that directly correlate to face-to-face MBS items as per the MBS changes online fact sheet, *Continuing MBS Telehealth Services*.[21]

It is important to note that:

- Telehealth MBS items changed during the COVID-19 pandemic such that both current and obsolete MBS telehealth items were included
- Items were excluded for health assessments for Aboriginal and Torres Strait Islander patients (small numbers), pregnancy support counselling, autism and eating disorders; all other telehealth MBS items were included (including the blood-borne virus, sexual and reproductive health items added in July 2021)
- There are many other MBS items for consultations than are listed in the fact sheet, with some of these likely to be face-to-face MBS items; as there is no identifiable direct correlation between the above MBS items and the telehealth items, the above MBS items were not included in the data extract.

A1.2 Data sources for antimicrobial resistance

This section provides information on the methods used by each of the sources of 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.

The Australian Society for Antimicrobials is funded by the Department to coordinate, analyse and report on AGAR data and to provide data for AURA.

AGAR operates a series of targeted survey programs each year on the level of AMR in selected bacteria detected from blood cultures. This provides information on AMR in serious infections and aligns with the European Antimicrobial Resistance Surveillance Network (EARS-Net).

Microbiology laboratories provide laboratory data, demographic data and isolates to two AGAR reference laboratories that undertake molecular testing on selected isolates for the following three programs:

- Australian Staphylococcal Surveillance Outcome Program (ASSOP)
- Australian Enterococcal Surveillance Outcome Program (AESOP)
- Gram-negative Surveillance Outcome Program (GnSOP).

Formerly known as Sepsis Outcome Programs, these programs were renamed in 2021 to better reflect AGAR's surveillance of bacteraemia rather than sepsis. AGAR data are reported annually to the WHO Global Antimicrobial Resistance and Use Surveillance System (GLASS).

In addition to susceptibility test data and demographic data, most participating laboratories provide limited outcome data on each episode of bacteraemia. AURA 2023 includes highlights of the analyses of 2020 and 2021 AGAR data.[22]

Participants

In 2020, 30 laboratories servicing 49 hospitals and their communities participated in GnSOP, ASSOP and AESOP; in 2021, 30 laboratories servicing 48 hospitals and their communities participated in these programs. Each of the three programs includes hospitals from all states and territories, including regional or district hospitals from the north of Western Australia (WA). Seven additional paediatric services and/or facilities providing specialist obstetric services have joined these programs since 2020.

The number of laboratories that provide services for different types of hospitals varies between each state and territory. The laboratories are mostly public but 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; therefore, the types of resistance likely to be observed are influenced by institution size, throughput, patient complexity and local AU patterns
- There is currently insufficient capacity to obtain sufficiently detailed clinical information to judge the clinical significance of resistance
- The level of participation in each program may vary from year to year, depending on available resources
- National data are reported using European Committee on Antimicrobial Susceptibility Testing (EUCAST) interpretive criteria.

Content included in AURA 2023 is drawn from reports prepared by Jan Bell, Peter Collignon, Louise Cooley, Geoffrey Coombs, Denise Daley, Thomas Gottlieb, Jon Iredell, Alicia Fajardo Lubian, Shakeel Mowlaboccus, Graeme Nimmo, Sally Partridge, Jennifer Robson, Princy Shoby and Morgyn Warner. Further information on AGAR can be found on the AGAR website.[23]

Australian Passive AMR Surveillance

The Australian Passive AMR Surveillance (APAS) system was established by the Commission in 2015 in collaboration with Queensland Health and uses OrgTRx information technology infrastructure. The Commission is funded by the Department to coordinate APAS and analyse and report on APAS data for AURA. 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 93 million AMR records from 2005 to 2022.

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 in 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 current APAS contributors have been implemented at a local level, along with national reporting by the Commission.[17–19,24,25] APAS data are reported annually to GLASS.

Participants

The following pathology services currently contribute data to APAS:

- ACT Pathology (all public and some private ACT 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 [SA])
- 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 and Launceston General Hospital, Tasmania (combined data from these two contributing laboratories capture most public patient data for Tasmania)
- Monash Health (Victoria)
- Alfred Health (Victoria)
- PathWest Laboratory Medicine (all WA public hospitals).

Historical data from 2006 were available from four of these pathology services: the former Sydney South West Pathology Service (which 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, 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, several 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, SA, WA and the ACT) are most representative. Queensland is comprehensively covered because of the involvement of Mater Pathology Brisbane. Data from Victoria are limited because there are only two contributing sites, and data are not available from the NT. Since APAS commenced, NSW transitioned all public laboratories to the statewide service, NSW Health Pathology. A process is underway in 2023 to integrate all NSW Health Pathology laboratories with APAS. 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.

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 their 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; AURA acknowledges the differences in the interpretation of results obtained by each method and is working to promote a single method that is nationally implemented:
  - APAS data are reported for antimicrobials for which at least 75% of isolates were tested using either the EUCAST, Clinical and Laboratory Standards Institute (CLSI) or calibrated dichotomous sensitivity (CDS) method, and for which at least 30 strains were tested for each grouping
  - Victoria, Queensland, SA, Tasmania and the ACT used EUCAST
  - WA used CLSI
  - NSW used CLSI, CDS and EUCAST
- 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; some pathology services were unable 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.[26]

Clinical Mycology Reference Laboratory and National Mycology Reference Centre

The analyses on in vitro susceptibility to antifungal agents for common *Candida* group species and *Aspergillus fumigatus* complex were prepared by Sarah E. Kidd from the National Mycology Reference Centre, SA Pathology, and Catriona L. Halliday and Sharon C-A. Chen from the Clinical Mycology Reference Laboratory (CMRL), NSW Health Pathology.

Clinical Mycology Reference Laboratory

The CMRL is a National Association of Testing Authorities (NATA) accredited laboratory within the Centre for Infectious Diseases and Laboratory Services, Institute of Clinical Pathology and Medical Research - NSW Health Pathology, at Westmead Hospital in Sydney.[27] It is in active partnership with the Centre for Infectious Disease - Public Health and the Sydney Infectious Diseases Consortium at the University of Sydney in medical mycology initiatives. The CMRL provides comprehensive services for the diagnosis and management of fungal infections through the provision of a broad range of routine and specialist mycological laboratory diagnostics, as well as expert clinical and technical advice. It has active translational research functions in the areas of molecular diagnostics, genomics and surveillance, evaluation of novel antifungal agents and antifungal drug trials. It collaborates with the Microbiology Discipline of the Royal College of Pathologists of Australasia (RCPA) Quality Assurance Programs and has professional links with the Mycoses Study Group Education and Research Consortium in the United States and with the Asia Fungal Working Group in the education and training of scientists and medical personnel.

National Mycology Reference Centre

The National Mycology Reference Centre is situated within SA Pathology, Adelaide. It is a NATA-accredited laboratory providing mycology services to all South Australian public hospitals, physician-requested testing, and reference services for private and interstate pathology providers. The Centre is actively involved in the teaching of medical mycology to students, medical technologists, scientists and those undergoing specialist training in microbiology, infectious diseases and dermatology. It hosts a regular national course in medical mycology, provides resources for fungal identification and training, including the Mycology Online website[28], and collaborates with the RCPA Quality Assurance Programs on the provision of a mycology program.

HOTspots program

The HOTspots program is a longitudinal surveillance platform that provides analysis and reporting of resistance in remote northern parts of Australia. The Digital Solutions for Antimicrobial Resistance Group, within the Commonwealth Scientific and Industrial Research Organisation, is the custodian for AMR data supplied by pathology laboratories in northern Australia to the HOTSpots program. The program is overseen by the HOTspots Advisory Committee, which includes infectious diseases physicians, microbiologists and public health experts. The program was funded by the Department.

Participants

Participating regions comprise two northern regions of far north WA (Kimberley and Pilbara), five regions that make up the NT (Alice Springs, Barkly, Darwin, East Arnhem and Katherine) and five regions of far north Queensland (Cairns and Hinterland, Mackay, North West, Torres and Cape, and Townsville).

Participating pathology services (Western Diagnostic Pathology, PathWest Laboratory Medicine WA, Territory Pathology, Pathology Queensland) provide data on all clinical specimens for which susceptibility testing was performed during the study period (2020–2021). Susceptibility tests were performed using either disc diffusion or commercial semi-automated broth microdilution (VITEK® 2 – bioMérieux, France). Data were generated using CLSI or EUCAST breakpoints relevant for each year, depending on the contributing laboratory. Only NT data were included in the analyses presented in AURA 2023, as data for WA and Queensland are available in APAS.

Considerations

Although coverage of HOTspots data is considered comprehensive for northern Australian community clinics and public hospitals, the data and their interpretation have several limitations:

- The four pathology providers that supply data to HOTspots are the main pathology providers for northern Australia, but it remains unclear what proportion of the entire northern Australian population is being missed in the data collection – there are likely people in the community who do not attend a healthcare facility and are therefore not included in the analyses
- The geolocation of patients with a hospital-associated bloodstream infection in NT (identified in Territory Pathology data) is the location where the sample is processed and does not necessarily imply the location where the patient acquired the infection
- Data are reported for antimicrobials for which at least 75% of isolates were tested using CLSI interpretative criteria.

The NT HOTspots data were extracted for inclusion in the analyses for AURA 2023 by Teresa Wozniak. More information on HOTspots is available at: https://research.csiro.au/amr-hotspots/

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 can provide timely information to states and territories to support actions in response. The Commission is funded by the Department to coordinate CARAlert and analyse and report on CARAlert data.

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 AURA
- 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, the isolate is sent to a confirming laboratory that has the capacity to confirm the CAR
- Reporting to clinicians in accordance with usual laboratory processes: the confirming laboratory reports back to the originating laboratory, which in turn reports to the clinician who initially requested the microbiological testing

- 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 from whom the specimen was collected; 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 Department 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.

In 2021 and 2022, 28 confirming laboratories participated in CARAlert, with at least one confirming laboratory in each state and territory. The CARs that each confirming laboratory 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 2022 calendar year.

Further information about CARAlert is available on the Commission's website.[29]

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).

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 daily to the Department for collation, analysis and publication on the Department's website. Quarterly and annual reports are published in the journal *Communicable Diseases Intelligence*.

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.

The NNN laboratories report data quarterly and annually on gonococcal AMR for a core group of antibacterial agents to the WHO Collaborating Centre for Sexually Transmitted Infections and Antimicrobial Resistance. This laboratory is based in Sydney and publishes quarterly and annual reports in the journal *Communicable Diseases Intelligence*. The current antibacterials routinely surveyed

are azithromycin, ceftriaxone, ciprofloxacin, penicillin and spectinomycin. In 2020 and 2021, gentamicin data were also reported, in line with the WHO GLASS indicators for *N. gonorrhoeae*.

Participants

Although most information gathered and reported by the AGSP is based on AMR 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, particularly for oropharyngeal infections and in high-risk populations. This program is important in detecting treatment failure and informing therapeutic strategies.

Considerations

Most cases of gonococcal infection are now diagnosed using nucleic acid techniques, without subsequent culture. Because current susceptibility testing methods depend on obtaining a culture of the organism, only a minority of cases undergo susceptibility testing.

Relative limitations of the AGSP data relate to the decrease in the number of isolates for antimicrobial susceptibility testing (AST) with the increased use of nucleic acid amplification testing (NAAT) either by clinician choice, or by necessity in remote settings. However, nationally, one-quarter of 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.

Content included in AURA 2023 is drawn from reports prepared by Tiffany Hogan. Further information on the AGSP can be found on the Department's website.[30]

Australian Meningococcal Surveillance Programme

The AMSP was established in 1994. It provides a national laboratory-based program for examining invasive meningococcal disease (IMD) caused by *N. meningitidis*.

The AMSP collects data on the strain phenotype (serogroup, serotype and sub-serotype) and AST 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 rates of IMD decreased following the introduction of the National Immunisation Program (NIP) in 2003 of a publicly funded serogroup C meningococcal conjugate vaccine. However, where increases in MenW and MenY disease occurred in Australia in 2016–2017, jurisdictional time-limited MenACWY vaccination programs were implemented 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. IMD 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 were not fully complying with data requirements for notification. An additional possible technical limitation is that in a small proportion of cases, meningococcal infection is detected using only NAAT and the culture is negative. Therefore, AMR data are not available for these cases.

Content included in AURA 2023 is drawn from reports prepared by Tiffany Hogan. Further information on the AMSP can be found on the Department's website.[31]

National Notifiable Diseases Surveillance System

The NNDSS was established in 1990 under the auspices of the Communicable Diseases Network Australia (CDNA).[32] The NNDSS coordinates the national surveillance of more than 70 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 their jurisdiction. De-identified unit records of notifications are supplied to the Department daily for analysis and publication in online fortnightly, quarterly and annual reports, and in the journal *Communicable Diseases Intelligence*. NNDSS data were provided by the Office of Health Protection and the Department, 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. 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 Department daily. The *National Health Security Act 2007* provides the legislative basis for the national notification of communicable diseases and authorises the exchange of health information between the Australian Government and state and territory governments. State and territory health departments transfer these notifications regularly to the NNDSS. The primary responsibility for public health action resulting from a notification resides with state and territory health departments.

Since 1998, 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 Tuberculosis Programme.

Considerations

AMRLN data included in this report are based on 2020 and 2021 data from each state and territory that were provided to the Commission by the Department, drawn from a snapshot of NNDSS data taken on 22 February 2023. The totals in this report may vary slightly from the totals reported in *Communicable Diseases Intelligence* quarterly 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 healthcare providers that are the subject of notification to health authorities is not known with certainty for any disease, and may vary among diseases, between jurisdictions and over time.

The NNDSS reports data from the 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.

Further information on the NNDSS and the AMRLN can be found on the Department's website.[33]

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 the 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 NSW.

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 NSW 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
- Data are reported for antimicrobials for which at least 75% of isolates were tested using the EUCAST interpretive criteria and at least 30 strains were tested; for *Streptococcus pneumoniae*, there were insufficient data to report the prevalence of resistance for strains causing meningitis.

Further information on SNP can be found on the SNP website.[34]

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Appendix 2

Priority organisms

Priority organisms

In 2014, as part of the development of the Antimicrobial Use and Resistance in Australia Surveillance System (AURA), the Australian Commission on Safety and Quality in Health Care (the Commission) worked with a range of clinical and technical experts, and with the states and territories, to identify a group of organisms considered 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 is substantial in 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 that have high public health importance and/or 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 AURA. The priority organisms for human health will continue to be reviewed and monitored to ensure that they remain in the appropriate set and to determine whether any other changes are required.

The priority organisms list was used by the Commission to identify resistances to be monitored through the National Alert System for Critical Antimicrobial Resistances (CARAlert). CARAlert was established by the Commission in 2016.

Table A2.1: Priority set 1: Organisms that have high public health importance and/or are common pathogens for which the impact of resistance is substantial in 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*

Table A2.2: Priority set 2: Organisms for which the impact of resistance is substantial in hospital settings

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

Table A2.3: Priority set 3: Organisms for which resistance is a marker of epidemiological resistance and/or antimicrobial use

Species	Core reportable agent
Campylobacter jejuni or *C. coli*	Ciprofloxacin

Table A2.4: 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

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Appendix 3

Terminology

Terminology

A3.1 Abbreviations

Term	Definition
ABS	Australian Bureau of Statistics
Aged Care NAPS	Aged Care National Antimicrobial Prescribing Survey
ACT	Australian Capital Territory
AESOP	Australian Enterococcal Surveillance 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
APC NMDS	Admitted Patient Care National Minimum Data Set
ASSOP	Australian Staphylococcal Surveillance Outcome Program
AST	antimicrobial susceptibility testing
ATC	Anatomical Therapeutic Chemical
AU	antimicrobial use
AURA	Antimicrobial Use and Resistance in Australia
β-lactamase inhibitors	beta-lactamase inhibitors
CAESAR	WHO Central Asian and European Surveillance of Antimicrobial Resistance
CA-MRSA	community-associated methicillin-resistant *Staphylococcus aureus*

Term	Definition
CAP	community-acquired pneumonia
CAR	critical antimicrobial resistance
CARAlert	National Alert System for Critical Antimicrobial Resistances
CARSS	Canadian Antimicrobial Resistance Surveillance System
CBP	clinical breakpoints
CDARS study	*Clostridioides difficile* Antimicrobial Resistance Surveillance study
CDC	Centers for Disease Control and Prevention
CDI	*Clostridioides difficile* infection
CDNA	Communicable Diseases Network Australia
CDS	calibrated dichotomous sensitivity
CI	confidence interval
CIS	clinical information system
CLSI	Clinical and Laboratory Standards Institute
COAG	Council of Australian Governments
COFs	Conditional Onset Flags
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
Department	Australian Government Department of Health and Aged Care
DID	defined daily doses per 1,000 inhabitants per day
EARS-Net	European Antimicrobial Resistance Surveillance Network
ECOFF	epidemiological cut-off values
ED	emergency departments
EEA	European Economic Area
ESAC-Net	European Surveillance of Antimicrobial Consumption Network
ESBL	extended-spectrum β-lactamase
ESPAUR	English Surveillance Programme for Antimicrobial Utilisation and Resistance
EUCAST	European Committee on Antimicrobial Susceptibility Testing

Term	Definition
GBS	Group B *Streptococcus*
GLASS	Global Antimicrobial Resistance and Use Surveillance System
GnSOP	Gram-negative Surveillance Outcome Program
GP	general practitioner
HAI	healthcare-associated infection
HA-MRSA	healthcare-associated methicillin-resistant *Staphylococcus aureus*
HCTM	Hospital Canselor Tuanku Muhriz
HITH	Hospital in the Home
HLR	high-level resistance
LHD	Local Health District
LLR	low-level resistance
MBS	Medicare Benefits Schedule
MDR	multidrug-resistant
MDR-TB	multidrug-resistant tuberculosis
MEC	minimum effective concentration
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
NFRC	National Federation Reform Council
NIP	National Immunisation Program
NNDSS	National Notifiable Diseases Surveillance System
NNN	National Neisseria Network
NPAAC	National Pathology Accreditation Advisory Council
NSQHS	National Safety and Quality Health Service
NSW	New South Wales
NT	Northern Territory
OBD	occupied bed day

Term	Definition
OECD	Organisation for Economic Co-operation and Development
OPAT	Outpatient Parenteral Antimicrobial Therapy
OT	operating theatres/recovery
pAmpC	plasmid-borne AmpC
PBS	Pharmaceutical Benefits Scheme
PRN	'pro re nata', meaning there is no scheduled administration for the medication
QALY	quality-adjusted life year
Qld	Queensland
RMT	ribosomal methyltransferase
RPBS	Repatriation Pharmaceutical Benefits Scheme
SA	South Australia
SA3	Statistical Area Level 3
SEIFA	Socio-Economic Indexes for Areas
SH-UHN ASP	Sinai Health-University Health Network Antimicrobial Stewardship Program
SNP	Sullivan Nicolaides Pathology
SONAAR	Scottish One Health Antimicrobial Use and Antimicrobial Resistance
Tas	Tasmania
TG	*Therapeutic Guidelines: Antibiotic*
UMMC	University Malaya Medical Centre
URTI	upper respiratory tract infection
UTI	urinary tract infection
Vic	Victoria
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.
Anatomical Therapeutic Chemical (ATC) classification	An internationally accepted classification system for medicines that is maintained by the World Health Organization (WHO). 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 antibacterial, antifungal, antiviral and antiparasitic agents. When the surveillance data include only antibacterials, the term 'antibacterial' is used. The terms antibacterial and antibiotic have the same meaning.
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)	A systematic approach to reduce the risks associated with increasing antimicrobial resistance and to extend the effectiveness of antimicrobial treatments. AMS may incorporate a broad range of strategies, including governance, monitoring, reviewing and promoting appropriate antimicrobial use.
antimicrobial susceptibility test (AST)	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 48 hours or less after they are admitted to a hospital, or if collected in the community, outpatient clinics or emergency departments.
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 (WHO). 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.
defined daily dose (DDD) per 1,000 people per day	Sales or prescription data about medicine use in the community can be expressed as defined daily doses (DDD) per 1,000 people per day to give a population estimate for the use of a medicine (or group of medicines). For example, 10 DDD 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.

Term	Definition
defined daily dose (DDD) per 1,000 occupied bed days (OBD)	Antimicrobial use in hospitals is usually measured as a rate using occupied bed days (OBD) whereby antimicrobial use (in DDD) 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 (NAUSP), 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. DDD is defined by the WHO.
extended-spectrum β-lactamases (ESBL)	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	A healthcare facility established under Commonwealth, state, or territory legislation as a hospital or a free-standing day procedure unit, and authorised to provide treatment and/or care to patients.
hospital in the home (HITH)	Provision of care to hospital admitted patients in their place of residence as a substitute for hospital accommodation. Place of residence may be permanent or temporary.
hospital-onset	Description applied to an organism that is acquired by a patient at least 48 hours after being admitted to a hospital.
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 2023 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[1,2], 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 (MDR) 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.

Term	Definition
National Safety and Quality Health Service (NSQHS) Standards	The NSQHS Standards were developed by the Australian Commission on Safety and Quality in Health Care (the Commission) in collaboration with the Australian Government, states and territories, the private sector, clinical experts, patients and carers. The primary aims of the NSQHS Standards are: • To protect the public from harm • To improve the quality of health service provision. They provide a quality assurance mechanism that tests whether relevant systems are in place to ensure that expected standards of safety and quality are met.
occupied bed days (OBD)	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 OBD.
Outpatient Parenteral Antimicrobial Therapy (OPAT)	The delivery of antimicrobials to patients that require longer-term durations of antimicrobials administered by any route other than orally. The antimicrobials are usually administered by clinical staff at either the patient's home or in an ambulatory care facility.
OrgTRx	The Queensland Health information technology platform that is used for the Australian Passive AMR Surveillance (APAS) 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)	The PBS Schedule lists all of the medicines available to be dispensed to patients at a Government-subsidised price.
Primary Health Network (PHN)	PHNs are independent organisations funded by the Australian Government to manage health regions. A board oversees their work and clinical councils and community advisory committees provide advice. The goals of PHNs are to: • Improve the efficiency and effectiveness of health services for people, particularly those at risk of poor health outcomes • Improve the coordination of health services and increase access and quality support for people.
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.[3]
susceptibility	Where there is a high likelihood of therapeutic success using a standard dosing regimen of the agent or when there is a high likelihood of therapeutic success because exposure to the agent is increased by adjusting the dosing regimen or by 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.

Term	Definition
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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