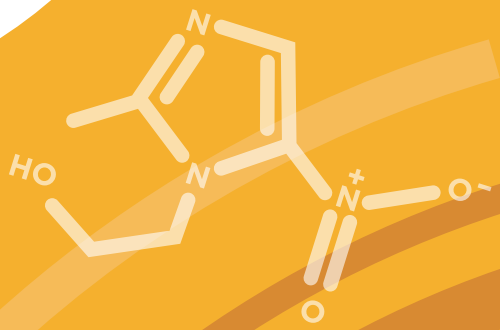
AUSTRALIAN COMMISSION
ON SAFETY AND QUALITY IN HEALTH CARE

Government of South Australia
SA Health

Antimicrobial use in Australian hospitals

2015 annual report

National Antimicrobial Utilisation Surveillance Program



AURA
Antimicrobial Use and Resistance in Australia

NAUSP
National Antimicrobial Utilisation Surveillance Program

Antimicrobial use in Australian hospitals

2015 annual report
of the
National Antimicrobial Utilisation Surveillance Program

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Abbreviations

AIHW	Australian Institute of Health and Welfare
AMS	antimicrobial stewardship
AURA	Antimicrobial Use and Resistance in Australia
DDD	defined daily dose
ICU	intensive care unit
NAPS	National Antimicrobial Prescribing Survey
NAUSP	National Antimicrobial Utilisation Surveillance Program
OBD	occupied bed day
SA Health	South Australian Department for Health and Ageing
WHO	World Health Organization

Executive summary

Patients in Australian hospitals are benefiting from more appropriate use of antibiotics. Total-hospital antibacterial use during 2015 was 7.6% less compared with 2011. This improvement is due to hospitals and clinicians implementing effective antimicrobial stewardship (AMS) programs that ensure patients receive the most appropriate antibiotic treatment. This improvement in appropiate antibiotic treatment will reduce the emergence of antibiotic-resistant bacteria.

Key findings of the analyses of the 2015 National Antimicrobial Utilisation Surveillance Program (NAUSP) data include the following:

- On a defined daily doses (DDDs) per 1000 occupied bed days (OBDs) basis, the 20 antibacterials most frequently dispensed nationally were amoxicillin–clavulanate, cefazolin, amoxicillin, flucloxacillin, doxycycline, cefalexin, piperacillin–tazobactam, ceftriaxone, metronidazole, azithromycin, benzylpenicillin, gentamicin, ciprofloxacin, vancomycin, sulfamethoxazole–trimethoprim, meropenem, trimethoprim, roxithromycin, clindamycin and clarithromycin. Together, these accounted for 93% of antibacterials dispensed in contributing hospitals.
- Use of highly reserved antibacterials such as colistin, daptomycin, linezolid and tigecycline is very low – less than 5 DDDs per 1000 OBDs in most contributing hospitals. Aggregated use of these antibacterials in Principal Referral Hospitals increased in the second quarter of 2015. Variation in usage rates between hospitals is marked. For daptomycin and linezolid, although mean usage rates were low (1.86 and 1.59 DDDs per 1000 OBDs, respectively), the annual usage rates were more than quadruple the mean rate in the hospitals where use was highest.
- For several antibacterial classes, use varies between states and territories. The classes with the greatest variation are aminoglycosides and antipseudomonal penicillin combinations. Use of aminoglycosides is about one-third to one-quarter lower in Victoria and Western Australia than in other states and territories. Usage rates of antipseudomonal penicillin combinations are about 50% higher in Western Australia than in other states and territories.
- Australian usage rates continue to be higher than in the Netherlands and Sweden, but are now lower than in Denmark.[4-6] Broader comparisons with other countries are limited by differences in data collection methods and units of measurement.

The South Australia Department of Health and Ageing (SA Health) and the Australian Commission on Safety and Quality in Health Care (the Commission) are committed to supporting strategies to continue to enhance antimicrobial stewardship (AMS) in Australia.

NAUSP is a key program partner of the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System, which the Commission established with funding provided by the Australian Government Department of Health. NAUSP provides standardised measurement of antimicrobial use in Australian adult public and private hospitals.

NAUSP is an important tool for hospitals to support their local AMS programs, and to meet the requirements for accreditation against National Safety and Quality Health Service (NSQHS) Standard 3: Preventing and Controlling Healthcare Associated Infections.[1] The NSQHS Standards were developed by the the Commission to protect the public from harm and to improve the quality of care provided by health service organisations through the implementation of quality assurance and quality improvement mechanisms.

NAUSP directly supports implementation of the Australian Government's first National Antimicrobial Resistance Strategy[2,3] and initiatives to improve the appropriate use of antimicrobials. It does this by:

- Providing data to enable monitoring of compliance with best-practice AMS and to enable feedback on antimicrobial prescribing to prescribers

- Enabling states and territories to develop and implement specific local initiatives to support AMS in hospital settings
- Providing data to strengthen existing measures that support appropriate use of antimicrobials
- Providing flexible and useful benchmarking within hospitals (across units and wards), between hospitals, and between states and territories.

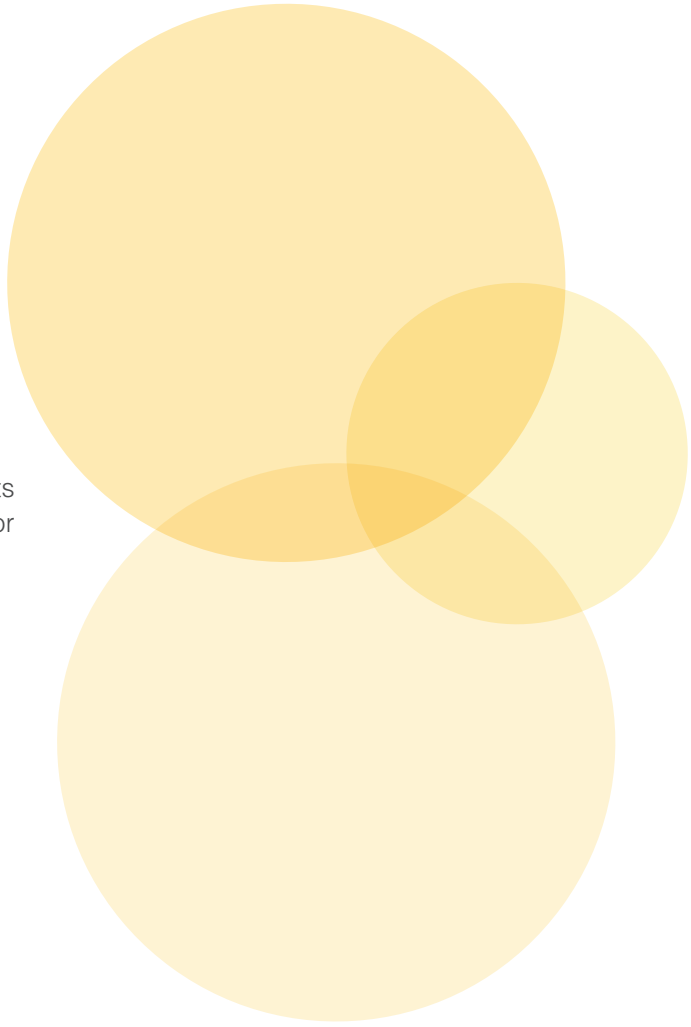
Findings from NAUSP help to strengthen AMS programs by increasing awareness of prescribing and usage patterns, and providing data for education of health professionals, targeted quality improvement and monitoring of performance over time.

Since 2008, all Australian states and territories have been represented in the program. The number of hospitals participating in NAUSP has increased each year. From 2011 to 2015, participation increased from 69 to 159 hospitals.

In 2015, data from 159 hospitals (138 public and 21 private) were included in the analyses. All Principal Referral Hospitals and almost 85% (90/106) of Public Acute Group A and B Hospitals participated in the program.

During 2015, the aggregate annual rate for total-hospital antibacterial use was 916.4 defined daily doses (DDDs) per 1000 occupied bed days (OBDs), an apparent decrease of 2% compared with the 2014 rate, and a decrease of 7.6% compared with the 2011 rate (992.4 DDDs per 1000 OBDs).

SA Health developed and activated a web portal for data submission in 2016. Further enhancements are under way to increase reporting functionality for contributing hospitals.



Introduction

Antimicrobial resistance is a major public health concern, contributing to poor patient outcomes, morbidity, mortality and substantial costs to the healthcare system. The September 2016 United Nations declaration on antimicrobial resistance reinforces the World Health Organization's Global Action Plan on Antimicrobial Resistance.[7] Australia, as a signatory to the United Nations declaration, is well placed to contribute effectively to the global response through implementation of its first National Antimicrobial Resistance Strategy 2015–2019.[2] Surveillance programs such as the National Antimicrobial Utilisation Surveillance Program (NAUSP) support improved understanding of the use of antimicrobials in hospitals and raise awareness among health professionals about how to prevent antimicrobial-resistant infections.

NAUSP is a key program partner of the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System, which the Australian Commission on Safety and Quality in Health Care (the Commission) established with funding provided by the Australian Government Department of Health. The AURA Surveillance System plays a pivotal role in informing local, state, territory and national policy, and in the development of strategies to prevent and contain antimicrobial resistance in Australia.

NAUSP focuses on standardised measurement of antimicrobial use in Australian adult public and private hospitals. It is administered by the Infection Control Service, Communicable Disease Control Branch, at the South Australia Department Health and Ageing (SA Health). Development and implementation of NAUSP have been an ongoing collaboration between SA Health and the Commission since 2013.

In 2015, the Australian Government released Australia's first National Antimicrobial Resistance Strategy 2015–2019, which outlines a framework to address antimicrobial resistance using an integrated and coordinated One Health approach.[2] The Implementation Plan that supports the strategy was released in November 2016.[3]

NAUSP supports achievement of the objectives of the national strategy by facilitating monitoring of antimicrobial use to enable implementation of antimicrobial stewardship (AMS) practices that improve the appropriate use of antimicrobials.

Since it began in July 2004, NAUSP has diversified and grown into a program that supports the challenges of AMS across Australian adult hospitals. The data available from NAUSP have contributed to local, state and territory, and national antimicrobial prescribing strategies to improve the quality of care delivered to patients.

Hospitals contribute to NAUSP voluntarily. The number of hospitals has more than doubled since the endorsement of the National Safety and Quality Health Service (NSQHS) Standards in 2011. Participation in NAUSP supports successful implementation of NSQHS Standard 3: Preventing and Controlling Healthcare Associated Infections.

This report is the second of its kind for NAUSP. It includes analyses of national data on antimicrobial use in 159 public and private adult acute care hospitals in 2015. For public hospitals, this represents approximately half of all facilities categorised by the Australian Institute of Health and Welfare (AIHW) as Principal Referral Hospitals, Public Acute Group A Hospitals, Public Acute Group B Hospitals or Public Acute Group C Hospitals. A growing number of private hospitals are participating in NAUSP.

All Australian states and territories were represented in NAUSP in 2015; 31 hospitals have contributed continuously since July 2004, and 13 South Australian hospitals have contributed continuously since the program began there in 2001. Figure 1 and Table 1 show the growth in the number of hospitals participating in NAUSP since 2004. All Principal Referral Hospitals, and more than 80% of Public Acute Group A and Public Acute Group B Hospitals now participate in the program.

This report includes historical comparisons over five and 10 years, and international comparisons, as appropriate.[4-6] Interstate and intrastate data are presented, along with comparisons of antimicrobial usage rates between hospital peer groups for selected antibacterial classes.

Effective surveillance of inpatient antimicrobial use requires quantitative measures and data against which hospitals can benchmark their use. This benchmarking provides a baseline, and allows continual feedback for hospital AMS activities and interventions.

Figure 1 Number of public and private hospitals that have contributed to NAUSP, 2004–15

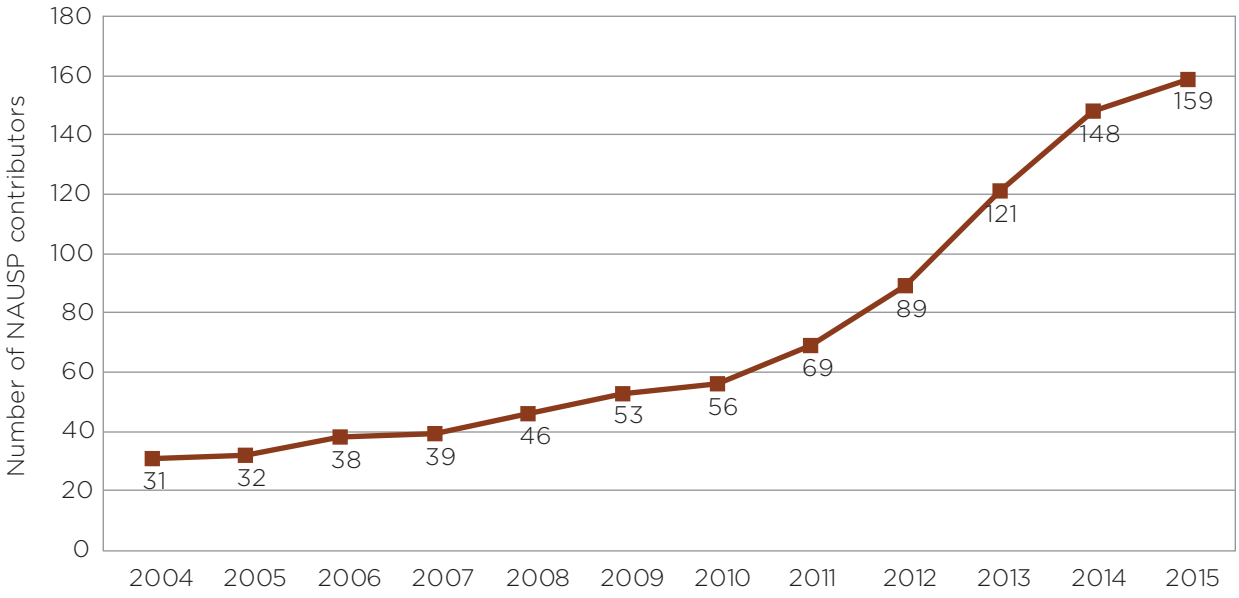


Table 1 Annual number of NAUSP contributor hospitals (public and private), by peer group, 2005–15

Year	Australian hospital peer group[a]									
	Principal Referral	Public Acute Group A	Public Acute Group B	Public Acute Group C	Specialist Women's Hospitals	Private Acute Group A	Private Acute Group B	Private Acute Group C	Unpeered	Total
2005	13	7	4	3	0	2	3	0	0	32
2006	15	9	6	3	0	2	3	0	0	38
2007	15	9	7	3	0	2	3	0	0	39
2008	17	9	9	3	0	4	3	0	1	46
2009	18	13	11	3	0	4	3	0	1	53
2010	18	15	11	3	0	5	3	0	1	56
2011	20	21	12	3	1	6	4	1	1	69
2012	25	32	14	3	2	7	4	1	1	89
2013	29	45	23	4	2	8	6	3	1	121
2014	29	53	32	10	3	9	7	4	1	148
2015	30	55	36	12	4	9	7	5	1	159

a Hospitals that contributed to NAUSP during the period 2005–15 have been assigned to AIHW 2015 peer groups.[8]

Methods

Contributing hospitals

Public and private hospitals contribute data voluntarily to NAUSP throughout each year.

Table 2 shows the numbers of public and private hospitals that contributed to NAUSP in 2015, by state and territory, and AIHW peer group classification. The number of contributing hospitals, and the number with intensive care units, vary from year to year. Because the Northern Territory and the Australian Capital Territory had only one contributing hospital each, their results have been included with Queensland and New South Wales, respectively.

As hospitals join the program, data from up to 12 months before the date on which they joined may be contributed to NAUSP. These data are incorporated into subsequent reports, which may result in variations from previous reports. Hospitals must have submitted at least six months of data to be included in the analyses for this report.

The AIHW criteria used to classify hospitals were reviewed in 2013, and new peer groups were adopted for the 2014 NAUSP annual report.[9]

Peer groups were further reviewed and amended to include private hospital peer groups in November 2015. For the current report, the 2015 hospital peer group classification was used for benchmarking and analyses. A small number of recently opened hospitals had not been assigned to a peer group by the AIHW at the time of the analyses. These facilities were assigned to peer groups for the analyses on the basis of hospital size and activity.

Historically, private hospitals have been assigned to an appropriate AIHW public hospital peer group for analyses of NAUSP data for annual reports, and for routine bimonthly and annual reporting. This convention will continue until private hospital representation increases sufficiently to allow reporting in accordance with the AIHW private hospital peer group classifications. In this annual report, private hospital data have been included in intrastate usage rate analyses, where the hospitals are de-identified, and in aggregated statewide and peer group analyses.

Table 2 Public and private hospitals that contributed to NAUSP, by state and territory, and hospital peer group, 2015

	Peer group									
State or territory	Principal Referral	Public Acute Group A	Public Acute Group B	Public Acute Group C	Specialist Women's Hospitals	Private Acute Group A	Private Acute Group B	Private Acute Group C	Unpeered	Total
ACT and NSW	12	22	15	3	0	0	0	0	1	53
NT and Qld	6	12	7	5	1	5	1	1	0	38
SA	2	4	4	3	1	2	4	1	0	21
Tas	1	2	1	0	0	0	0	1	0	5
Vic	6	11	7	0	1	1	1	2	0	29
WA	3	4	2	1	1	1	1	0	0	13
Total	**30**	**55**	**36**	**12**	**4**	**9**	**7**	**5**	**1**	**159**

Data elements

Pharmacy departments of participating hospitals supply NAUSP with aggregate monthly details of antimicrobials issued to individual inpatients and ward imprest supplies (that is, ward stock managed by the pharmacy) via dispensing reports. Hospital occupancy data are collected in the form of overnight occupied bed days (OBDs).

NAUSP assigns each contributing hospital a unique code. The code is used to report in a de-identified way on usage rates of selected antimicrobials and therapeutic groups.

Units of measurement

Antimicrobial surveillance data are reported as usage rates. Quantities of antimicrobials are aggregated over the period of interest at hospital level and converted to standardised usage rates – these are based on the World Health Organization (WHO) definition of defined daily dose (DDD), with 1000 OBDs as the denominator. The DDD for any medicine is the average maintenance dose per day for an average adult for the main indication of the medicine. A limitation of using the DDD as defined by WHO is that, occasionally, the DDD does not match usual daily doses used in Australian hospital clinical practice (see Appendix 1 for more information). At present, NAUSP uses WHO DDDs so that comparisons can be made with international surveillance programs.

Values calculated from raw data submitted to NAUSP include:

- The DDDs of the antibacterial
- The aggregate number of grams of the antibacterial used for a month
- Monthly antibacterial usage rates (as DDDs per 1000 OBDs)
- Three- or five-month moving averages of the usage rates.

Standardised usage density rates are widely accepted as appropriate measures of adult medicine use in non-ambulatory settings, and are adopted by international antimicrobial surveillance programs.[4-6] Use of an internationally established standard rate enables comparison of usage data for antibacterials that have different doses, aggregation of data to assess use by antibacterial class, and comparisons with data from other surveillance programs or studies. However, such comparisons need to be made with care because of variations in the casemix of patients and in international healthcare practices.

Data quality

Automated and manual processes are used to validate all data submitted to NAUSP. The database used provides alerts when quantities fall outside a usual or expected range. This enables verification of data at an early stage of data submission. Rolling data validation activities are undertaken monthly, and additional checks are made before production of the annual report. Semi-automated statistical algorithms are used to compare data with previous submissions, detect irregular values, validate suspect values against original contributor data and processed usage data, and confirm denominator and numerator data that are used to calculate usage rates. Pharmacists are involved in this process, enabling NAUSP officers to apply reasoned and skilled judgement, and to notify contributors of any anomalies that require attention or resubmission of data.

Records of data validation activities undertaken in 2015 revealed that 5917 individual data entries were manually checked, with 91 (1.54%) errors detected. Types of errors detected and corrected included:

- Inadvertent inclusion of antimicrobials issued to excluded wards or to patients as discharge supplies
- Unused antimicrobials being returned to pharmacy without being subtracted from the hospital's antimicrobial usage
- Antimicrobials assigned an incorrect alias by NAUSP during data loading
- Incorrect parameter settings for automated usage and OBD reports generated by contributors
- Incomplete or inaccurate data as a result of changes in contributors' data download methods.

The NAUSP team alerts contributors if data are suspected to be erroneous. However, each contributing site is responsible for the accuracy of its data.

Data exclusions

Data collected by NAUSP exclude:

- Most topical antimicrobial formulations (except some inhalations), antimycobacterials (except rifampicin), antifungals, antivirals, antiparasitics, and infusor packs of antibacterials for use outside hospital settings
- Antimicrobial use in paediatric hospitals, and paediatric wards and neonatal units within general hospitals – use in this population cannot easily be translated into a standard usage density rate based on the WHO definition of DDDs
- Antimicrobial use for outpatient areas, discharge prescriptions and external services (for example, hospital in the home), to ensure that data reflect in-hospital use of antimicrobials
- Antimicrobials issued by pharmacies to individuals and wards classified as specialty areas, such as psychiatric, rehabilitation, dialysis and day-surgery units.

Data classification, restrictions and limitations

Data provided to NAUSP do not include the indication for which antimicrobials are used, or any patient-specific data. Although some contributing hospitals provide data on ward-by-ward antimicrobial consumption, data for specialist areas (with the exception of intensive care units) have not generally been available.

This report presents usage rates for the most commonly used antibacterials and antibacterial classes.[a] A comprehensive list of antimicrobials for which data are collected by NAUSP, the WHO Anatomical Therapeutic Classification and the DDD for each route of administration are available from the NAUSP website.[b]

The NAUSP cohort is heavily weighted towards large public hospitals, where AMS activities are generally well established. NAUSP has removed restrictions on participation that were based on minimum bed numbers. Participant hospitals are required to meet the criteria for categorisation into one of the eight AIHW peer groups: Principal Referral Hospital; Specialist Women's Hospital; Public Acute Group A, B or C Hospitals; or Private Acute Group A, B or C Hospitals.

The data presented in this report are correct at the time of publication, and reflect usage rates based on data on antibacterial quantities and OBDs supplied by individual contributors. Minor discrepancies between annual reports may occur as a result of data submitted retrospectively by contributing hospitals.

a Because this report is confined to reporting on use of systemic antibacterials in Australian hospitals, the term 'antibacterial' is used when referring to the output of analyses of the NAUSP data, and when comparisons are made with data reported by other countries.

b www.sahealth.sa.gov.au/nausp

Overview of antibacterial usage rates

The participating hospitals for 2015 were from the following AIHW peer groups (percentage representation in each hospital peer group is shown in parentheses):

- Principal Referral Hospital – 30 contributors (100%)
- Specialist Women's Hospital – 4 contributors (67%)
- Public Acute Group A Hospital – 55 contributors (89%)
- Public Acute Group B Hospital – 36 contributors (80%)
- Public Acute Group C Hospital – 12 contributors (8%)
- Private Acute Group A Hospital – 9 contributors (41%)
- Private Acute Group B Hospital – 7 contributors (19%)
- Private Acute Group C Hospital – 5 contributors (10%).

Reasons for differences in antibacterial usage rates within and between public and private hospitals are complex; they may include multiple factors, such as:

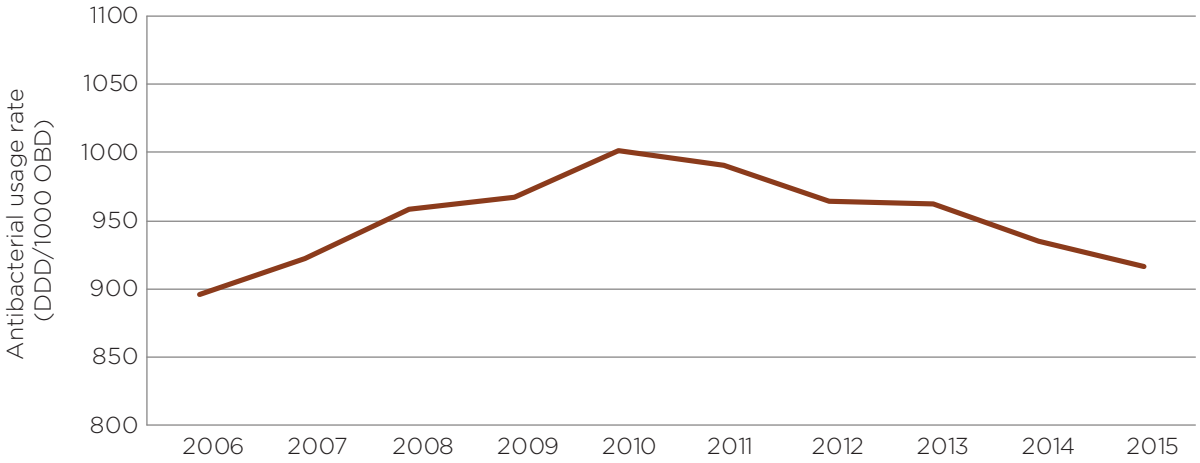
- Differences in casemix
- Differences in antimicrobial resistance rates
- Differences in implementation and impact of AMS programs
- Changes in hospital formularies, policies, protocols and regulation.

Annual usage rates for antibacterial classes

This report covers total in-hospital antibacterial usage data collected from 159 contributor hospitals across Australia, as shown in Table 2.

For January–December 2015, the aggregate total-hospital (intensive care unit plus non-intensive care unit) antibacterial usage rate for all NAUSP contributor hospitals (n = 159) was 916 DDDs per 1000 OBDs (see Figure 2a). This is a 2.1% decrease from 2014, when the total-hospital antibacterial usage rate was 936 DDD per 1000 OBDs (n = 129). The median annual usage rate was 936 DDDs per 1000 OBDs, and the mean usage rate across the 159 institutions was

Figure 2a Annual total-hospital antibacterial usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, 2006–15



957 DDDs per 1000 OBDs (range 322–1808 DDDs per 1000 OBDs).

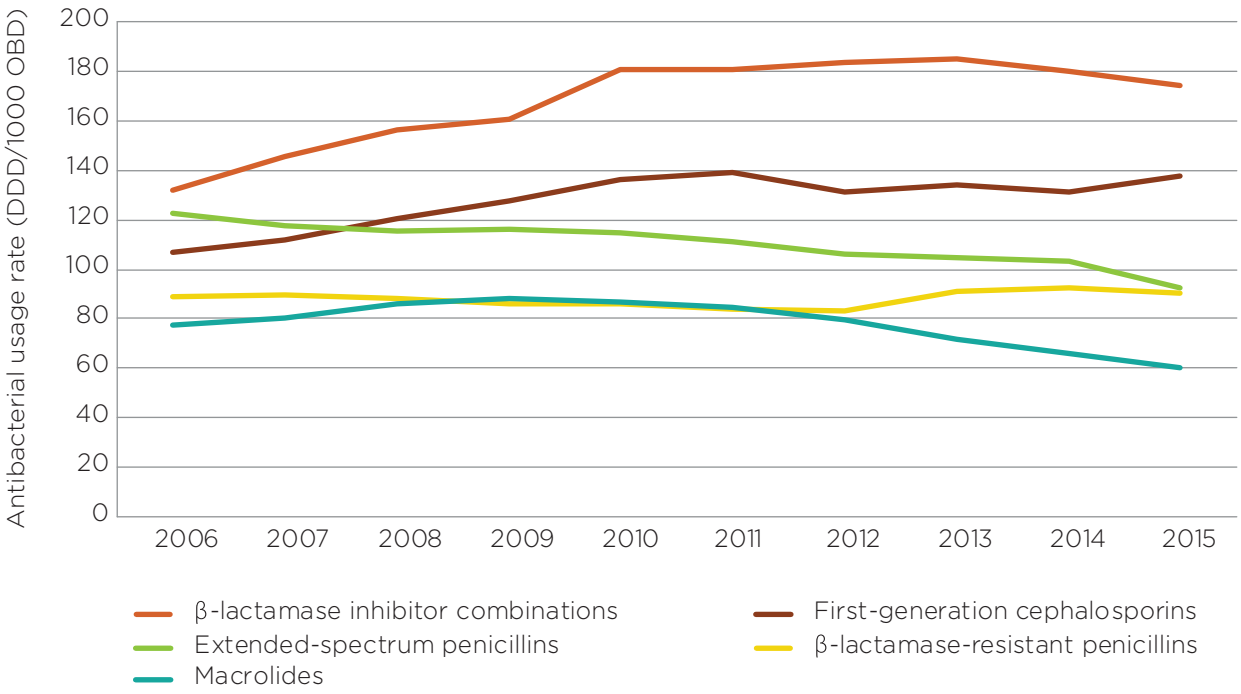
Antibacterial use in hospitals that contribute to NAUSP peaked in 2010, after which there has been a gradual decline, as shown in Figure 2a. Figures 2a–2c show the total-hospital annual aggregate rate of antibacterial use across all peer groups from 2006 to 2015. Figures 3–5 show the trends in usage rates for three of the AIHW hospital peer groups for the same period: Principal Referral Hospitals, Public Acute Group A Hospitals and Public Acute Group B Hospitals. For these analyses, data from Public Acute Group C and Specialist Women's Hospitals were not included because of the low number of contributors.

Table 1 shows the growth in the number of contributors in each hospital peer group during the same period.

The usage rates of five high-use antibacterial classes are shown in Figures 2b, 3b, 4b and 5b. These antibacterial classes have been highlighted because they represent more than 60% of antibacterials used in NAUSP contributor hospitals. Beta-lactamase inhibitor combinations are the antibacterial class used most across all peer groups.

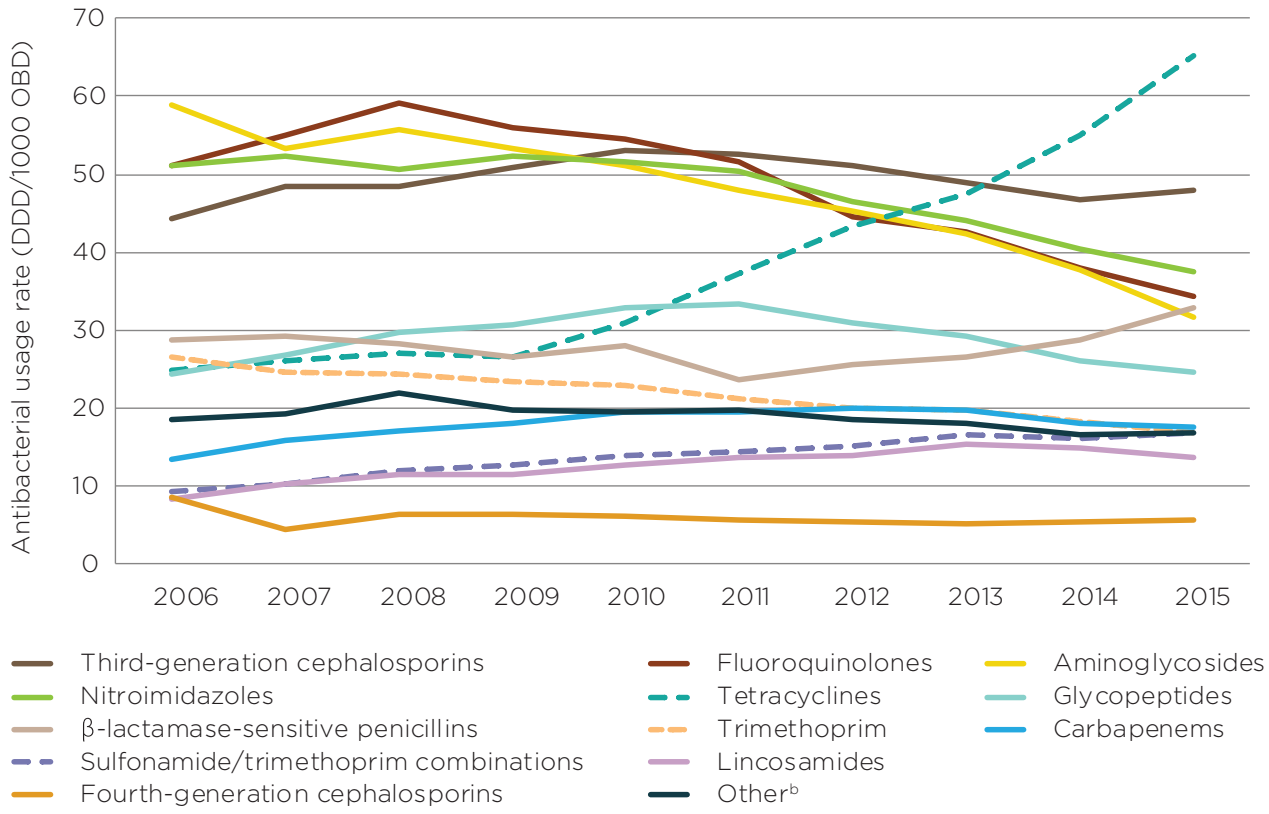
Figures 2c, 3c, 4c and 5c show usage rates for other antibacterial classes. As expected, there is wide variation between peer groups in the usage rates and rankings of antibacterials used.

Figure 2b Annual total-hospital aggregate usage rates (DDD/1000 OBD) for the five most commonly used antibacterial classes[a] in NAUSP contributor hospitals, 2006–15



a The five antibacterial classes represent more than 60% of antibacterials used in NAUSP contributor hospitals from 2006 to 2015.

Figure 2c Annual total-hospital aggregate usage rates (DDD/1000 OBD) for other antibacterial classes[a] in NAUSP contributor hospitals, 2006–15



a Other antibacterial classes combined account for less than 40% of antibacterials used in NAUSP contributor hospitals from 2006 to 2015.

b 'Other' comprises amphenicols, monobactams, nitrofurans, other antibacterials (linezolid and daptomycin), other cephalosporins and penems (ceftaroline), polymyxins, rifamycins, second-generation cephalosporins, steroids (fusidic acid), streptogramins and streptomycins.

Figure 3a Annual total-hospital aggregate antibacterial usage rates (DDD/1000 OBD) in Principal Referral Hospitals that contributed to NAUSP, 2006–15

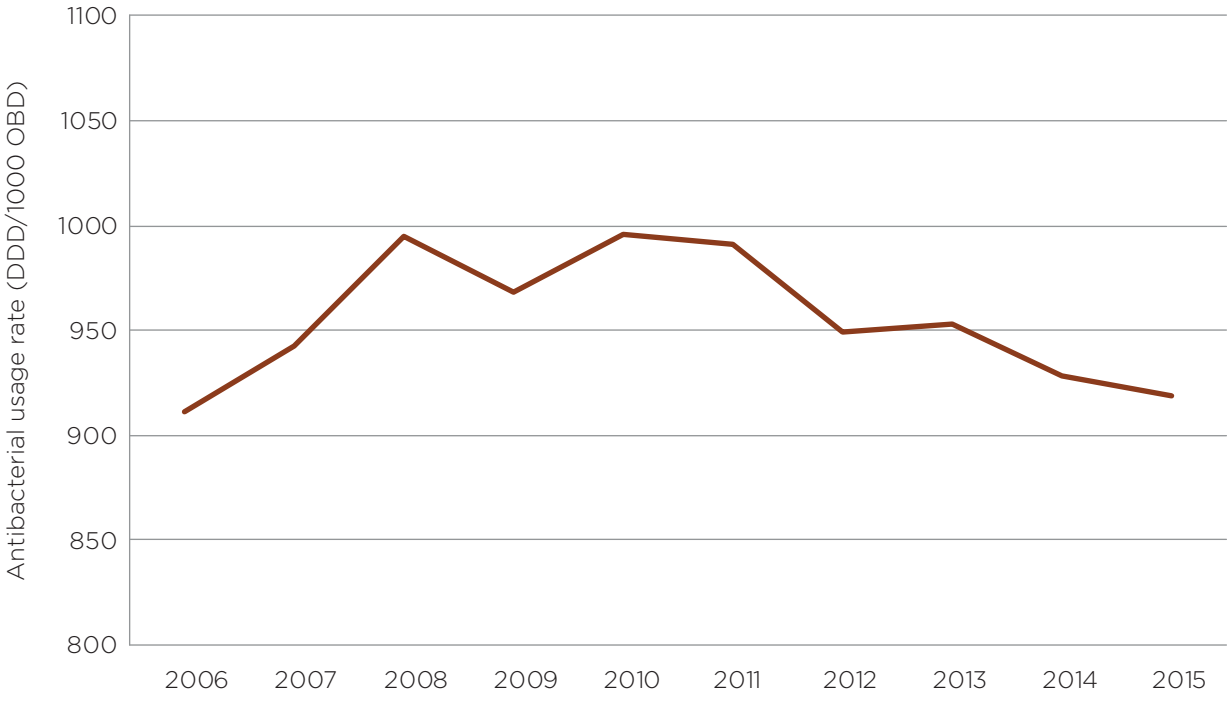


Figure 3b **Annual total-hospital aggregate usage rates (DDD/1000 OBD) for the five most commonly used antibacterial classes in Principal Referral Hospitals that contributed to NAUSP, 2006–15**

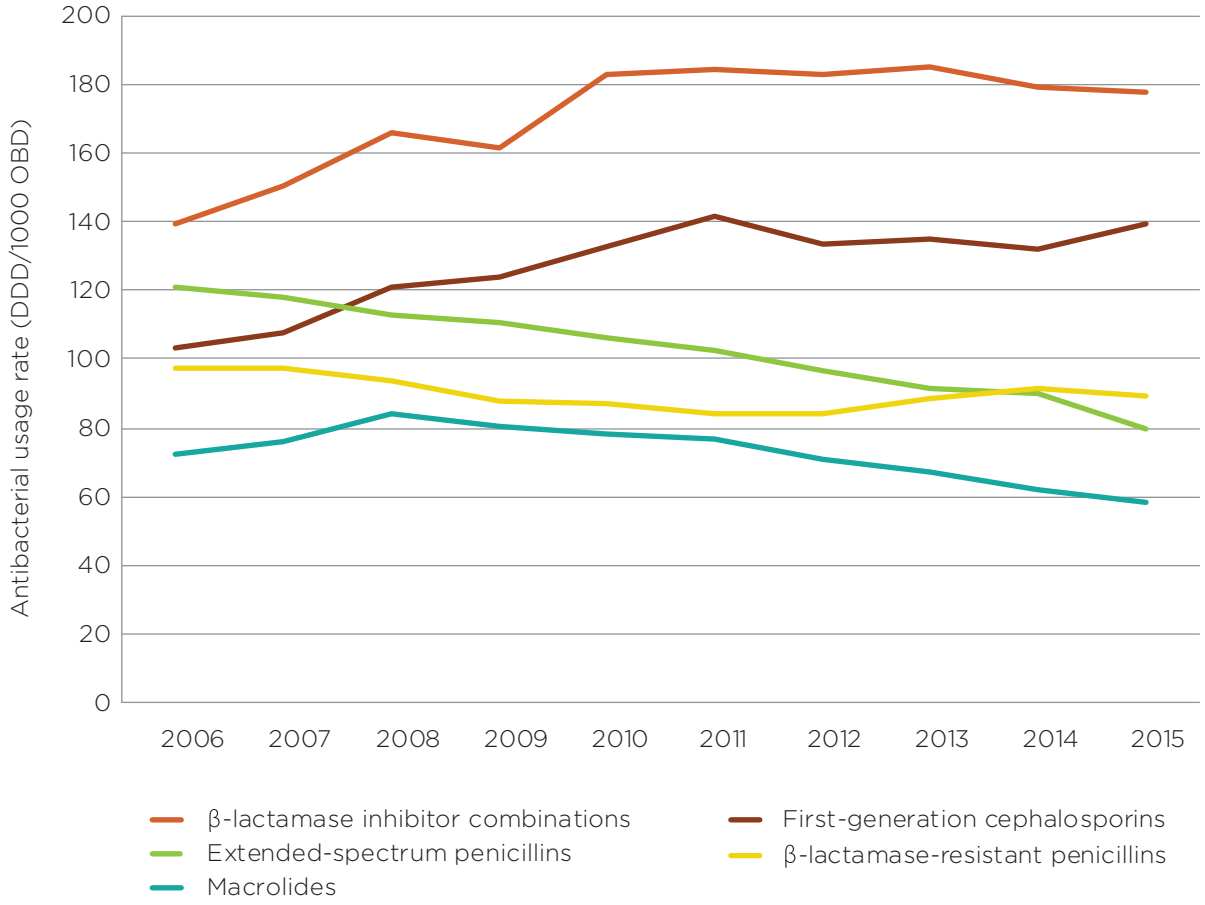
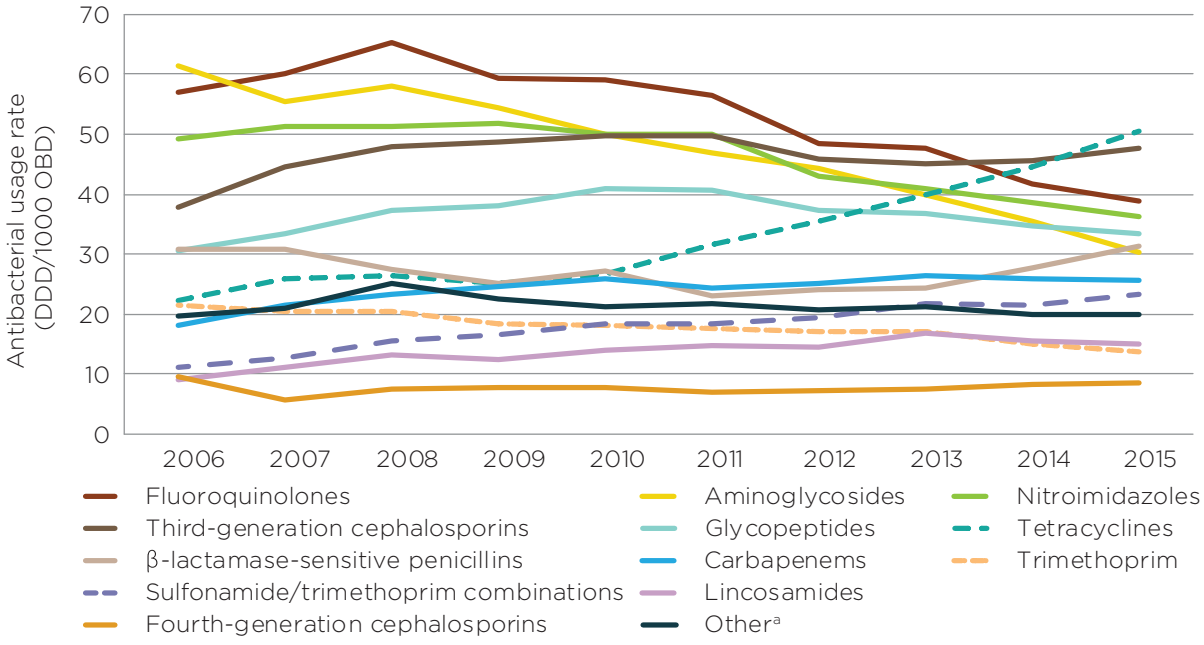


Figure 3c **Annual total-hospital aggregate usage rates (DDD/1000 OBD) for other antibacterial classes in Principal Referral Hospitals that contributed to NAUSP, 2006–15**



a 'Other' comprises amphenicols, monobactams, nitrofurans, other antibacterials (linezolid and daptomycin), other cephalosporins and penems (ceftaroline), polymyxins, rifamycins, second-generation cephalosporins, steroids (fusidic acid), streptogramins and streptomycins.

Figure 4a Annual total-hospital antibacterial usage rates (DDD/1000 OBD) in Public Acute Group A Hospitals that contributed to NAUSP, 2006–15

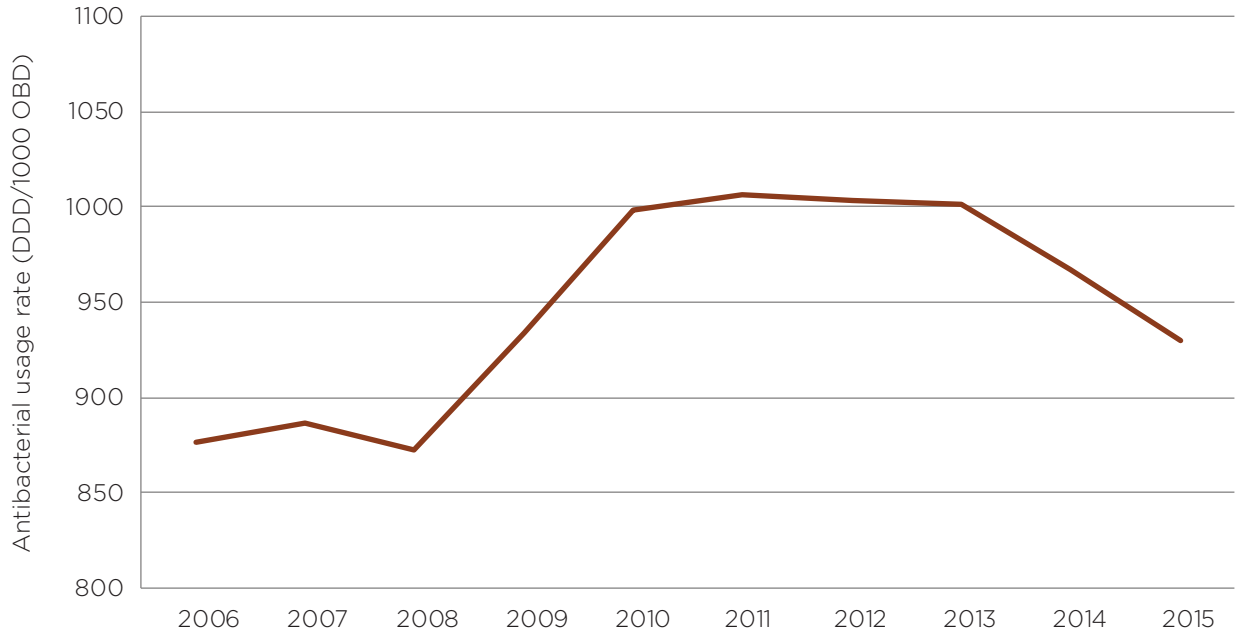


Figure 4b Annual total-hospital antibacterial usage rates (DDD/1000 OBD) for the five most commonly used antibacterial classes in Public Acute Group A Hospitals that contributed to NAUSP, 2006–15

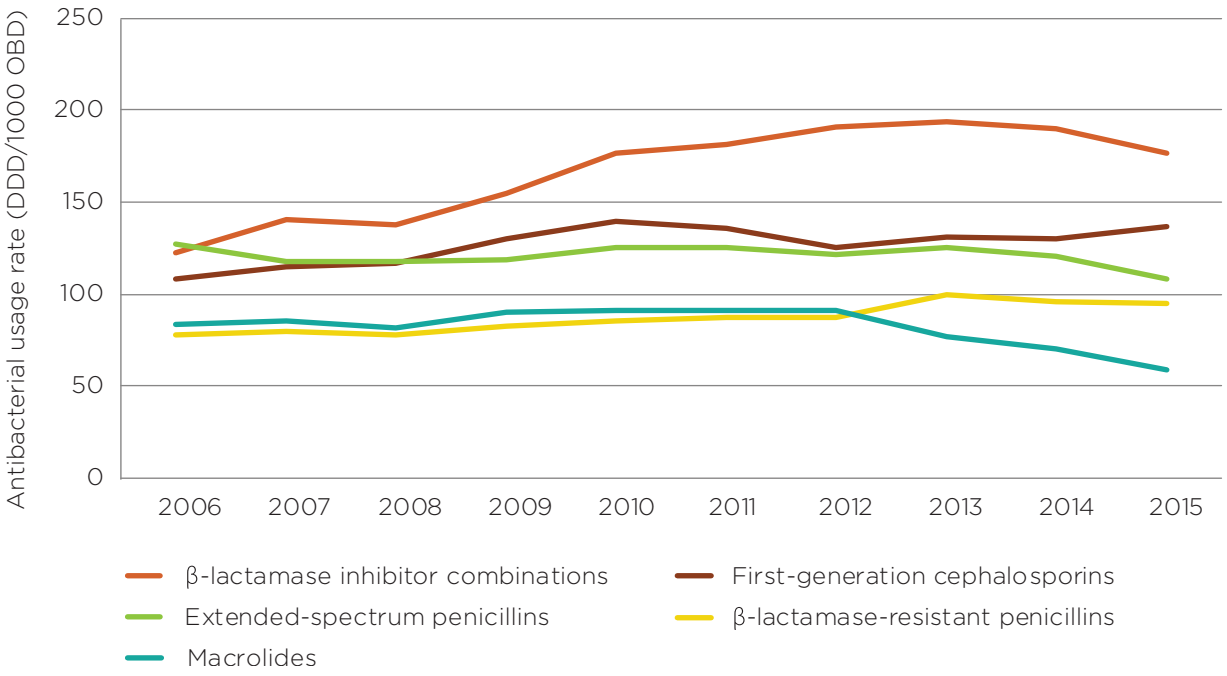
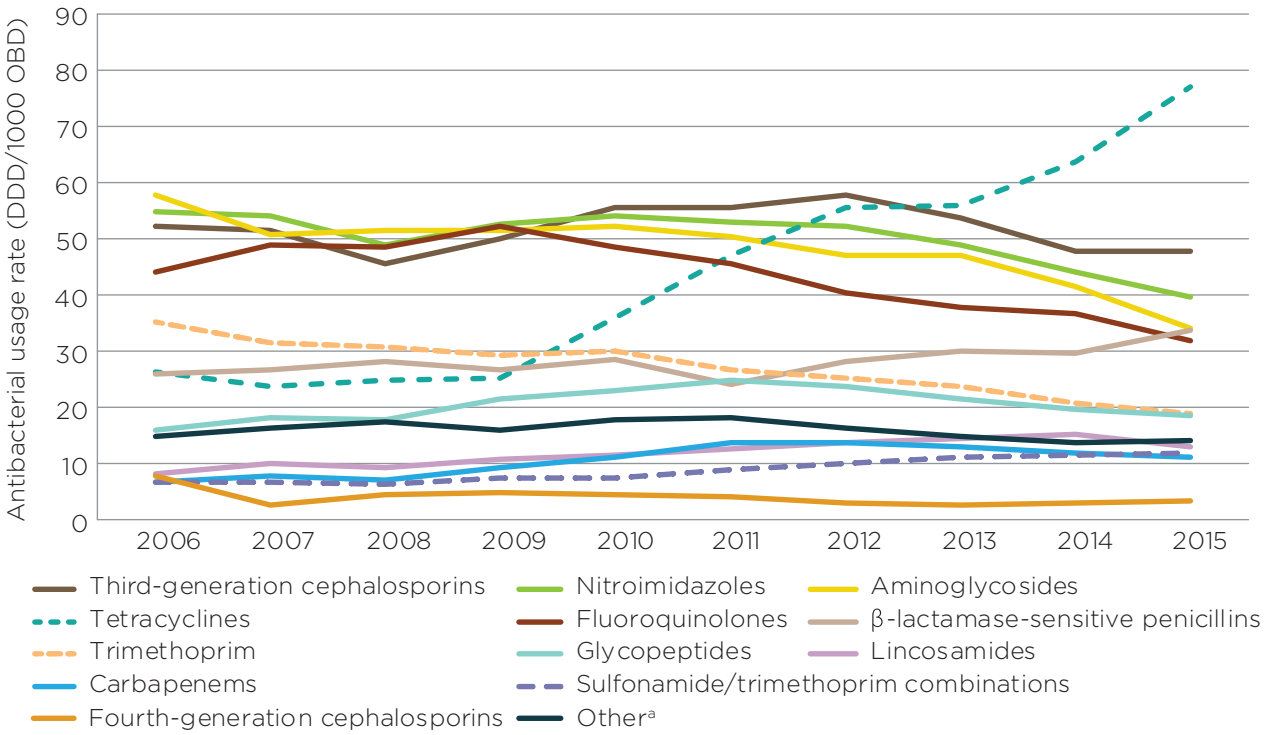


Figure 4c Annual total-hospital antibacterial usage rates (DDD/1000 OBD) for other antibacterial classes in Public Acute Group A Hospitals that contributed to NAUSP, 2006–15



a 'Other' comprises amphenicols, monobactams, nitrofurans, other antibacterials (linezolid and daptomycin), other cephalosporins and penems (ceftaroline), polymyxins, rifamycins, second-generation cephalosporins, steroids (fusidic acid), streptogramins and streptomycins.

Figure 5a Annual total-hospital antibacterial usage rates (DDD/1000 OBD) in Public Acute Group B Hospitals that contributed to NAUSP, 2006–15

Figure 5b Annual total-hospital antibacterial usage rates (DDD/1000 OBD) for the five most commonly used antimicrobial classes in Public Acute Group B Hospitals that contributed to NAUSP, 2006–15

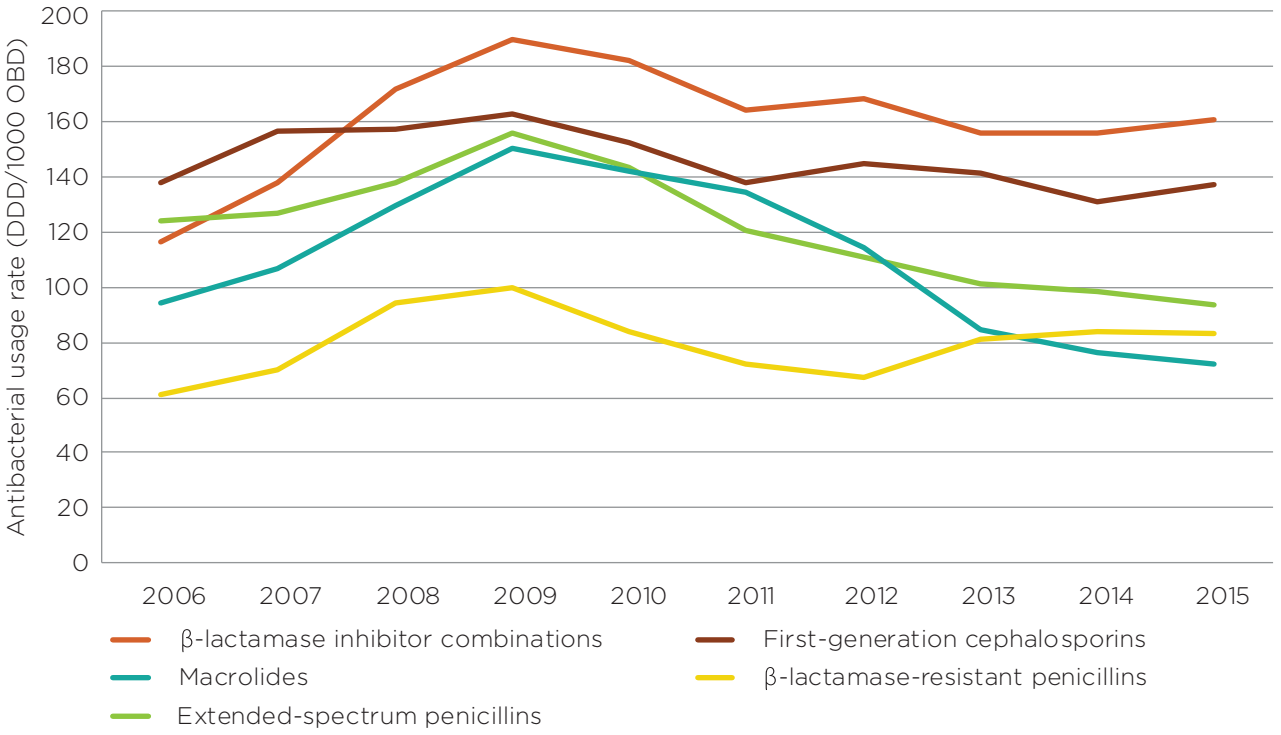
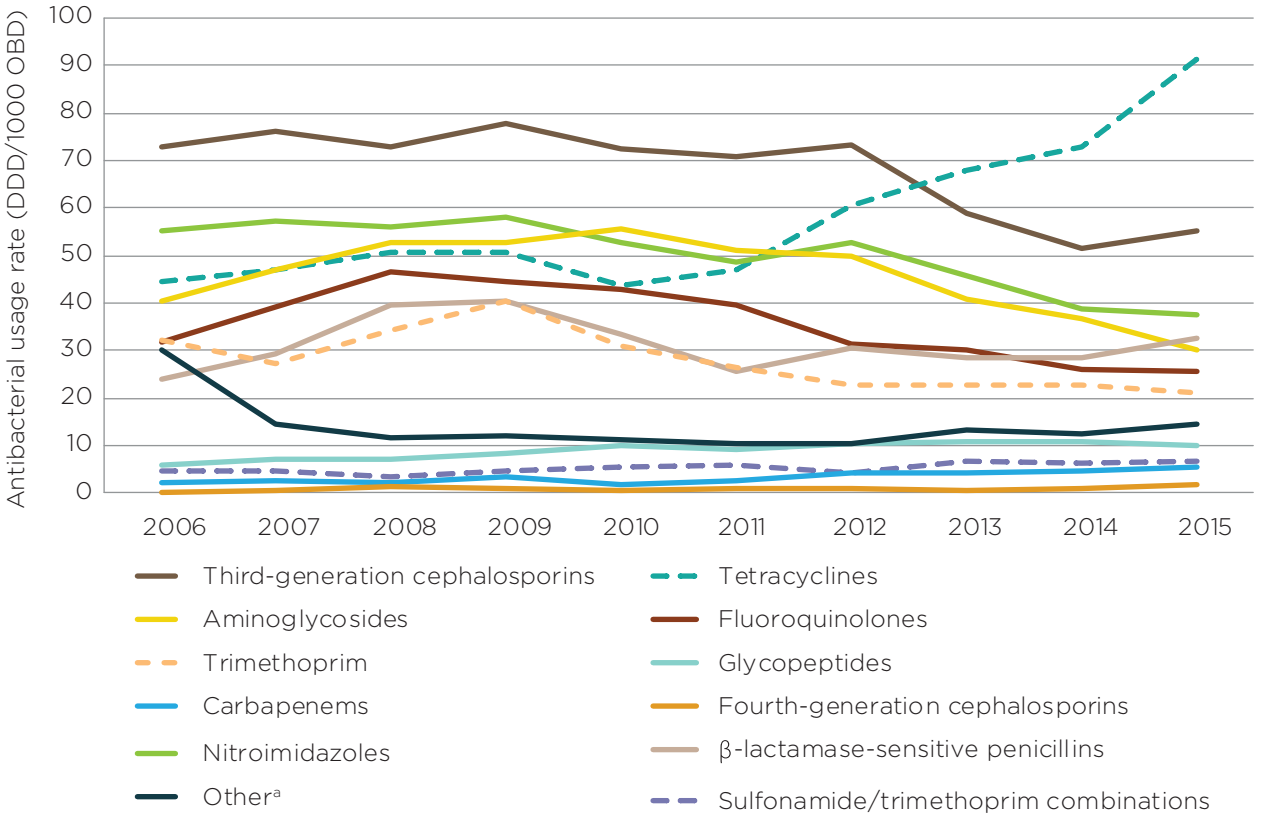


Figure 5c Annual total-hospital antibacterial usage rates (DDD/1000 OBD) for other antibacterial classes in Public Acute Group B Hospitals that contributed to NAUSP, 2006–15



a 'Other' comprises amphenicols, monobactams, nitrofurans, other antibacterials (linezolid and daptomycin), other cephalosporins and penems (ceftaroline), polymyxins, rifamycins, second-generation cephalosporins, steroids (fusidic acid), streptogramins and streptomycins.

Top 20 antibacterials used in public and private hospitals that contributed to NAUSP in 2015

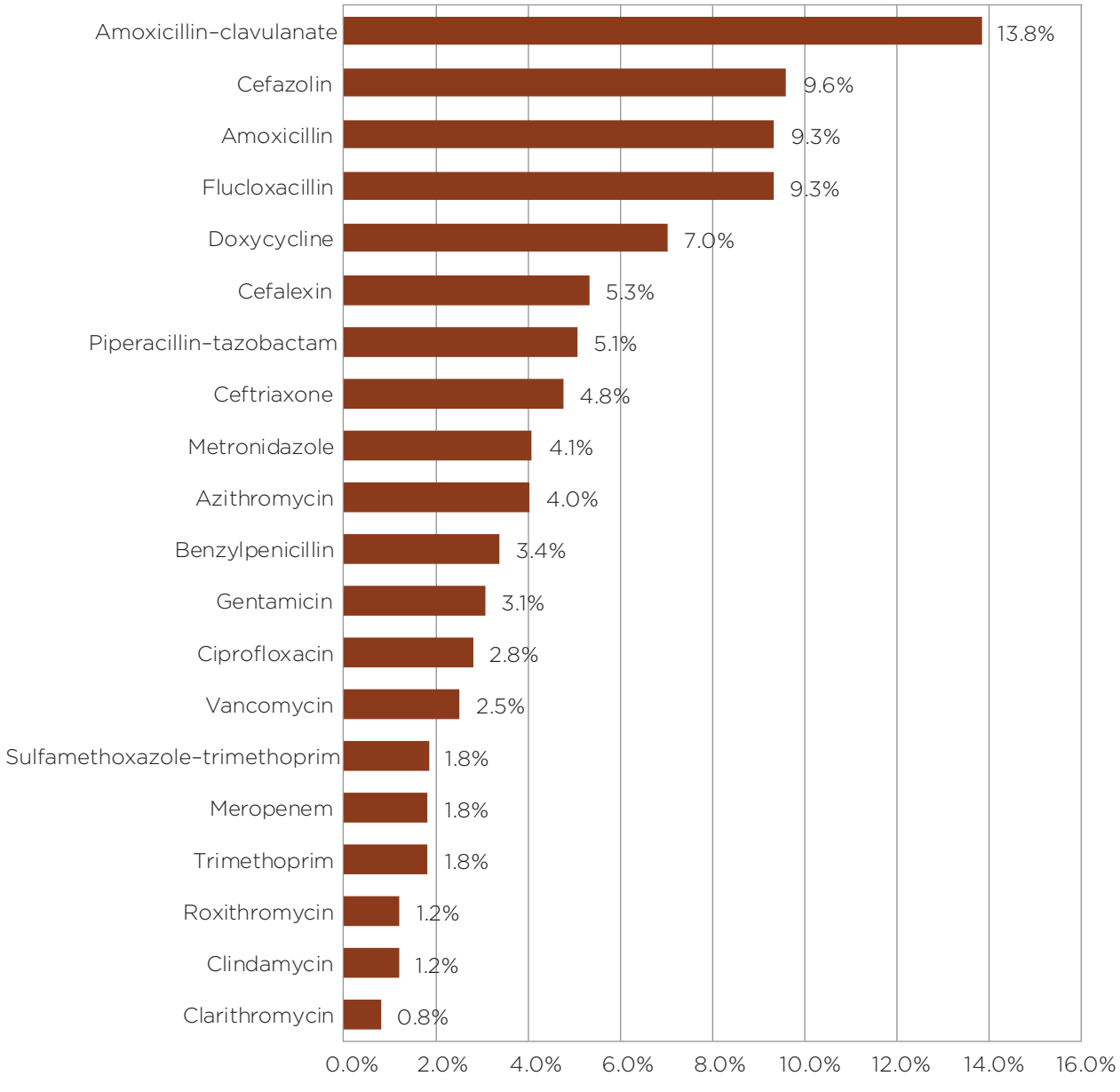
Twenty antibacterials accounted for 93% of all antibacterials used in public and private hospitals that contributed to NAUSP in 2015, on a DDDs per 1000 OBDs basis (Figure 6). Six antibacterials – amoxicillin–clavulanate, cefazolin, amoxicillin, flucloxacillin, doxycycline and cefalexin – represented 54% of antibacterials used in these hospitals. The same usage pattern was reported in the 2014 NAUSP annual report.[9] Ten antibacterials accounted for 72.4% of use.

A slight change in the ranking occurred in 2015 compared with 2014. Cefazolin moved from being the third most frequently used antibacterial to the second. This may reflect updated recommendations for dosing in surgical prophylaxis, with cefazolin doses increasing from 1 gram to 2 grams for many surgical procedures.[10]

Highly reserved antibacterials accounted for very small percentages of total antibacterial use – for example, linezolid (0.12%), daptomycin (0.12%) and colistin (0.07%).

These findings are consistent with those from the National Antimicrobial Prescribing Survey (NAPS), which found that cefazolin, ceftriaxone,

Figure 6 Top 20 antibacterials as a percentage of all antibacterials used in NAUSP contributor hospitals, 2015



metronidazole, amoxicillin–clavulanate and piperacillin–tazobactam were the most commonly prescribed antibacterials in participating hospitals in 2015.[11]

Comparison of antibacterial usage rates by state and territory

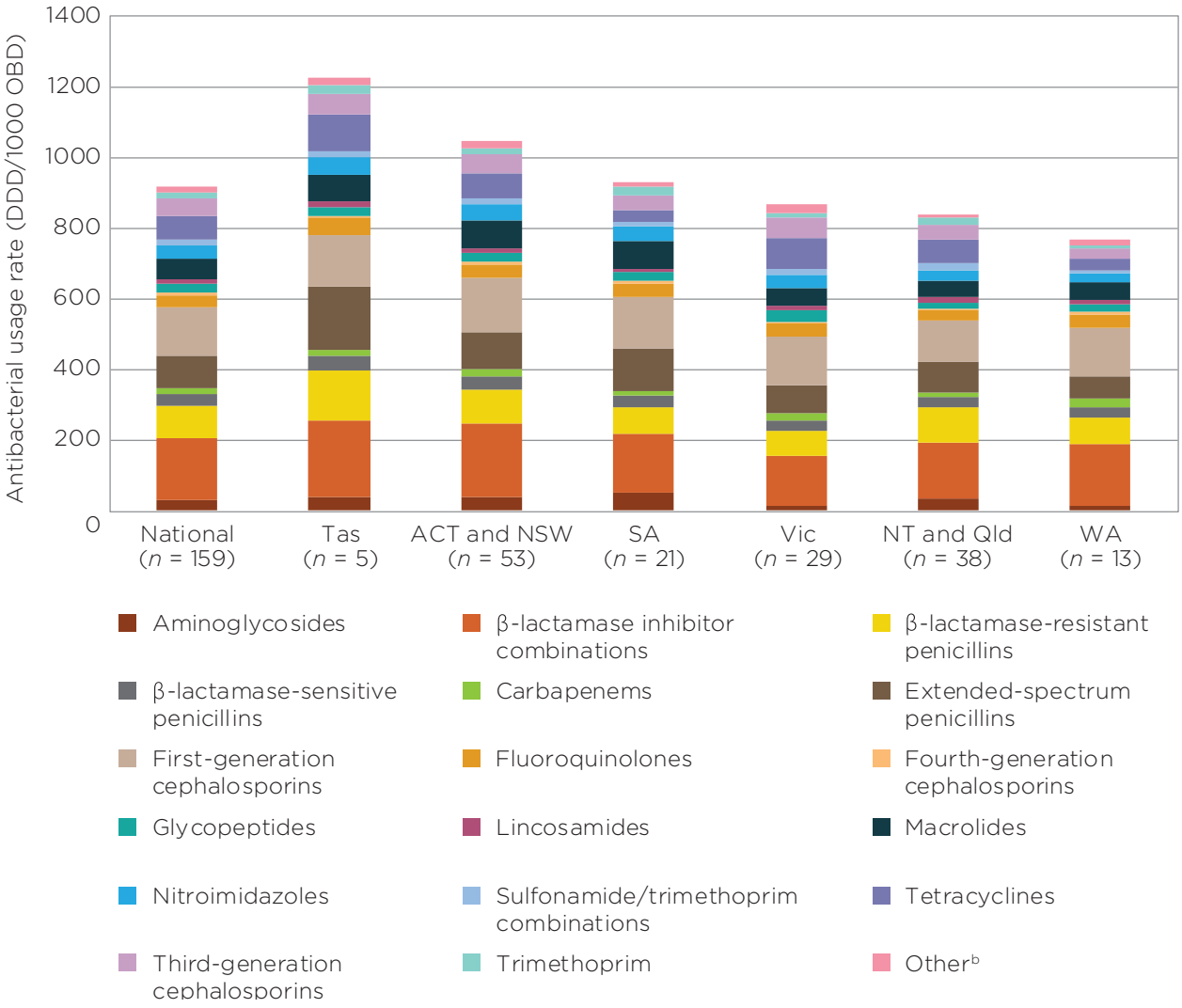
Total-hospital antibacterial usage rates for NAUSP contributors for 2015 are shown by state and territory in Figure 7. Ranking of total-hospital antibacterial use by state and territory is the same as reported in 2014, with the exception of Queensland, which was previously ranked lowest.

A factor that could account for the change in Queensland's ranking is that, in 2015, the data from one Northern Territory hospital that contributed to NAUSP were combined with Queensland hospital data for the analyses. In addition, Queensland public hospital data do not include liquid formulations (estimated to account for 2% of antibacterial use). However, it is not possible to determine whether either of these differences contributed to the change in ranking.

Surveillance of six major antibacterial classes

Six antibacterial classes have formed the basis of NAUSP contributor reports for more than a decade.

Figure 7 Total-hospital aggregate antibacterial usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, 2015



a 'Other' comprises amphenicols, monobactams, nitrofurans, other antibacterials (linezolid and daptomycin), other cephalosporins and penems (ceftaroline), polymyxins, rifamycins, second-generation cephalosporins, steroids (fusidic acid), streptogramins and streptomycins.

These antibacterials are a focus of surveillance of antimicrobial use because of their potential impact on the development of antimicrobial resistance.[12] The potential for inappropriate prescribing, high cost and unfavourable side-effect profiles (for example, aminoglycosides) are also reasons for close monitoring of the use of these antibacterial classes.

These six major classes of antibacterials used in Australian hospitals are:

- Aminoglycosides (amikacin, gentamicin and tobramycin)
- Antipseudomonal penicillins with β-lactamase inhibitor (piperacillin–tazobactam and ticarcillin–clavulanate)
- Carbapenems (ertapenem, imipenem–cilastatin, meropenem)
- Fluoroquinolones (ciprofloxacin, moxifloxacin and norfloxacin)
- Glycopeptides (teicoplanin and vancomycin)
- Third- and fourth-generation cephalosporins (cefepime, cefotaxime, ceftazidime and ceftriaxone).

The national aggregate usage rate for these antibacterials in 2015 was 209 DDDs per 1000 OBDs (Figure 8). The mean was 214 DDDs per 1000 OBDs (range 189–245). The classes for which use varied most between states and territories in 2015 were aminoglycosides and antipseudomonal penicillin combinations (Figure 8).

Figure 9 shows usage rates in 2015 of the six major antibacterial classes as a percentage of total antibacterial use, by state and territory, and nationally. For several states and territories, the rankings were different from the total usage rates shown in Figure 8. For example, the proportional contribution of these classes to antibacterial use in Western Australia and Victoria is higher than

Figure 8 Antibacterial usage rates (DDD/1000 OBD) in NAUSP contributor hospitals for the six major antibacterial classes, by state and territory, 2015

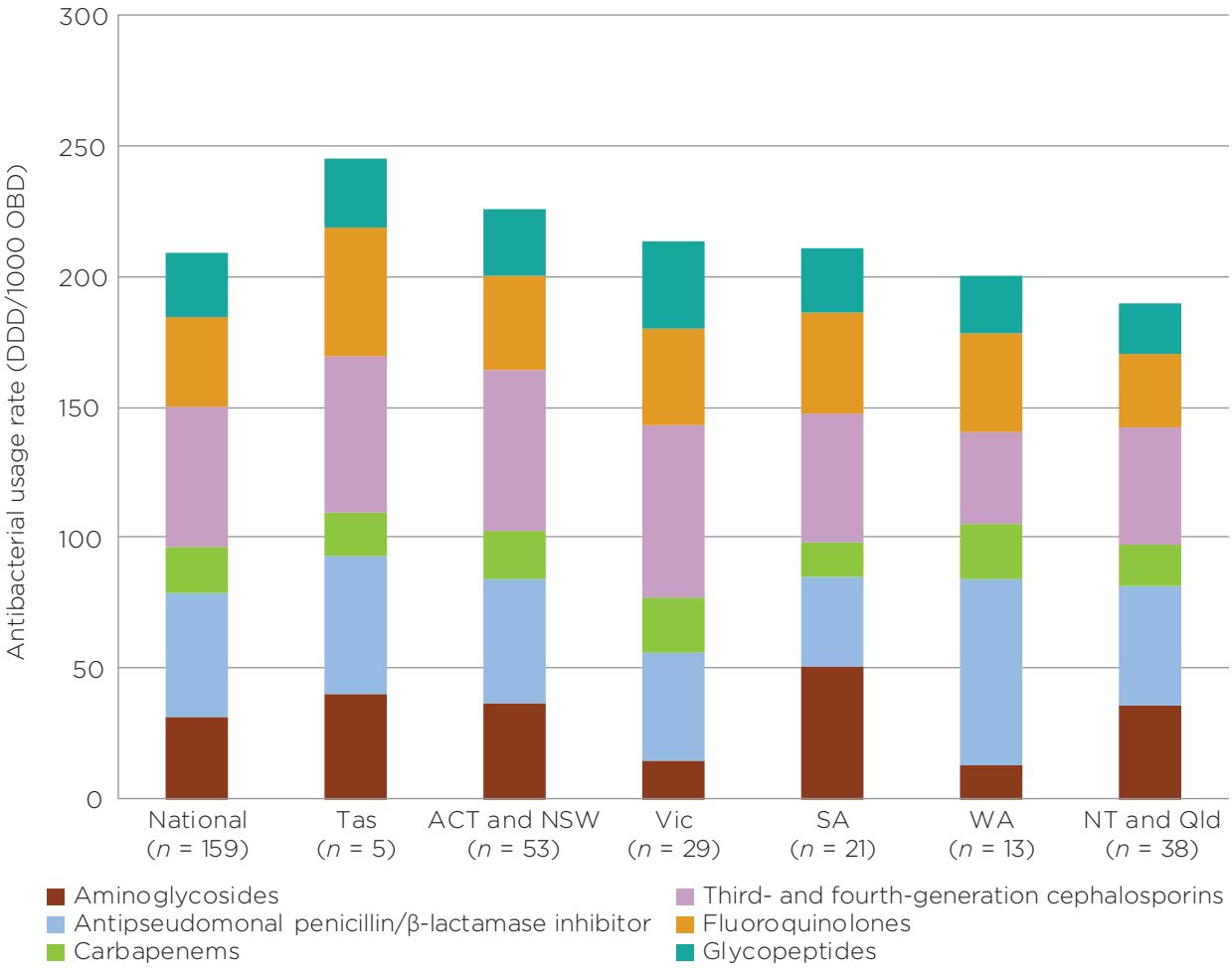
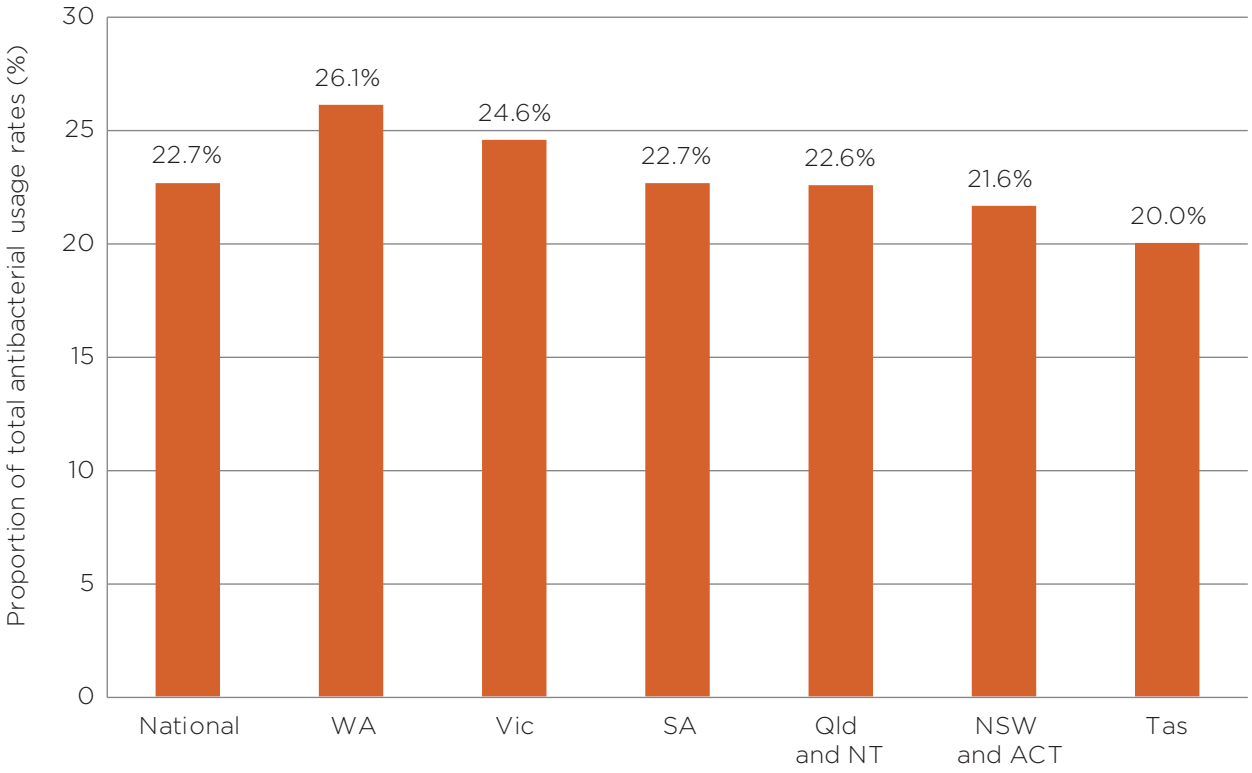


Figure 9 **Antibacterial usage rates (DDD/1000 OBD) in NAUSP contributor hospitals for the six major antibacterial classes, as a proportion of total antibacterial usage rates, by state and territory, 2015**



in Tasmania and New South Wales/Australian Capital Territory.

Intrastate antibacterial usage rates

As explained under 'Methods', NAUSP contributor hospitals are assigned an alphanumeric code for de-identified external reporting. The following sections describe comparative antibacterial usage rates at individual hospitals by state and territory. Where only small numbers of hospitals from each peer group in each state and territory participated, peer groups have been combined, and private hospitals have been assigned to an equivalent public hospital peer group for the analysis.

It is notable that, for New South Wales and the Australian Capital Territory, Queensland and the Northern Territory, and Victoria, the antibacterial usage rate is lower in many Principal Referral Hospital contributors than in smaller facilities.

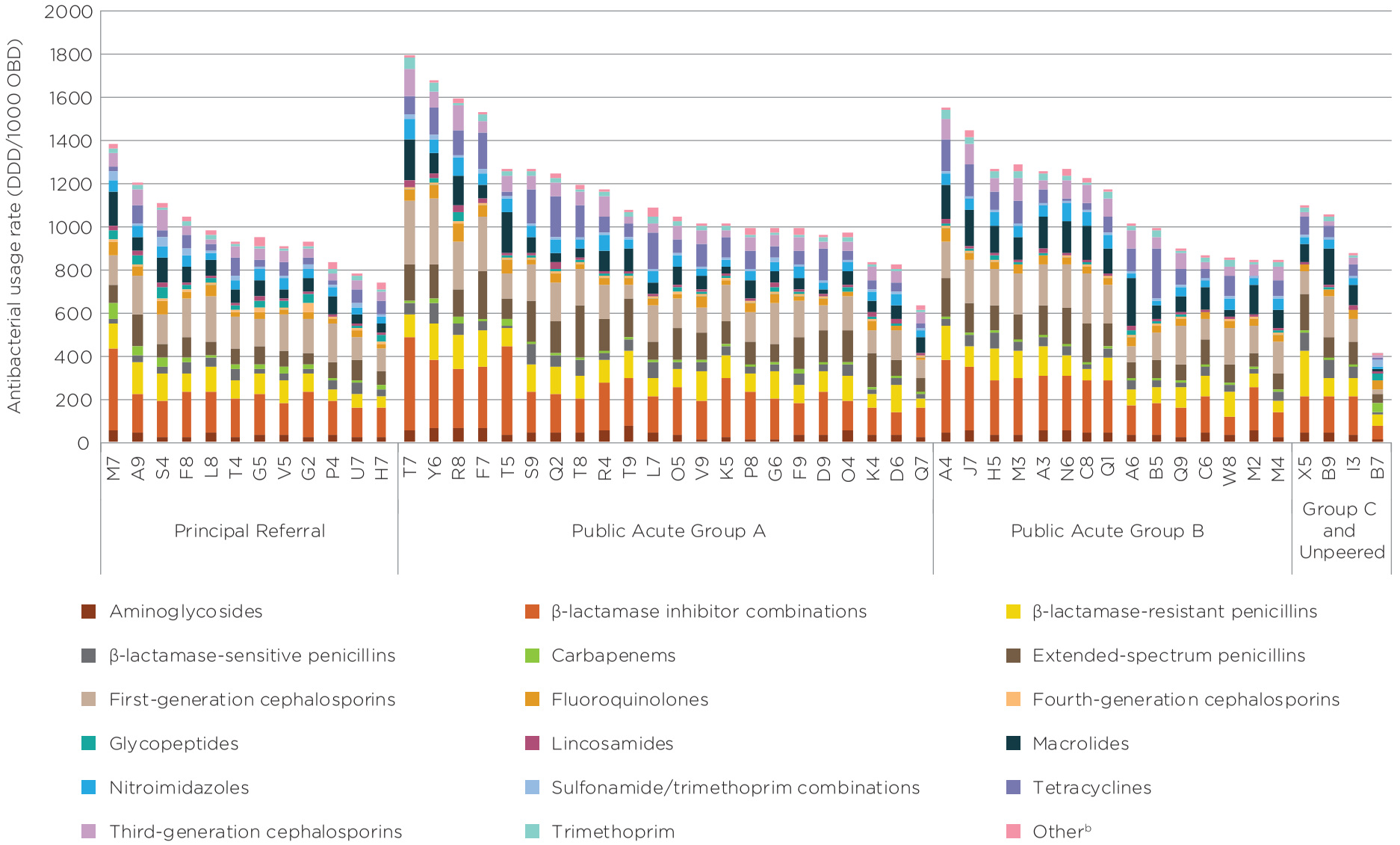
See Appendix 2 for a list of hospitals that contributed data for the 2015 analyses.

New South Wales and Australian Capital Territory

New South Wales had the most contributors to NAUSP in 2015 (53). The cohort comprised 12 Principal Referral, 22 Public Acute Group A, 15 Public Acute Group B and three Public Acute Group C Hospitals, and one hospital that the AIHW had not assigned to a peer group. In the 2015 reporting period, no private hospitals participated in the program. Data from one Australian Capital Territory hospital are included in the analysis.

During 2015, the mean total-hospital antibacterial usage rate for New South Wales and the Australian Capital Territory was 1079 DDDs per 1000 OBDs (range 416–1792; median 1026; Figure 10). In comparison, in 2014, the total-hospital antibacterial usage rate was 1092 DDDs per 1000 OBDs (range 566–2040; median 1005).

Figure 10 Total-hospital antibacterial usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by peer group[a], New South Wales and Australian Capital Territory, 2015



a Data from one New South Wales hospital that the Australian Institute of Health and Welfare had not assigned to a peer group are benchmarked with the Public Acute Group C cohort.
b 'Other' comprises amphenicols, monobactams, nitrofurans, other antibacterials (linezolid and daptomycin), other cephalosporins and penems (ceftaroline), polymyxins, rifamycins, second-generation cephalosporins, steroids (fusidic acid), streptogramins and streptomycins.

Queensland and Northern Territory

In 2015, 38 hospitals contributed to NAUSP from Queensland and the Northern Territory. The cohort comprised six Principal Referral, one Specialist Women's, 12 Public Acute Group A, seven Public Acute Group B and five Public Acute Group C Hospitals, and seven private facilities. Data from one Northern Territory hospital are included in the analysis.

During 2015, the mean total-hospital antibacterial usage rate for Queensland and the Northern Territory was 916 DDDs per 1000 OBDs (range 378–1808; median 849; Figure 11). In comparison, the 2014 total-hospital antibacterial usage rate for Queensland hospitals was 848 DDDs per 1000 OBDs (range 330–1412; median 822).

South Australia

A total of 21 hospitals from South Australia contributed to NAUSP in 2015: two Principal Referral Hospitals, four Public Acute Group A Hospitals, four Public Acute Group B Hospitals, three Public Acute Group C Hospitals, one Specialist Women's Hospital and seven private facilities.

The mean total-hospital antibacterial usage rate for South Australia was 873 DDDs per 1000 OBDs (range 341–1445; median 850; Figure 12). In comparison, in 2014, the total-hospital antibacterial usage rate was 892 DDDs per 1000 OBDs (range 458–1300; median 880).

Tasmania

Five Tasmanian hospitals contributed to NAUSP in 2015: one Principal Referral Hospital, two Public Acute Group A Hospitals, one Public Acute Group B Hospital and one private hospital.

The mean total-hospital antibacterial usage rate was 1220 DDDs per 1000 OBDs (range 1183–1254; median 1207; Figure 13). In comparison, in 2014, the total-hospital antibacterial usage rate was 1242 DDDs per 1000 OBDs (range 792–1552; median 1336).

Peer groups are not shown in Figure 13 because of the small number of contributors from Tasmania.

Victoria

From Victoria, 29 hospitals contributed to NAUSP during 2015: six Principal Referral Hospitals, 11 Public Acute Group A Hospitals, seven Public Acute Group B Hospitals, one Specialist Women's Hospital and four private hospitals.

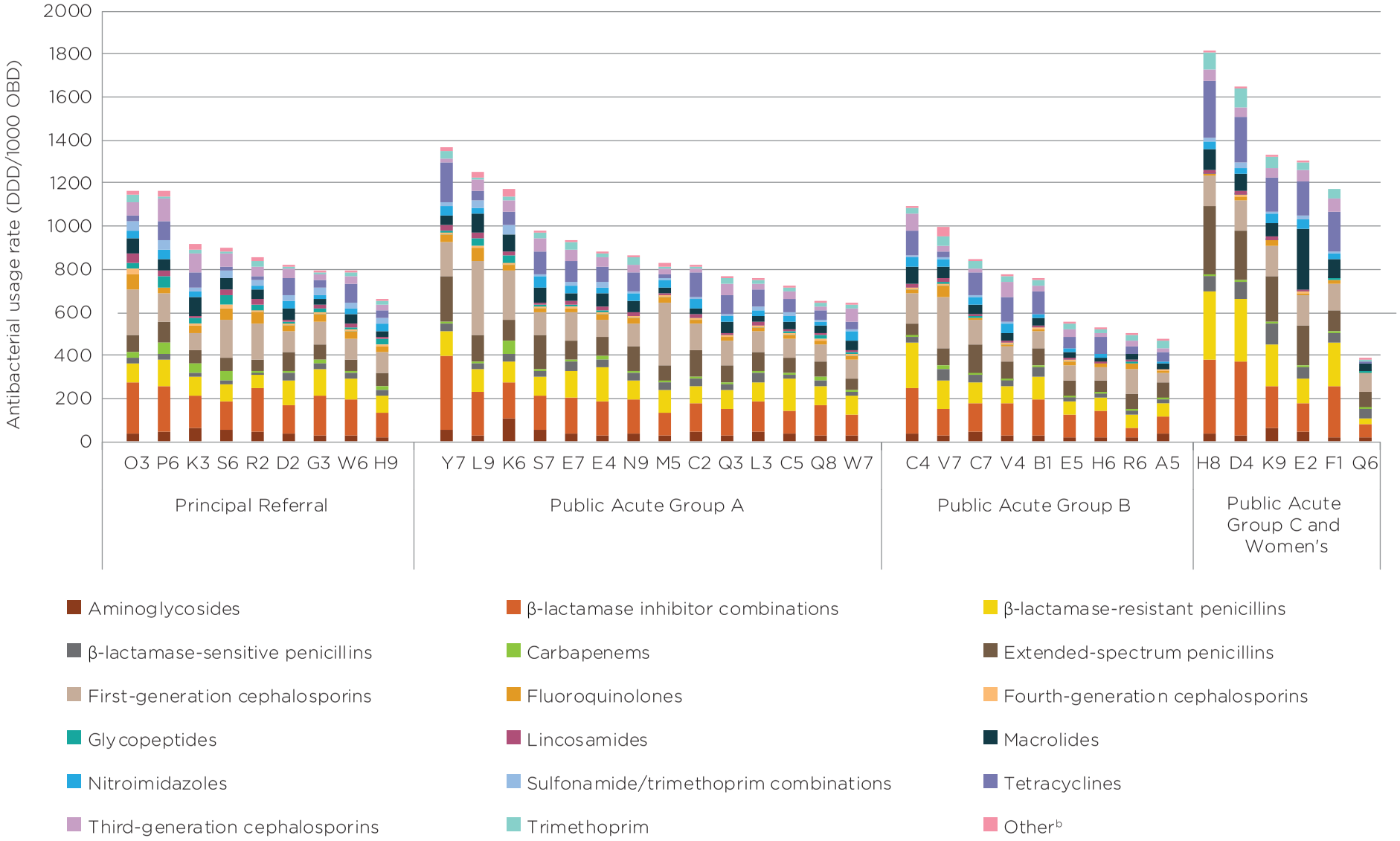
The mean total-hospital antibacterial usage rate was 887 DDDs per 1000 OBDs (range 322–1524; median 893; Figure 14). In comparison, in 2014, the total-hospital antibacterial usage rate was 940 DDDs per 1000 OBDs (range 544–1552; median 887).

Western Australia

Thirteen hospitals from Western Australia contributed to NAUSP in 2015. The cohort comprised three Principal Referral Hospitals, four Public Acute Group A Hospitals, two Public Acute Group B Hospitals, one Public Acute Group C Hospital, one Specialist Women's Hospital and two private facilities.

The mean total-hospital antibacterial usage rate in Western Australia was 763 DDDs per 1000 OBDs (range 392–1139; median 788; Figure 15). In comparison, in 2014, the total-hospital antibacterial usage rate was 812 DDDs per 1000 OBDs (range 373–1168; median 812).

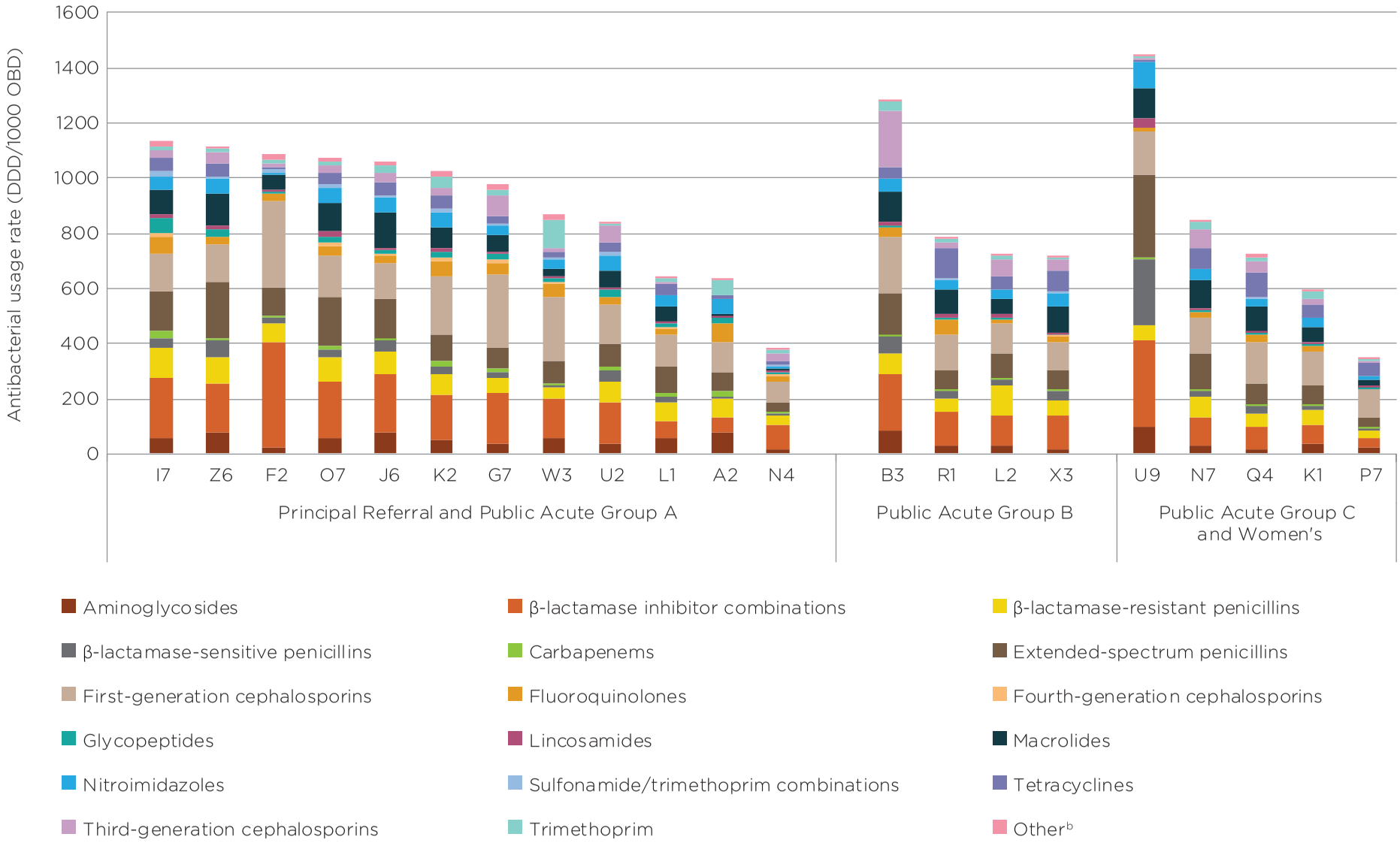
Figure 11 Total-hospital antibacterial usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by peer group, Queensland and Northern Territory, 2015[a]



a Private hospitals are included in the Principal Referral, Public Acute Group A and Public Acute Group B Hospital peer groups.

b 'Other' comprises amphenicols, monobactams, nitrofurans, other antibacterials (linezolid and daptomycin), other cephalosporins and penems (ceftaroline), polymyxins, rifamycins, second-generation cephalosporins, steroids (fusidic acid), streptogramins and streptomycins.

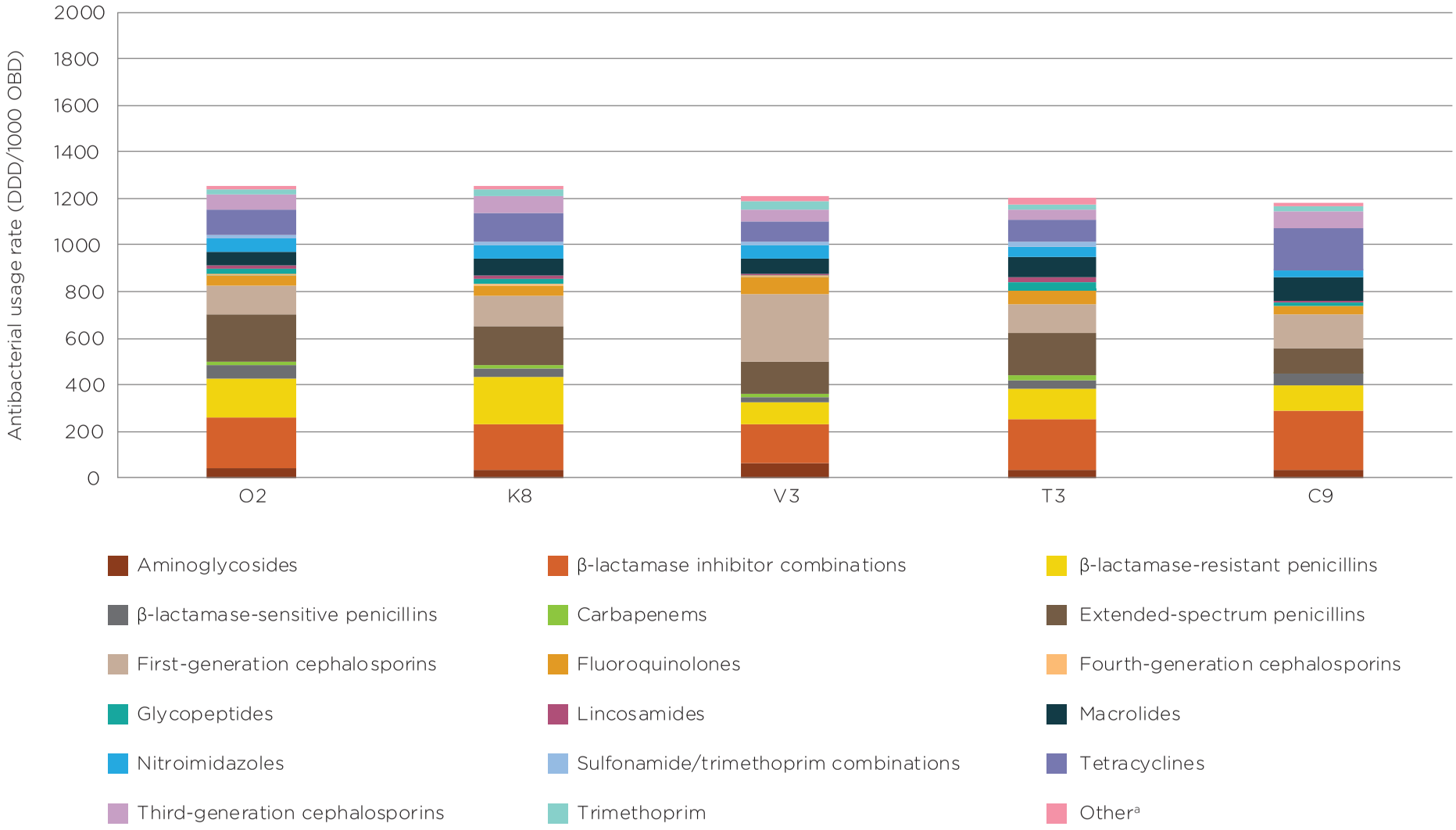
Figure 12 Total-hospital antibacterial usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by peer group, South Australia, 2015[a]



a Private hospitals are included in the Public Acute Group A and Public Acute Group C Hospital peer groups.

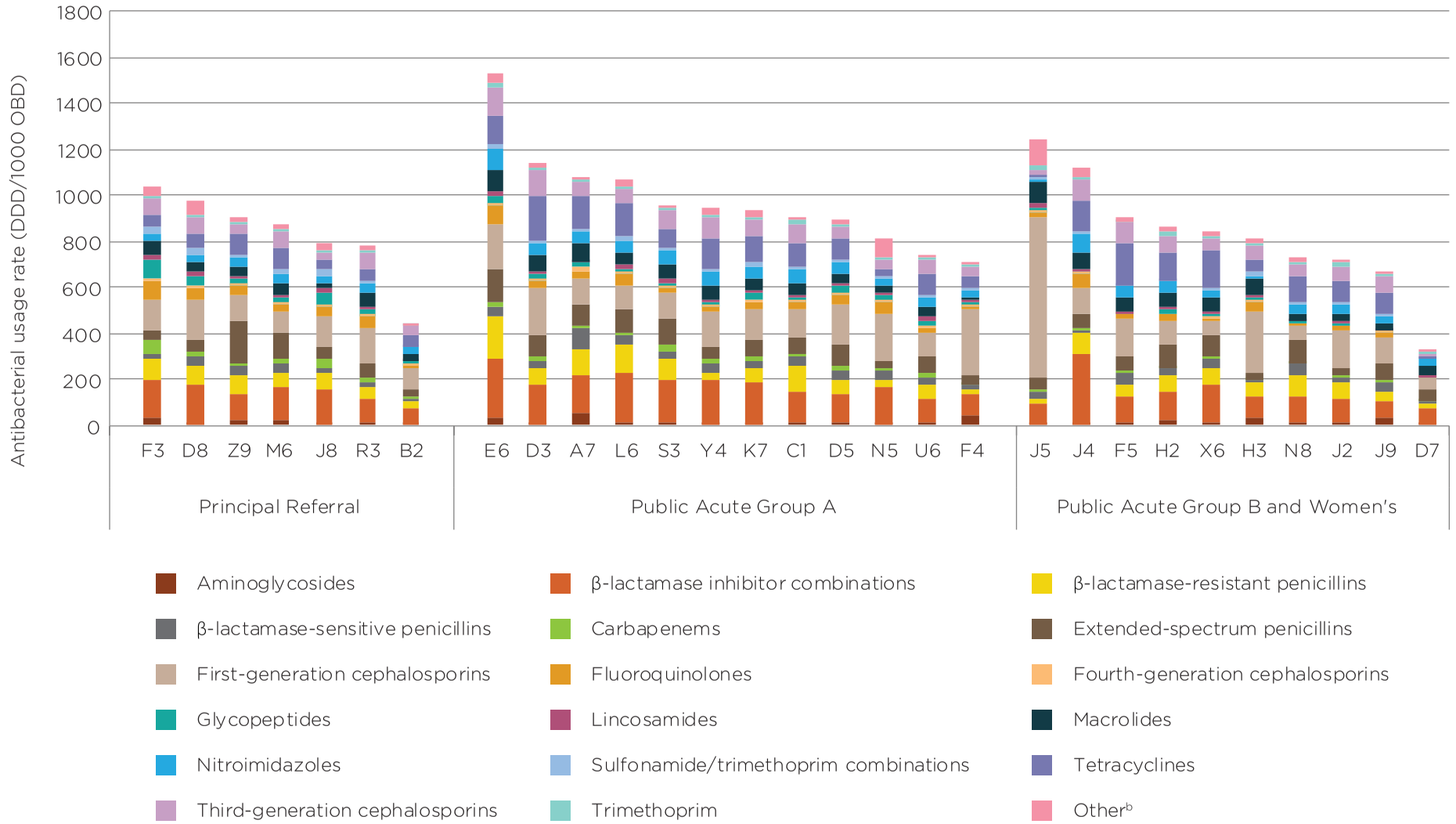
b 'Other' comprises amphenicols, monobactams, nitrofurans, other antibacterials (linezolid and daptomycin), other cephalosporins and penems (ceftaroline), polymyxins, rifamycins, second-generation cephalosporins, steroids (fusidic acid), streptogramins and streptomycins.

Figure 13 Total-hospital antibacterial usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, Tasmania, 2015



a 'Other' comprises amphenicols, monobactams, nitrofurans, other antibacterials (linezolid and daptomycin), other cephalosporins and penems (ceftaroline), polymyxins, rifamycins, second-generation cephalosporins, steroids (fusidic acid), streptogramins and streptomycins.

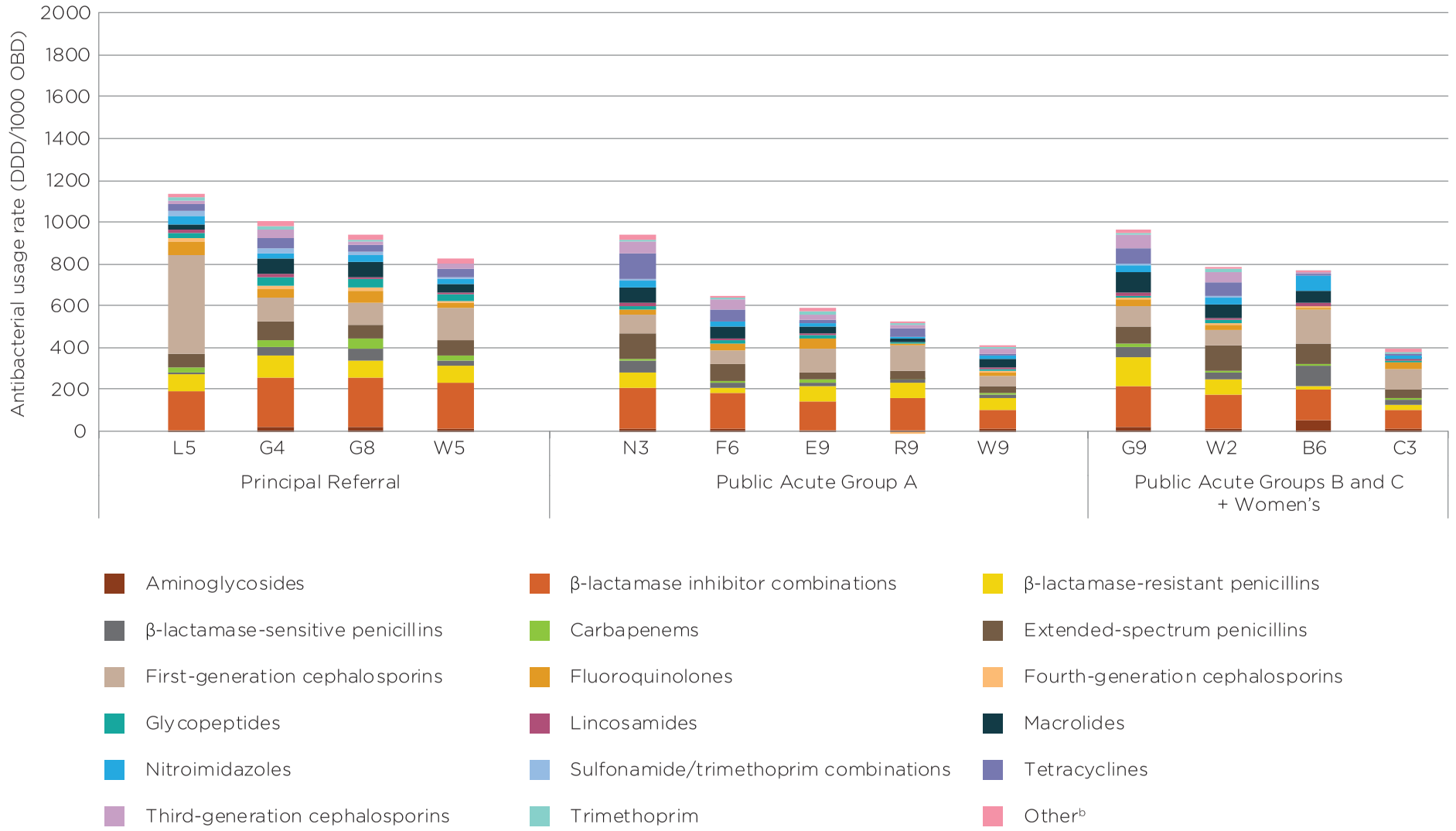
Figure 14 Total-hospital antibacterial usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by peer group, Victoria, 2015[a]



a Private hospitals are included in the Principal Referral, Public Acute Group A and Public Acute Group B Hospital peer groups.

b 'Other' comprises amphenicols, monobactams, nitrofurans, other antibacterials (linezolid and daptomycin), other cephalosporins and penems (ceftaroline), polymyxins, rifamycins, second-generation cephalosporins, steroids (fusidic acid), streptogramins and streptomycins.

Figure 15 Total-hospital antibacterial usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by peer group, Western Australia, 2015[a]



a Private hospitals are included in the Principal Referral and Public Acute Group A Hospital peer groups.
b 'Other' comrpises amphenicols, monobactams, nitrofurans, other antibacterials (linezolid and daptomycin), other cephalosporins and penems (ceftaroline), polymyxins, rifamycins, second-generation cephalosporins, steroids (fusidic acid), streptogramins and streptomycins.

Annual hospital antibacterial usage rates by antibacterial class, 2011–15

Antibacterial classes are categorised into therapeutic groups using the WHO Anatomical Therapeutic Classification system (see Appendix 3). The Anatomical Therapeutic Classification system and use of DDDs enables international and other comparisons of drug consumption statistics.

Aggregation of NAUSP antibacterial usage data into therapeutic groups allows:

- Assessment of the relative use of particular classes of antibacterials
- Comparisons between contributing hospitals of pooled class-specific antibacterial usage rates
- Benchmarking with usage data from similar studies.

Changes in usage rates over time may occur as a result of several factors, such as changes in prescribing practice, evolving clinical practice and establishment of AMS programs. Another factor that may indirectly change usage rates is the increasingly common reduced length of acute hospital inpatient stay. Changes in usage rates may also reflect simple variations between WHO-defined DDDs and the doses used in Australian hospital clinical practice.

Total-hospital and intensive care unit usage rates

Annual usage rate data from NAUSP contributors, aggregated by year and antibacterial class, for the five years to December 2015 show a continuing reduction in usage rates for aminoglycosides, fluoroquinolones, macrolides, nitroimidazoles (metronidazole) and fusidic acid. In contrast, consistent, although often small, increases in aggregated annual usage rates were seen for sulfamethoxazole–trimethoprim and tetracyclines (see Table 3). Reasons for the increased use of sulfamethoxazole–trimethoprim are not clear.

For tetracyclines, a likely cause of increased use is antimicrobial stewardship interventions encouraging use of doxycycline.

Usage rates in intensive care units (ICUs) are higher than total-hospital usage rates for most antibacterial classes (see Table 4). Aggregate ICU usage rates have also declined since 2011. Notable reductions in use have occurred for aminoglycosides, metronidazole and extended-spectrum penicillins (amoxicillin and ampicillin).

The 2015 mean ICU usage rate for Principal Referral Hospitals that contributed to NAUSP was 1484 DDDs per 1000 OBDs (range 644–1965; median 1484), as shown in Figure 16. In Public Acute Group A Hospitals, the mean ICU usage rate was 1476 DDDs per 1000 OBDs (range 302–2154; median 1545) (Figure 17).

Analyses of the six antibacterial classes with the greatest potential to fuel multidrug resistance show a mean of 704 DDDs per 1000 OBDs (range 180–1108; median 684) in Principal Referral Hospitals, and a mean of 627 DDDs per 1000 OBDs (range 75–939; median 677) in Public Acute Group A Hospitals (Figures 18 and 19).

Table 3 Total-hospital antibacterial usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by antibacterial class, 2011–15

Antibacterial class	2011 (*n* = 74)	2012 (*n* = 93)	2013 (*n* = 122)	2014 (*n* = 147)	2015 (*n* = 159)
Aminoglycosides	48.0	45.3	42.4	37.8	31.8
Amphenicols	0.0	0.0	0.0	0.0	0.0
β-lactamase inhibitor combinations	181.2	183.5	184.8	179.8	174.1
β-lactamase-resistant penicillins	84.0	83.4	91.2	92.3	90.3
β-lactamase-sensitive penicillins	23.7	25.7	26.6	28.8	32.9
Carbapenems	19.7	20.1	19.8	18.1	17.5
Extended-spectrum penicillins	111.3	106.0	104.6	103.2	92.6
First-generation cephalosporins	139.2	130.9	134.1	131.1	138.0
Fluoroquinolones	51.8	44.4	42.6	38.0	34.3
Fourth-generation cephalosporins	5.6	5.4	5.2	5.4	5.7
Glycopeptides	33.6	31.0	29.2	26.1	24.5
Lincosamides	13.7	14.0	15.5	14.8	13.6
Macrolides	84.5	79.9	71.8	66.3	60.1
Monobactams	0.2	0.4	0.4	0.4	0.3
Nitrofurans	1.1	0.9	0.9	0.9	0.9
Nitroimidazoles (metronidazole)	50.4	46.5	44.2	40.5	37.6
Other antibacterials (daptomycin + linezolid)	1.4	2.3	2.3	2.4	2.3
Other cephalosporins and penems (ceftaroline)	0.0	0.0	0.0	0.1	0.1
Polymyxins	0.6	0.7	0.9	0.7	0.7
Rifamycins	7.9	6.3	5.9	4.9	4.6
Second-generation cephalosporins	5.9	5.6	5.7	5.5	6.5
Steroids (fusidic acid)	2.3	1.9	1.6	1.3	1.1
Streptogramins	0.4	0.5	0.5	0.5	0.4
Streptomycins	0.1	0.0	0.0	0.0	0.0
Sulfonamide/trimethoprim combinations	14.6	15.2	16.6	16.0	16.9
Tetracyclines	37.6	43.3	47.4	54.9	65.1
Third-generation cephalosporins	52.5	51.1	48.9	46.7	48.0
Trimethoprim	21.2	20.1	19.7	18.3	16.8
Total	**992.4**	**964.3**	**962.5**	**934.7**	**916.4**

Note: Figures may vary slightly from previous reports as a result of retrospective data adjustments. Statistical analyses of change over time have not been undertaken because of small numbers. The potential to assess the significance of change over time will be explored in future analyses.

Table 4 Antibacterial usage rates (DDD/1000 OBD) in NAUSP contributor hospital intensive care units, by antibacterial class, 2011–15

Antibacterial class	2011 (*n* = 40)	2012 (*n* = 56)	2013 (*n* = 65)	2014 (*n* = 69)	2015 (*n* = 74)
Aminoglycosides	53.8	43.8	35.6	34.9	30.3
Amphenicols	0.0	0.0	0.0	0.0	0.0
β-lactamase inhibitor combinations	247.9	251.5	253.9	256.7	257.9
β-lactamase-resistant penicillins	107.1	106.8	104.5	113.3	106.8
β-lactamase-sensitive penicillins	40.0	44.8	47.9	48.1	48.0
Carbapenems	126.2	131.0	142.7	131.1	127.5
Extended-spectrum penicillins	117.0	100.0	87.7	83.3	81.2
First-generation cephalosporins	124.8	117.3	127.5	133.5	149.3
Fluoroquinolones	130.5	98.7	89.1	78.9	69.4
Fourth-generation cephalosporins	23.4	21.4	18.7	23.6	23.7
Glycopeptides	172.6	165.4	163.5	145.6	138.3
Lincosamides	21.6	22.2	23.9	23.0	21.7
Macrolides	167.9	166.3	159.2	153.7	141.6
Monobactams	0.5	1.1	0.9	1.0	1.6
Nitrofurans	0.1	0.2	0.5	0.3	0.3
Nitroimidazoles (metronidazole)	86.4	72.5	64.2	58.0	57.9
Other antibacterials (linezolid + daptomycin)	8.0	12.2	11.6	13.0	12.2
Other cephalosporins and penems (ceftaroline)	0.0	0.0	0.1	0.4	0.5
Polymyxins	4.8	3.0	4.2	2.8	3.3
Rifamycins	11.4	6.8	7.9	7.9	9.2
Second-generation cephalosporins	1.1	1.2	1.6	1.6	2.0
Steroids (fusidic acid)	2.2	1.9	1.1	1.5	1.5
Streptogramins	0.1	0.2	0.4	0.6	0.2
Streptomycins	0.0	0.0	0.1	0.0	0.1
Sulfonamide/trimethoprim combinations	46.9	42.9	47.6	44.8	46.2
Tetracyclines	22.9	26.7	25.5	29.6	37.0
Third-generation cephalosporins	114.6	110.1	103.3	100.6	106.8
Trimethoprim	4.9	5.5	4.4	4.0	4.9
Total	**1636.8**	**1553.5**	**1527.7**	**1491.7**	**1479.3**

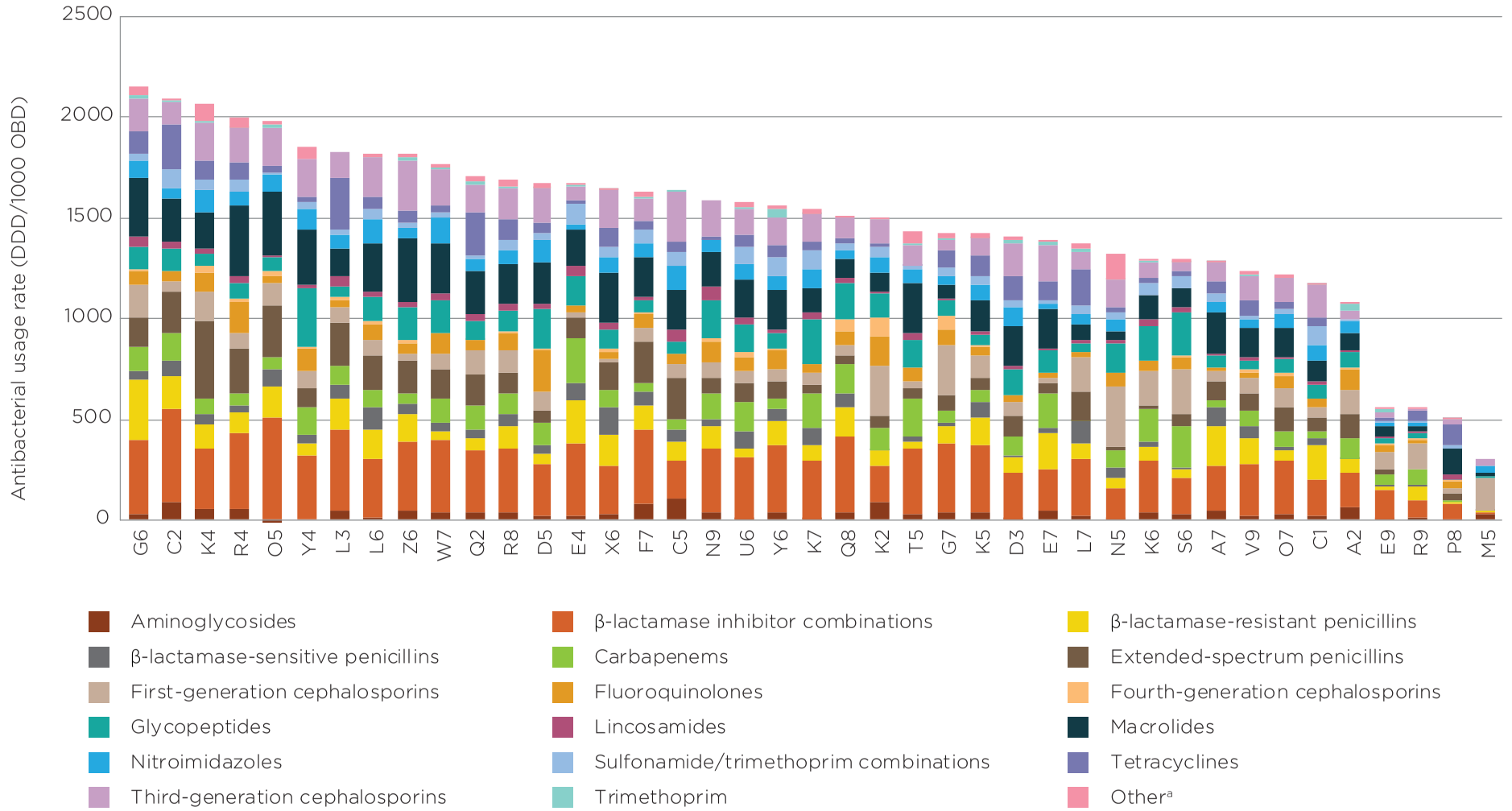
Note: Figures may vary slightly from previous reports as a result of retrospective data adjustments. Statistical analyses of change over time have not been undertaken because of small numbers. The potential to assess the significance of change over time will be explored in future analyses.

Figure 16 Intensive care unit antibacterial use (DDD/1000 OBD) by NAUSP contributors, Principal Referral Hospitals, 2015

a 'Other' comprises amphenicols, monobactams, nitrofurans, other antibacterials (linezolid and daptomycin), other cephalosporins and penems (ceftaroline), polymyxins, rifamycins, second-generation cephalosporins, steroids (fusidic acid), streptogramins and streptomycins.

Note: Four private hospitals are included in these data. One Principal Referral Hospital was unable to supply separate intensive care unit data.

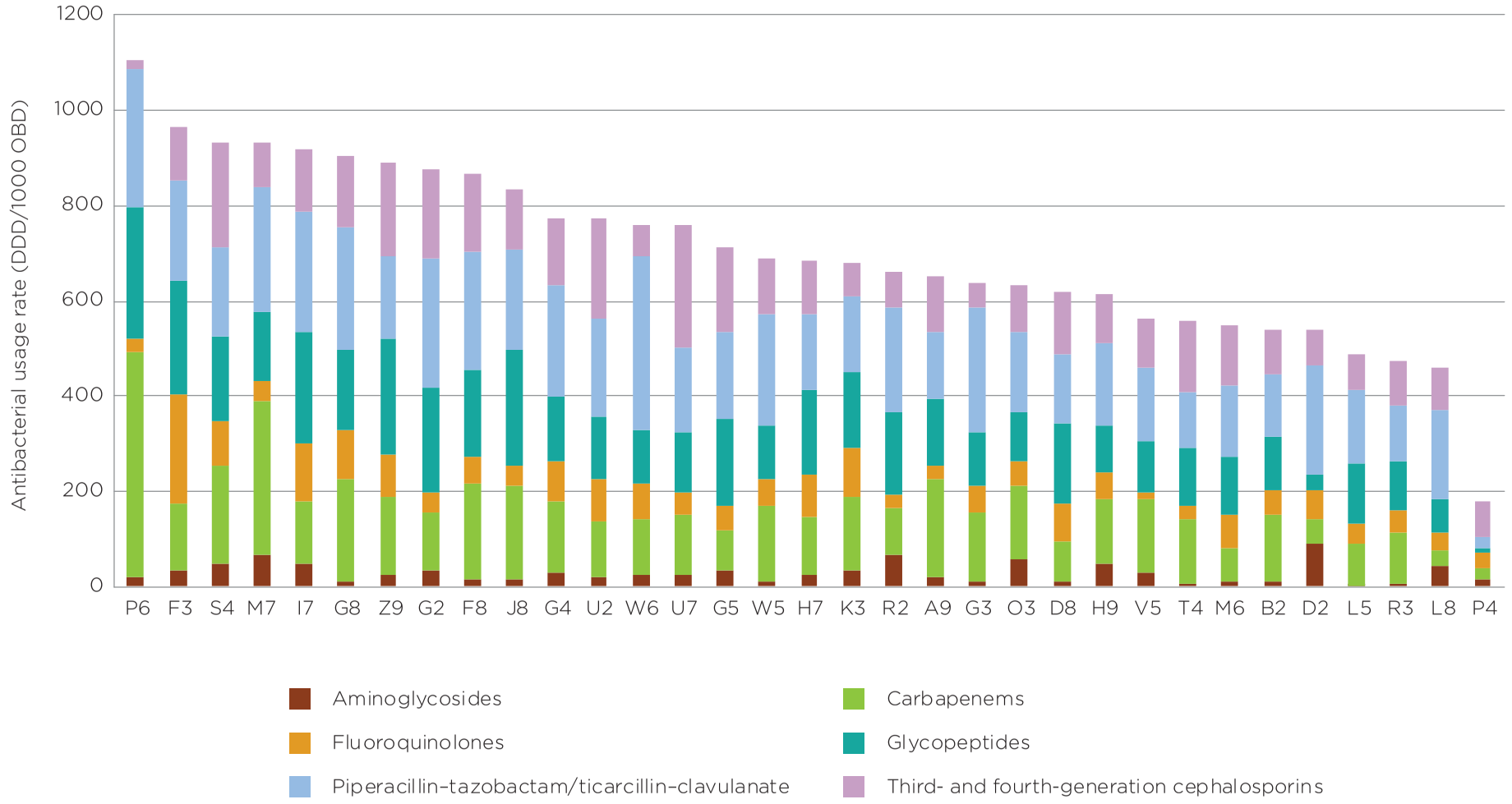
Figure 17 Intensive care unit antibacterial use (DDD/1000 OBD) by NAUSP contributors, Public Acute Group A Hospitals, 2015



a 'Other' comprises amphenicols, monobactams, nitrofurans, other antibacterials (linezolid and daptomycin), other cephalosporins and penems (ceftaroline), polymyxins, rifamycins, second-generation cephalosporins, steroids (fusidic acid), streptogramins and streptomycins.

Note: Seven private hospitals are included in these data. Not all Public Acute Group A Hospitals were able to supply separate intensive care unit data.

Figure 18 Intensive care unit use (DDD/1000 OBD) of six major antibacterial classes by NAUSP contributors, Principal Referral Hospitals, 2015



Note: Four private hospitals are included in these data. One Principal Referral Hospital was unable to supply separate intensive care unit data.

Figure 19 Intensive care unit use (DDD/1000 OBD) of six major antibacterial classes by NAUSP contributors, Public Acute Group A Hospitals, 2015

Note: Seven private hospitals are included in these data. Not all Public Acute Group A Hospitals are able to supply separate intensive care unit data.

Usage rates for individual antibacterials, 2011–15

This section summarises usage rates of individual antibacterials and trends over the past five years.

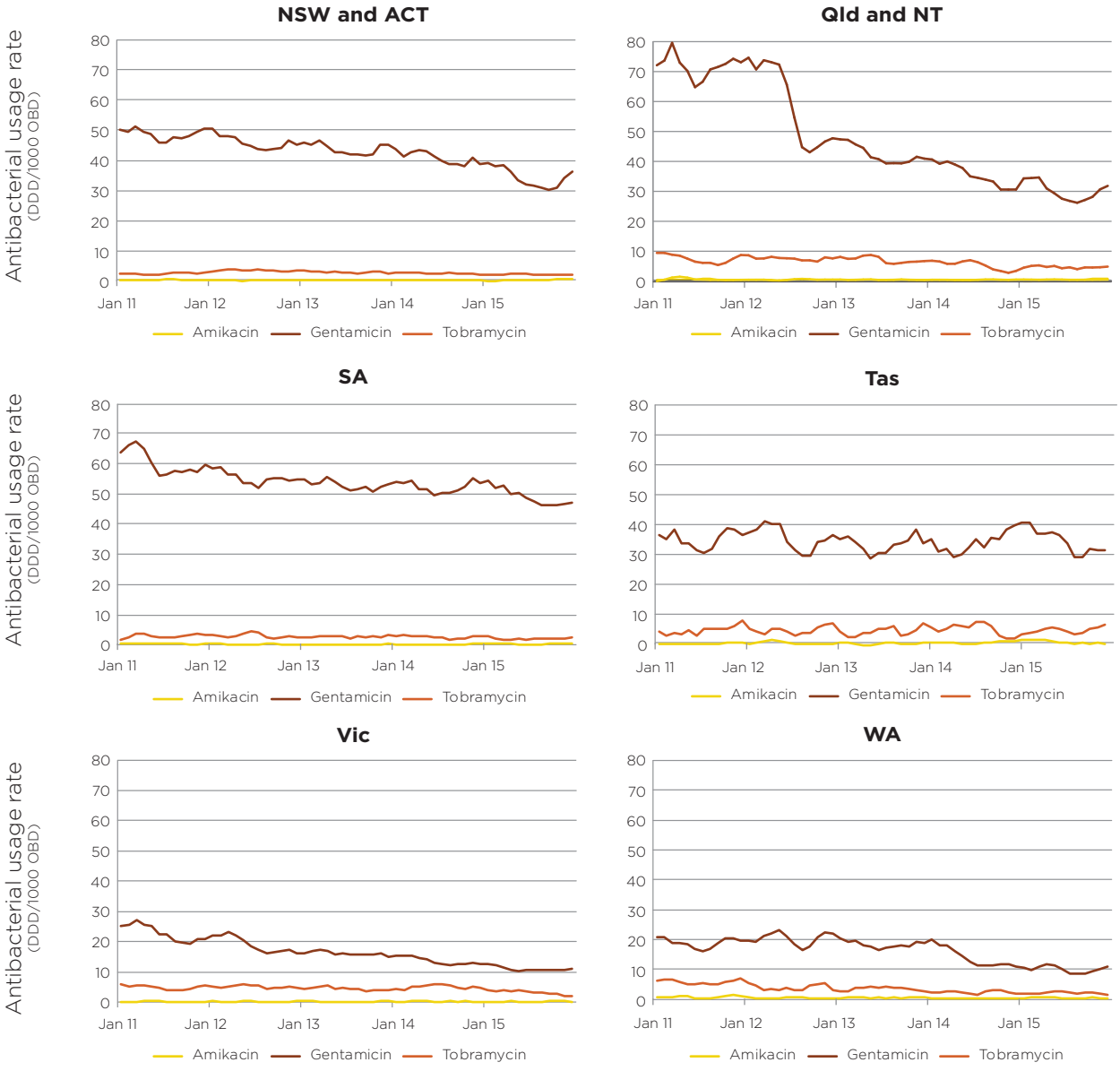
Aminoglycosides – amikacin, gentamicin, tobramycin

Gentamicin is the most commonly used aminoglycoside in NAUSP contributor hospitals.

Usage rates decreased from 2011 to 2015, and there are large variations between states and territories (Figure 20). Use of aminoglycosides is about one-third to one-quarter lower in Victoria and Western Australia than in other states and territories.

Amikacin and tobramycin usage rates remain low compared with gentamicin rates. Amikacin and

Figure 20 Aminoglycoside usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by state and territory, 2011–15 (3-month moving average)



Note: Tobramycin usage rates include inhaled formulations.

tobramycin are more expensive than gentamicin, and are reserved for specific indications. Higher usage rates of tobramycin appear to be confined to larger hospitals with referral services for cystic fibrosis patients who are at increased risk of lung infections caused by *Pseudomonas aeruginosa*.

Carbapenems – doripenem, ertapenem, imipenem, meropenem

Meropenem is the main carbapenem used in NAUSP contributor hospitals, possibly as a result of the lower incidence of neurotoxicity and superior activity against *Pseudomonas* species compared with other carbapenems.[14] Meropenem has become a key reserve-line antibacterial because it can be used to treat infections with extended-spectrum β-lactamase-producing microorganisms (whose incidence is increasing).

Usage rates of other carbapenems are low, and possibly influenced by prescribing preferences in particular hospitals (Figure 21).

Figure 21 Carbapenem usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by state and territory, 2011–15 (3-month moving average)

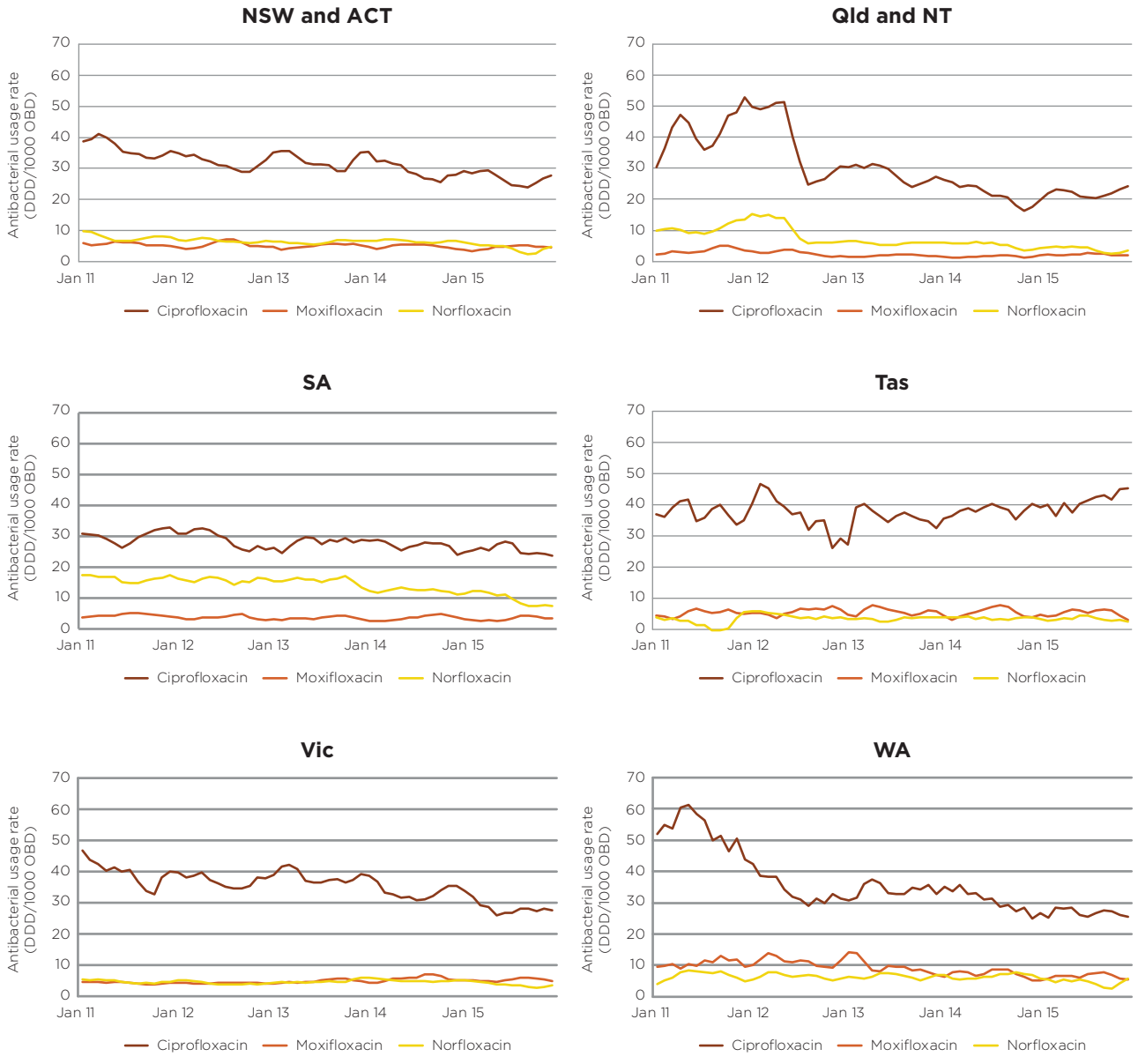
Note: No doripenem use was recorded in South Australia or Tasmania.

Fluoroquinolones – ciprofloxacin, norfloxacin, moxifloxacin

Fluoroquinolone usage rates have decreased since 2011 (Figure 22). Most Australian hospitals and statewide formularies (where they exist) place restrictions on the use of fluoroquinolones, and there are few indications where a fluoroquinolone is the first-line recommendation.[10]

Ciprofloxacin is the most frequently used fluoroquinolone; it has higher bioavailability than norfloxacin and a financial benefit over moxifloxacin. Usage rates of norfloxacin and moxifloxacin have remained relatively constant because they have a limited number of standard indications.

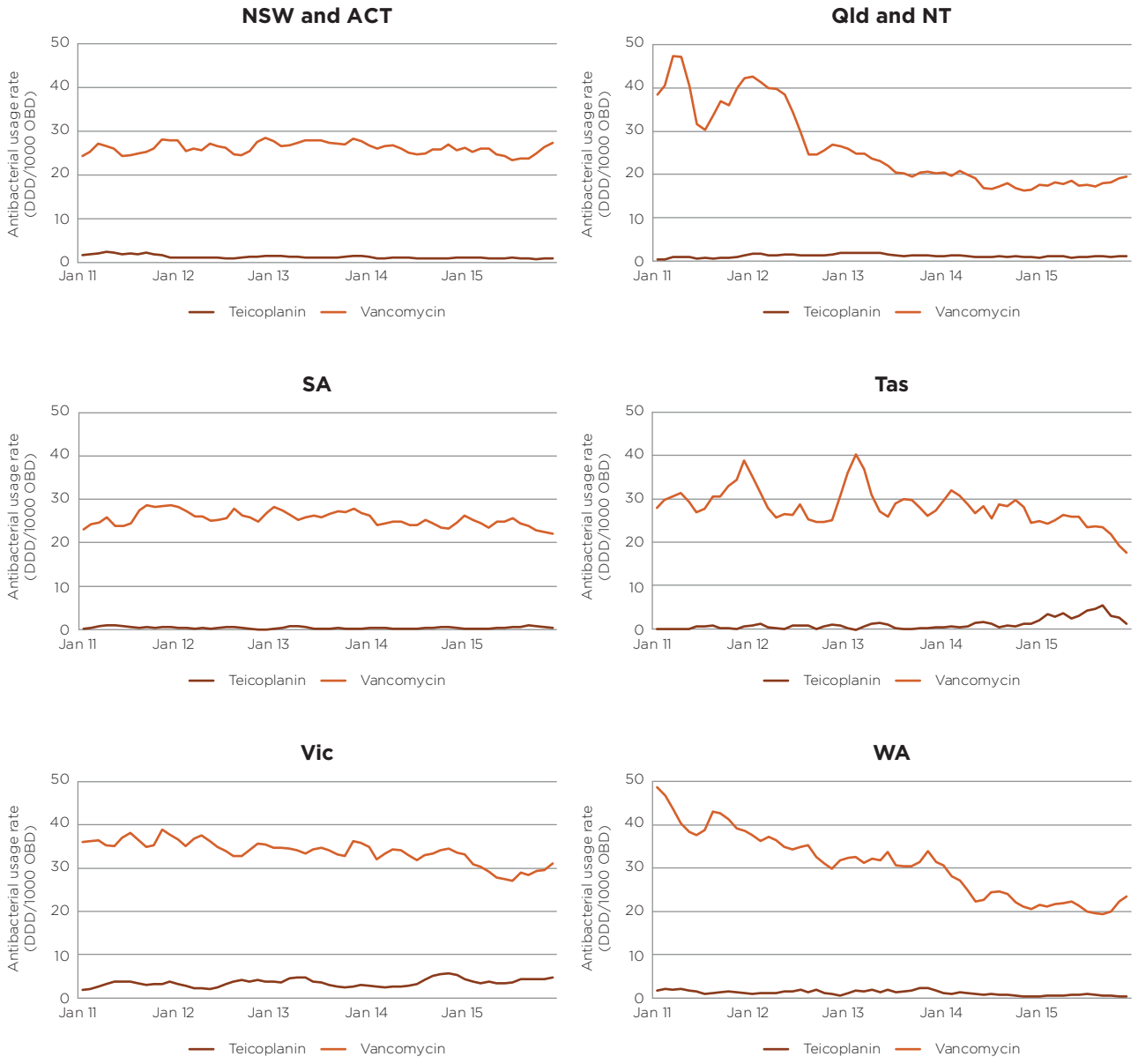
Figure 22 Fluoroquinolone usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by state and territory, 2011–15 (3-month moving average)



Glycopeptides – teicoplanin, vancomycin

Teicoplanin and vancomycin are the only glycopeptides available in Australia. Since 2011, aggregated vancomycin usage rates have decreased in several states and territories (Figure 23). Teicoplanin use remains low, possibly because of its higher cost, although large variations in usage rates occur between sites according to the range of specialist services offered.

Figure 23 Glycopeptide usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by state and territory, 2011–15 (3-month moving average)

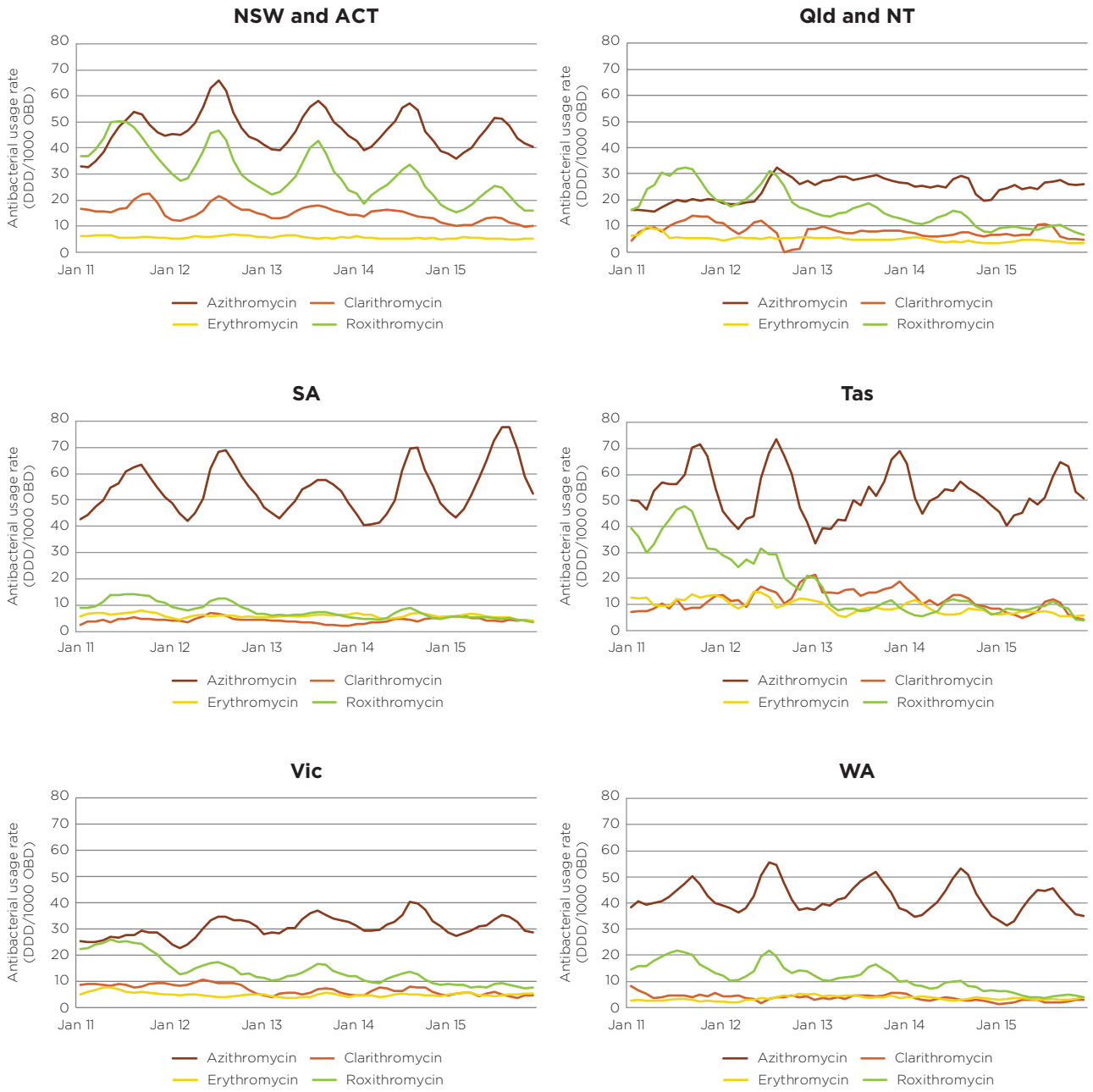


Macrolides – azithromycin, clarithromycin, erythromycin, roxithromycin

Marked seasonal variation is evident in the monthly usage rates for both azithromycin and roxithromycin, with most use in the winter months in the temperate climate states (Figure 24). Large variations in usage rates occur between individual hospitals; potential explanations include differences in hospital restrictions for some macrolides (specifically azithromycin), and differences in prescribing protocols for respiratory tract infections, particularly the treatment of community-acquired pneumonia.

Azithromycin is now the predominant macrolide used in hospitals that contribute to NAUSP, possibly because of its wide spectrum of activity and low likelihood of interaction with other medications. It is unclear what proportion of erythromycin use is as a gastric motility agent rather than as an antibacterial. NAUSP does not collect data on indications for use.

Figure 24 Macrolide usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by state and territory, 2011–15 (3-month moving average)



Penicillins – penicillin/β-lactamase inhibitor combinations: amoxicillin–clavulanate, piperacillin–tazobactam, ticarcillin–clavulanate

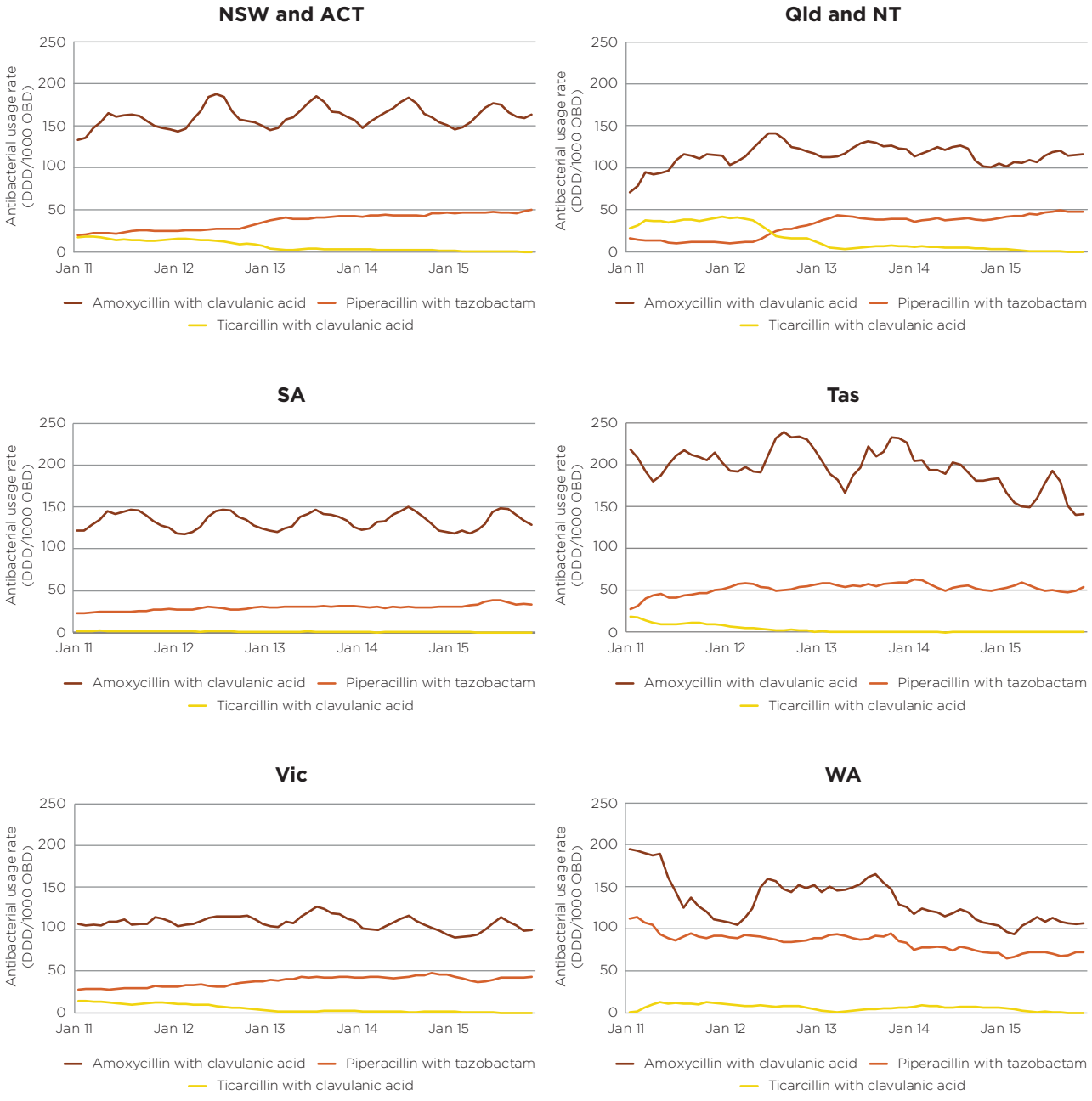
Two intravenous antipseudomonal penicillin/β-lactamase inhibitor combinations (piperacillin–tazobactam and ticarcillin–clavulanate) are available in Australia. Piperacillin–tazobactam is the primary penicillin/β-lactamase inhibitor combination used in NAUSP contributor hospitals. Since generic formulations have become available, it has become more affordable, and its anaerobic spectrum makes it suitable for use in people who are critically ill. Piperacillin–tazobactam is used in ICUs for pseudomonal ventilator-associated pneumonia. Outside the ICU setting, it is used in febrile neutropenia and intra-abdominal infections.

Amoxicillin–clavulanate is not antipseudomonal and is only available in oral formulations in Australia. It has a range of indications, including de-escalation from intravenous therapy. However, in 2015, some hospitals began using the intravenous formulation through the Special Access Scheme[15] for use after gastrointestinal surgery. The NAUSP data show that intravenous use accounted for less than 1% of total use in contributor hospitals in 2015.

Figure 25 shows that a changeover from use of ticarcillin–clavulanate to piperacillin–tazobactam occurred in all states and territories by 2013; ticarcillin–clavulanate is now rarely used. Usage rates of piperacillin–tazobactam vary between jurisdictions, with rates being 50% higher in Western Australia. Since 2014, use has remained stable.

Figure 25 also shows some seasonal variance in usage rates for amoxicillin–clavulanate, particularly in New South Wales and the Australian Capital Territory, South Australia, and Victoria, possibly reflecting its use in respiratory infections during winter months.

Figure 25 Penicillin/β-lactamase inhibitor combination usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by state and territory, 2011–15 (3-month moving average)

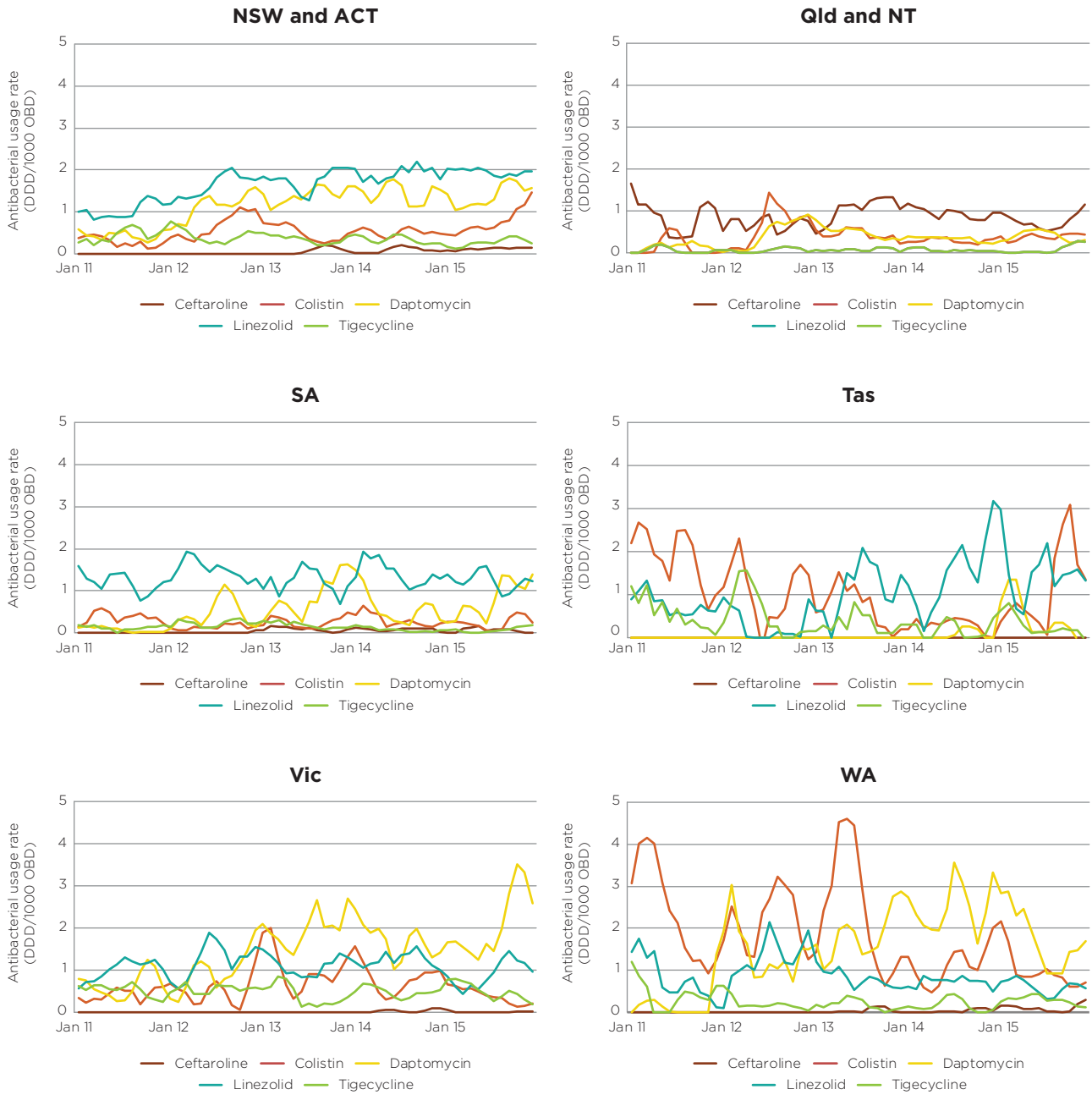


Reserve-line antibacterials – colistin, daptomycin, linezolid, tigecycline

Parenteral colistin has become an important antibacterial in the treatment of infections caused by carbapenemase-producing multidrug-resistant gram-negative organisms, where meropenem is ineffective. Colistin usage rates include both nebulised and parenteral formulations, as some NAUSP contributors are not able to provide separate data for each (Figure 26). Usage rates of daptomycin, while minimal, are increasing.

Although linezolid usage rates are low, there is marked variation between hospitals. Linezolid is reserved for complex infections caused by multidrug-resistant gram-positive organisms, including vancomycin-resistant enterococci (VRE). This multidrug-resistant organism is becoming more prevalent in Australia. Data are not yet available to determine whether linezolid use can be correlated with VRE infections. Tigecycline use remains very low in Australian hospitals.

Figure 26 Reserve-line antibacterial usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by state and territory, 2011–15 (3-month moving average)

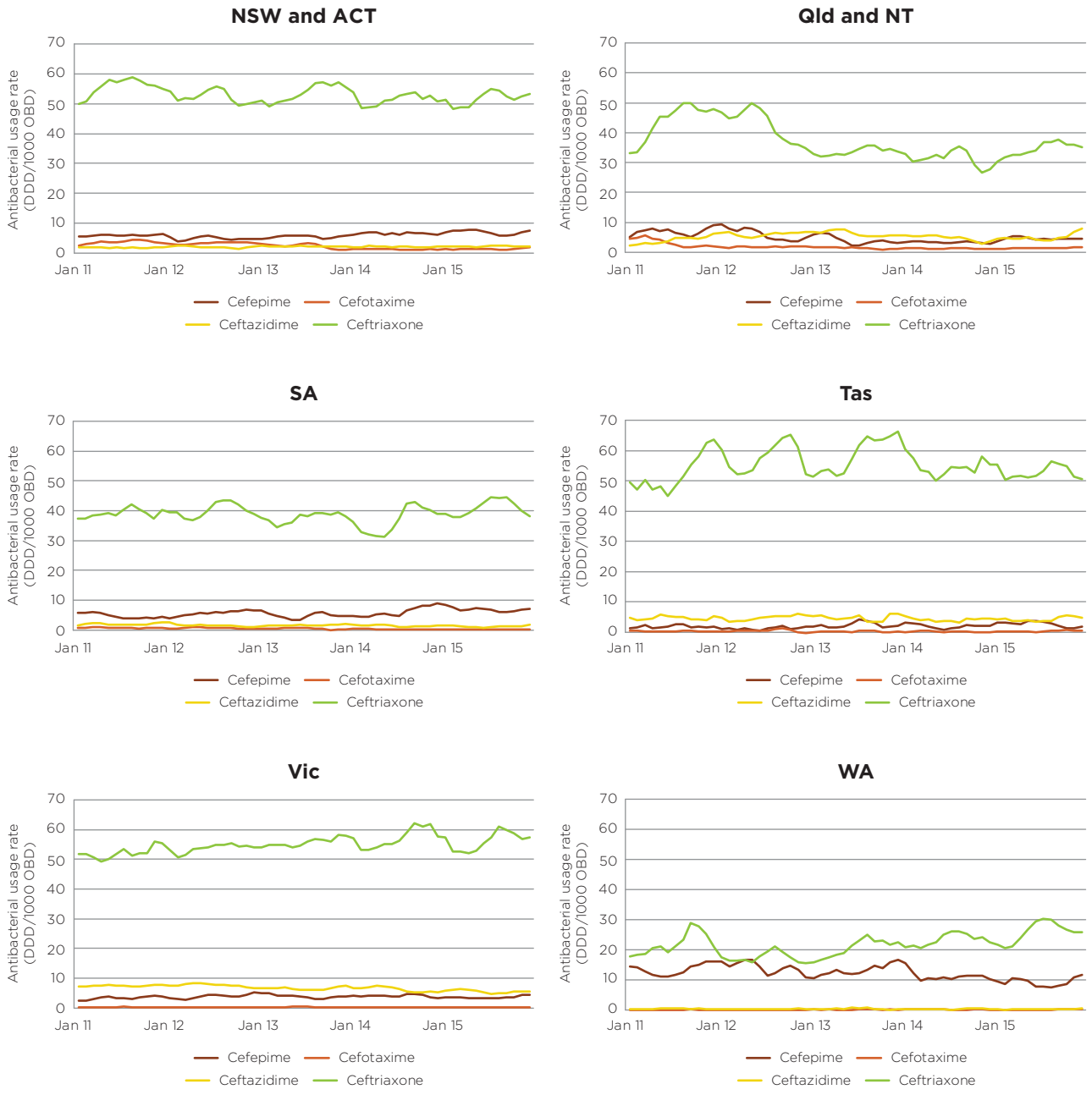


Third- and fourth-generation cephalosporins – cefepime, cefotaxime, ceftazidime, ceftriaxone

Figure 27 shows the usage rates of third- and fourth-generation cephalosporins (cefepime, cefotaxime, ceftazidime and ceftriaxone) from 2011 to 2015.

Ceftriaxone, a third-generation cephalosporin, shows a pattern of seasonal use, reflecting its role in the treatment of lower respiratory infections, which peak in the winter months. Usage rates of ceftriaxone are lower in Western Australia than in other states. The reason for this finding is unclear, and investigation of use of other antibacterials to replace ceftriaxone may be worthwhile to assist with understanding the variation.

Figure 27 Cephalosporin usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by state and territory, 2011–15 (3-month moving average)



Analysis of antibacterial use by hospital peer group

Use of broader-spectrum antibacterials, including those reserved to treat infections caused by multidrug-resistant organisms, would be expected to occur mainly in Principal Referral and Public Acute Group A Hospitals. Several antibacterial classes were analysed to determine whether this expectation is supported by data.

In the analyses below, private hospitals were included with public hospitals of similar size and patient mix. Data from four Specialist Women's Hospitals were not included in these analyses because of low numbers.

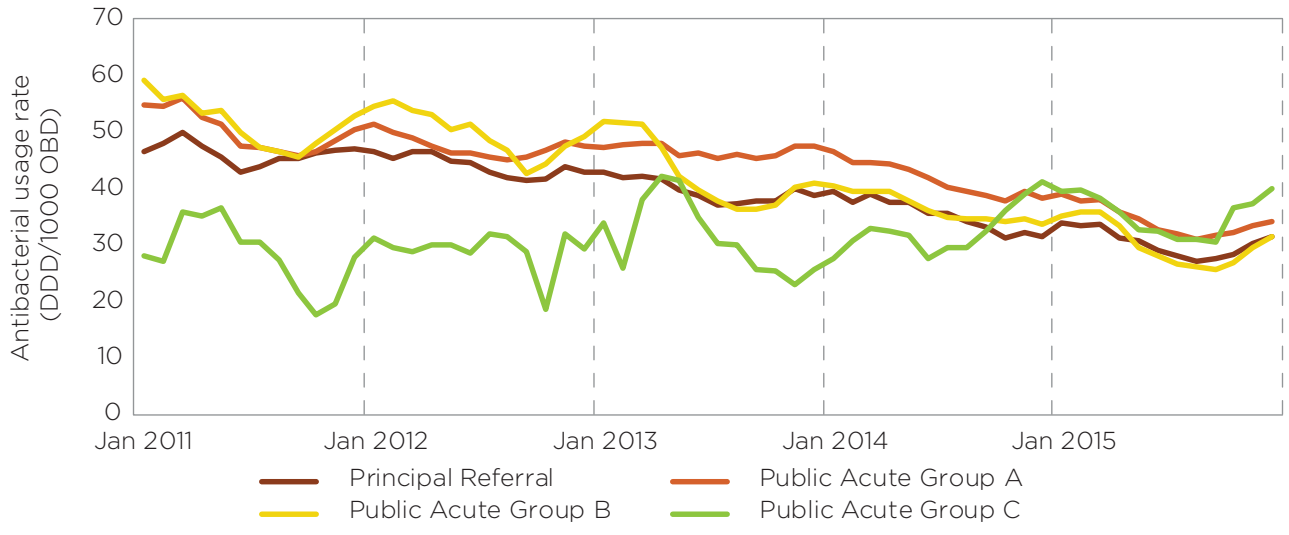
Aminoglycosides – amikacin, gentamicin, tobramycin

Aminoglycoside usage rates show downward trends in each peer group over the period 2011–15 (Figure 28). In 2015, usage rates in Principal Referral, Public Acute Group A and Public Acute Group B Hospitals were similar. The small number of contributors in the Public Acute Group C Hospital cohort means that it is not possible to comment on the trend in these smaller facilities. Gentamicin is the aminoglycoside used most in Australia and is widely used as initial empirical therapy.

Carbapenems – ertapenem, imipenem–cilastatin, meropenem

Carbapenems (mainly meropenem) have a broad spectrum and are reserved for treatment of infections caused by multidrug-resistant organisms. As expected, usage rates were highest in Principal Referral Hospitals, followed by Public Acute Group A and Public Acute Group B Hospitals (Figure 29). Use in small hospitals (Public Acute Group C) was minimal.

Figure 28 Aminoglycoside usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2011–15 (3-month moving average)



Fluoroquinolones – ciprofloxacin, moxifloxacin, norfloxacin

Usage rates of fluoroquinolones in hospitals that contribute to NAUSP declined from 2011 to 2015 (Figure 30). The greatest decline occurred in Principal Referral Hospitals. Usage rates for Public Acute Group C Hospitals are lower than for other peer groups, and do not show a downward trend as in the other peer groups. In 2015, usage rates of fluoroquinolones were similar in Public Acute Group A, B and C Hospitals.

Figure 29 Carbapenem usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2011–15 (3-month moving average)

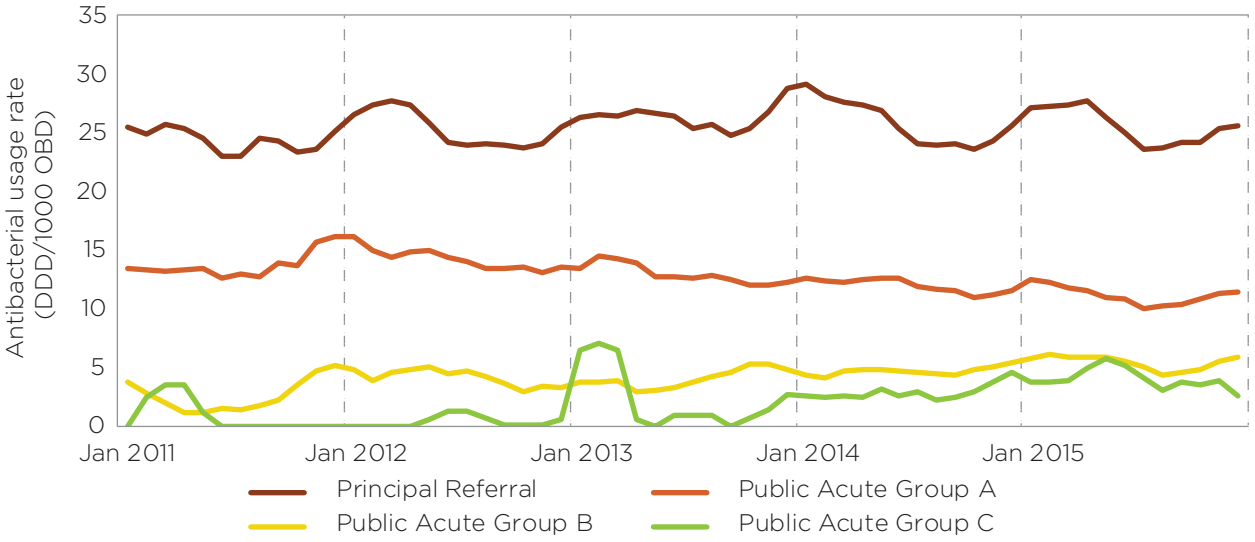
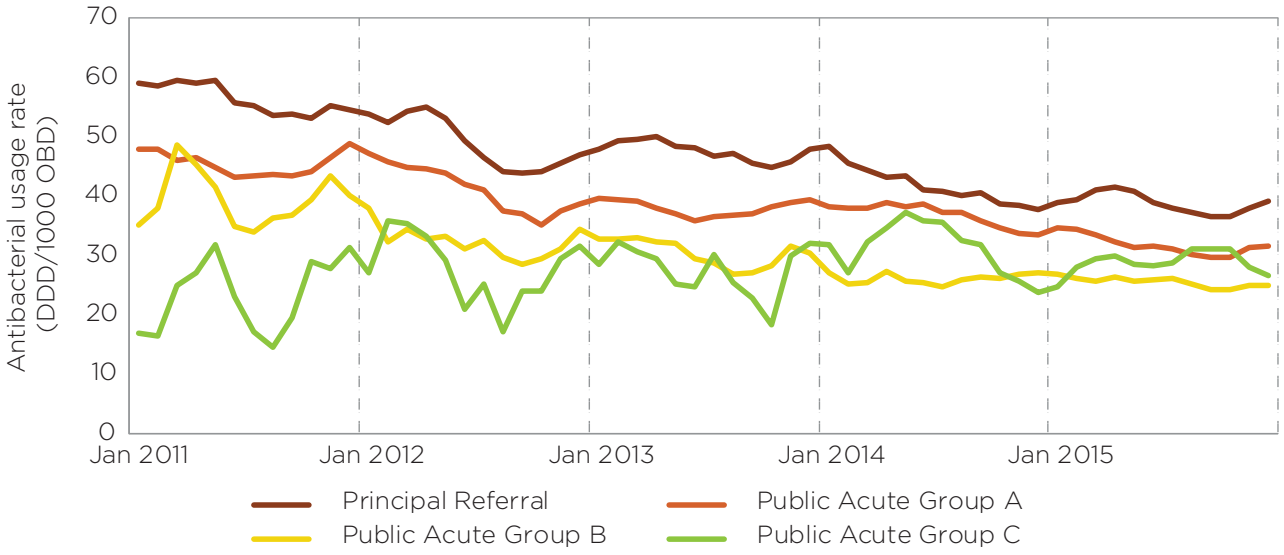


Figure 30 Fluoroquinolone usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2011–15 (3-month moving average)



Glycopeptides – teicoplanin, vancomycin

Usage rates of glycopeptides were highest in Principal Referral Hospitals and lowest in smaller hospitals that contributed to NAUSP in 2015, as expected for this reserve-line antibacterial class (Figure 31).

Macrolides – azithromycin, clarithromycin, erythromycin, roxithromycin

Macrolide usage rates show wide seasonal variation, with highest use in the winter months (Figure 32). Differences in use between peer groups are not as pronounced for macrolides as for other antibacterial classes. Most NAUSP contributor hospitals do not have restrictions on macrolides, except for intravenous azithromycin.

Figure 31 Glycopeptide usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2011–15 (3-month moving average)

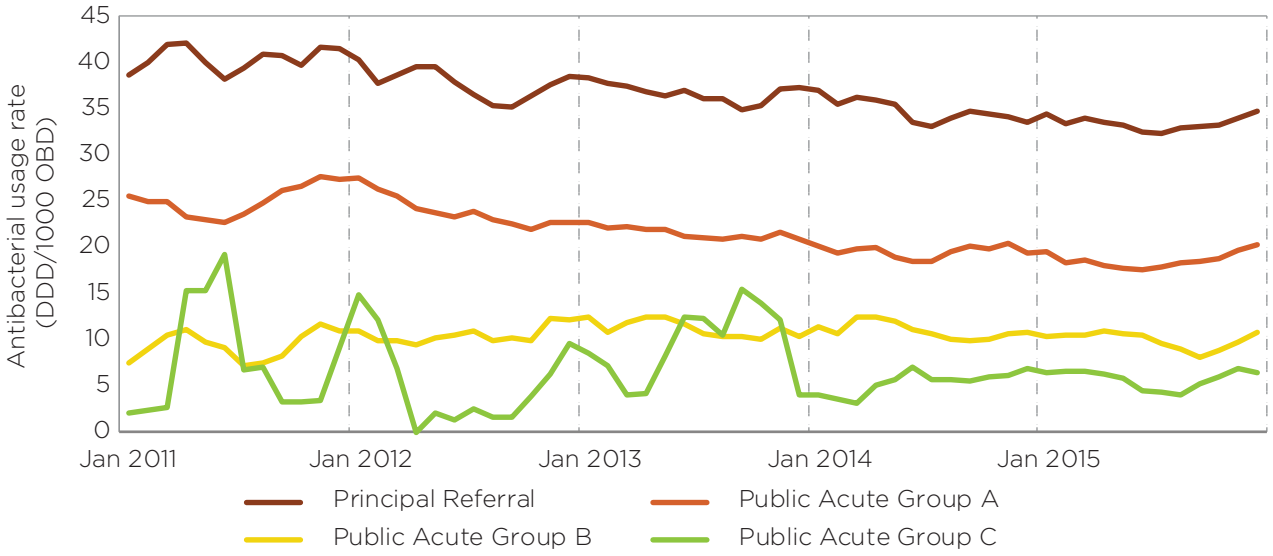
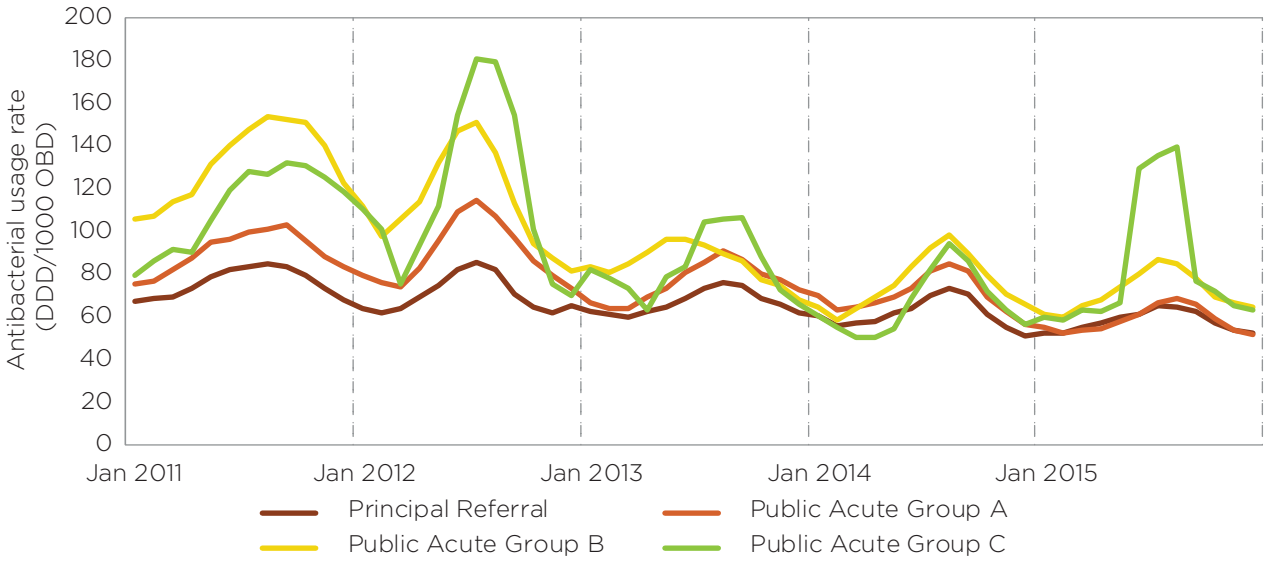


Figure 32 Macrolide usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2011–15 (3-month moving average)



Penicillins – antipseudomonal penicillin/β-lactamase inhibitor combinations: piperacillin–tazobactam, ticarcillin–clavulanate

Usage rates of antipseudomonal penicillin/β-lactamase inhibitor combinations were greatest in larger hospitals that contributed to NAUSP in 2015 (Figure 33). Because these antibacterials are generally restricted in these settings, this pattern is to be expected. Use in smaller NAUSP contributor hospitals increased in 2014 and 2015.

Reserve-line antibacterials – colistin, daptomycin, linezolid

Use of highly reserved antibacterials is mostly confined to Principal Referral and Public Acute Group A Hospitals that contributed to NAUSP from 2011 to 2015 (Figure 34). These antibacterials are used to treat people who are seriously ill when the causative organisms are resistant to standard treatment. These people are usually admitted to Principal Referral Hospitals for treatment.

Closer analysis of use of restricted antibacterials by Principal Referral Hospitals shows variation in

Figure 33 Piperacillin–tazobactam and ticarcillin–clavulanate usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2011–15 (3-month moving average)

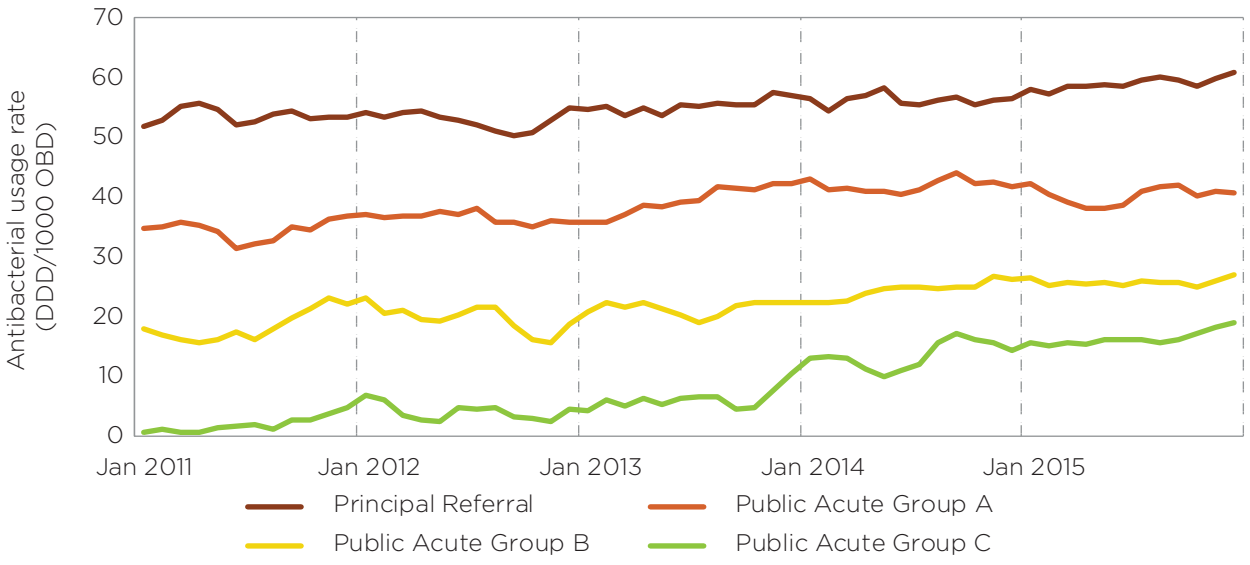
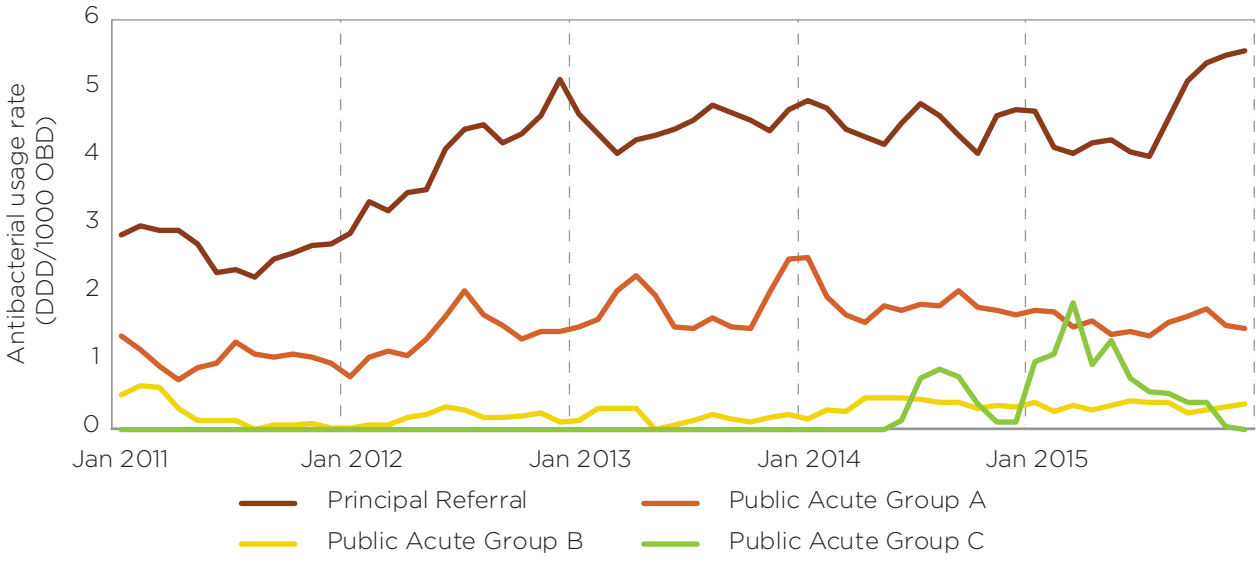


Figure 34 Colistin, daptomycin and linezolid usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2011–15 (3-month moving average)



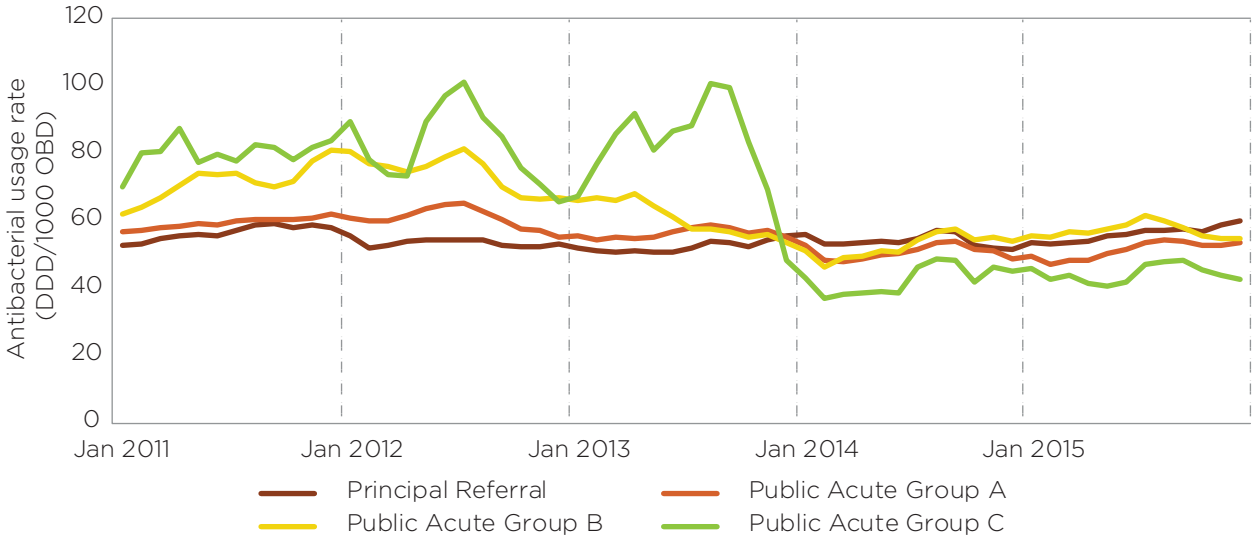
usage rates. The average usage rate of colistin in this peer group for 2015 was 1.13 DDDs per 1000 OBD. The median was 0.3 DDDs per 1000 OBDs (range 0–7.78 DDDs per 1000 OBDs). Similarly, for daptomycin and linezolid, although average usage rates were low (1.86 and 1.59 DDDs per 1000 OBDs, respectively), the annual rates in the hospitals with highest use were more than quadruple the average rate.

Aggregate use of these restricted antibacterials in NAUSP contributor hospitals increased in the second quarter of 2015.

Third- and fourth-generation cephalosporins – cefepime, cefotaxime, ceftazidime, ceftriaxone

Usage rates of third- and fourth-generation cephalosporins were similar in all four peer groups (Figure 35) in 2014 and 2015. Although NAUSP data do not include any assessment of appropriateness of prescribing, in general, greater usage of broad-spectrum cephalosporins would be expected in larger hospitals. Review of hospital-level data could show whether use in hospitals other than those in the Principal Referral Hospital peer group was appropriate. The 2015 NAPS reported that approximately 40% of ceftriaxone prescriptions were inappropriate.[11] The reasons most often given for inappropriateness for respiratory tract infections were 'spectrum too broad' and 'antimicrobial not indicated'.[10]

Figure 35 Third- and fourth-generation cephalosporin usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2011–15 (3-month moving average)



Note: The drop in usage rates in November 2013 in Public Acute Group C Hospitals is explained by a hospital with very low usage rates of third- and fourth-generation cephalosporins that started contributing to NAUSP in November 2013. Because of the low numbers in this peer group, this had a marked effect on the average usage rate.

International surveillance programs and benchmarking

NAUSP has collected data on antibacterial use in a voluntary cohort of Australian hospitals since July 2004. Standardised methodology for collecting data and reporting on usage rates allows comparisons between Australian data and programs in other countries that measure, analyse and compare antibacterial usage. These comparisons are facilitated by the WHO standardised classification system for drug consumption, including the DDD (see Appendix 1).

Like Australia (for NAUSP), Denmark (DANMAP), Sweden (SWEDRES) and the Netherlands (NethMap) use OBDs as a denominator for calculating rates of antibacterial use. Figure 36 shows antibacterial usage rates in Australian hospitals that contributed to NAUSP during 2015, compared with the most recent rates published in surveillance reports for Denmark (2014)[6], the Netherlands (2016)[4] and Sweden (2015).[5]

Surveillance of antibacterial use is well established in many other developed countries. The European Centre for Disease Prevention and Control publishes *Surveillance of antimicrobial consumption in Europe* for the European Surveillance of Antimicrobial Consumption Network (ESAC-Net).[16] This report compiles usage data from 30 European countries in community and hospital sectors.

Although the ESAC-Net report represents a significant data holding, it cannot be directly compared with Australian data because the metric used is DDDs per 1000 inhabitants per day (a population measure) rather than DDDs per 1000 OBDs (a hospital inpatient measure). For a meaningful comparison to be made, NAUSP participation would need to include all Australian hospitals, and NAUSP data would need to be combined with Pharmaceutical Benefits Scheme dispensing data, to reflect both hospital and community antibacterial use.

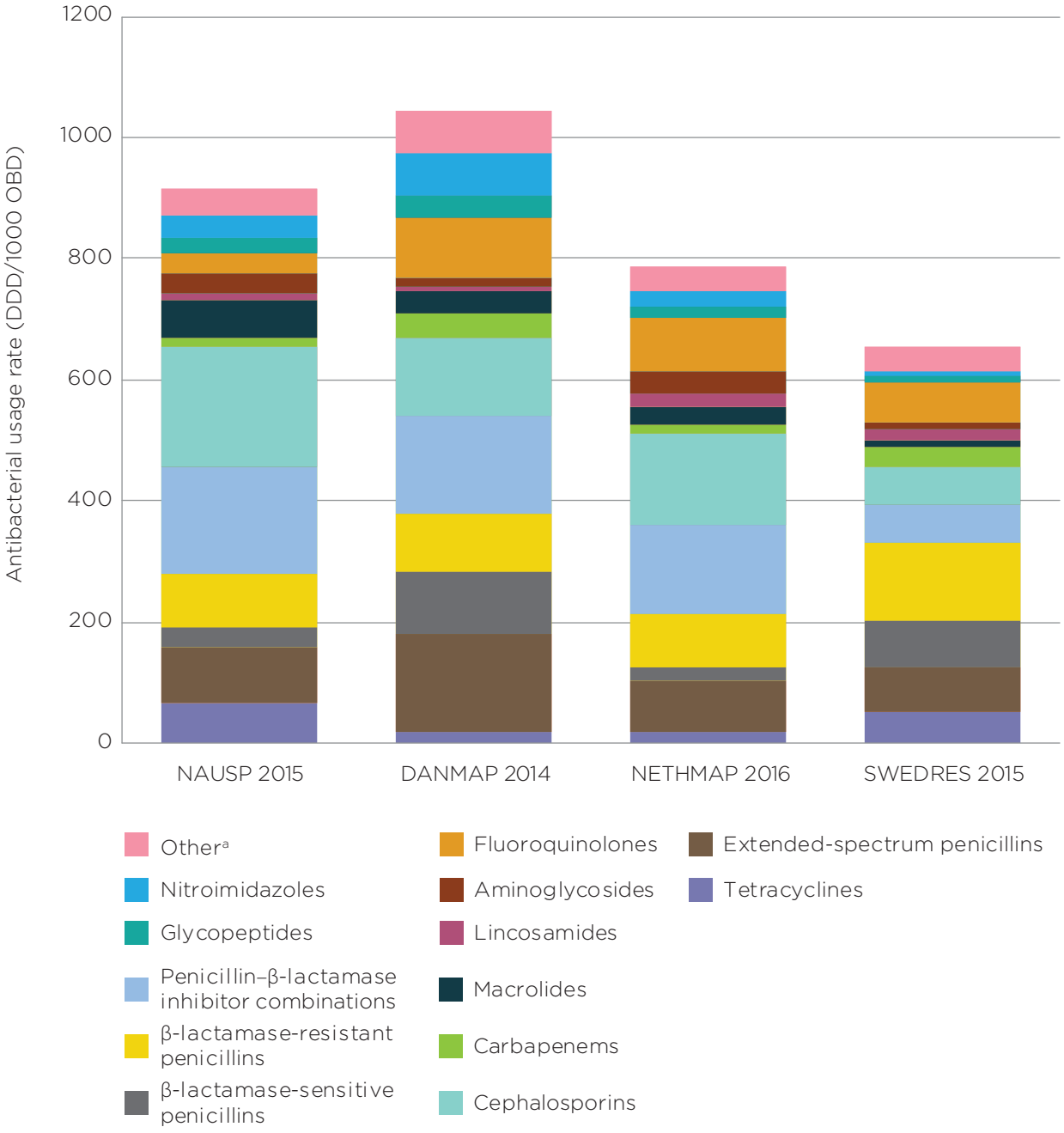
Although some inferences can be drawn from the comparison of usage rates in NAUSP contributor hospitals with other published data, care must be taken because of differences in methods (for example, data collection processes), patient populations, referral patterns and inpatient practices. Further differences may arise from variations between countries in the range of antibacterials available, resistance patterns, the types of specialty services provided (for example, a general hospital ward that includes an oncology unit) and, as mentioned above, sources of denominator data used in calculating usage rates. This is particularly the case for countries in the Asia–Pacific region, where AMS programs have historically been less well established than in Australia.

It is expected that establishment of formal antimicrobial surveillance systems will increase as a result of the WHO Global Action Plan on Antimicrobial Resistance and the United Nations Declaration on Antimicrobial Resistance, and provide opportunities in the future for comparative analyses.[7] Member states have been called on to undertake various activities, including:

- Incorporating antimicrobial resistance into healthcare, veterinary and agricultural training programs
- Collecting and reporting on antimicrobial use in humans to monitor trends
- Providing AMS programs.

Australia, with a nationally coordinated surveillance system for data collection and reporting through the AURA program, is well placed to lead the Asia–Pacific region in meeting the WHO goals.

Figure 36 Antibacterial usage rates (DDD/1000 OBD) in NAUSP contributor hospitals, and hospitals in Denmark, the Netherlands and Sweden, most recent available data



a 'Other' comprises lipopeptides, monobactams, methenamine, nitrofurans, oxazolidinones, polymyxins, rifamycins, short-acting sulfonamides, streptogramins, steroids, sulfonamide/trimethoprim combinations and trimethoprim.

Notes: Includes Australian data from NAUSP for January to December 2015 (159 hospitals), NethMap 2016 rates (from 2014), and SWEDRES 2015 rates (denominator data from 2014).

Conclusions and future directions

NAUSP continues to provide participating Australian hospitals with a rich data source for analysis and monitoring of antibacterial usage patterns and trends, and measurement of improvement in clinical prescribing practice. Measuring and evaluating antibacterial use, and assessing interventions to improve appropriateness of prescribing are key elements of AMS programs.

At present, the NAUSP cohort includes only a small number of private hospitals and Public Acute Group C Hospitals. Over time, it is anticipated that a sufficient number of private hospitals will contribute to NAUSP to enable benchmarking using the AIHW private hospital peer groups. This will support more accurate comparisons for all contributors. An increase in the number of Public Acute Group C Hospitals contributing to NAUSP will improve the overall representativeness of national data, and also provide contributing hospitals in this peer group with more robust comparator rates. Meaningful feedback on antimicrobial use for smaller sites is important, because they may not have direct access to specialist infectious diseases or AMS resources.

Nationally, aggregate usage rates decreased from 936 DDDs per 1000 OBDs in 2014 to 916 DDDs per 1000 OBDs in 2015. A natural assumption would be that this decrease is due to the increase in participation by Public Acute Group B and C Hospitals, since usage rates would be expected to be lower in smaller hospitals. However, data in this report do not support this assumption. A more likely reason is that effective AMS programs are operating in larger hospitals where the majority of antimicrobial use occurs.

Average usage rates varied between states and territories (see Figures 10–15). They were lower in 2015 than in 2014 in New South Wales/Australian Capital Territory, South Australia, Tasmania, Victoria and Western Australia. An increase in average statewide usage rates in Queensland/Northern Territory may be due to the inclusion of Northern Territory data from one hospital and/or the influence of new private hospital contributors.

For the first time, analyses of state and territory usage rates have been included for the six major antibacterial classes with the greatest potential to fuel multidrug resistance. These data (see Figure 9) may provide a potential baseline for future surveillance of quality of prescribing, as changes in overall usage rates and the percentage of total usage rates associated with these antibacterial classes are measured over time.

Careful interpretation is required for data pertaining to these six antibacterial classes because of a possible anomaly relating to DDDs. The DDD for piperacillin–tazobactam published by WHO is 14 grams. This DDD does not accurately reflect the Australian setting, where doses of 12 grams per day are routinely used (4 grams three times per day). The WHO-issued DDD is used consistently worldwide in analysis of drug consumption data, and may contribute to an overestimation of Australia's usage rate for piperacillin–tazobactam. The published DDDs are reviewed annually by the WHO; more work may be needed locally in this area, with potential adjustments to published DDDs to reflect local prescribing recommendations. An alternative metric, used by some other surveillance programs, is DDDs per 1000 admissions (separations). Further research is needed to determine whether this metric would be useful in Australian hospitals.

Quality Statement 7 of the Commission's Antimicrobial Stewardship Clinical Care Standard recommends switching to treatment with a narrow-spectrum antibacterial where a patient's clinical condition and the results of microbiology tests indicate that this is appropriate.[13]

Many AMS programs work to ensure that the narrowest spectrum antibacterial is used. A possible indicator of quality of prescribing is the ratio between broad-spectrum and narrow-spectrum antibacterial use. A trend towards a lower percentage of broad-spectrum antibacterials over time could indicate application of AMS principles – for example, prompt microbiological testing with timely cessation of empirical broad-spectrum antibacterials and appropriate prescribing of

narrow-spectrum antibacterials. This indicator could be employed within individual hospitals as a benchmark for improving the effectiveness of AMS activities from year to year; a formal target for this percentage has not been evaluated.

Analysis of data by peer group has revealed few unexpected trends, with usage rates of broader-spectrum antibacterials (for example, carbapenems, glycopeptides, and antipseudomonal penicillin combinations) higher in more acute settings.

Fluoroquinolone use is trending down in all peer groups except Public Acute Group C Hospitals, which showed a slight increase in the usage rate during 2013–15. It is difficult to attribute this observation to any particular cause or to interpret the data, because of the small number of contributors from this peer group. Possible reasons may include more generalist rather than specialist prescribing, less mature AMS programs, and transfer of patients to complete therapy initiated in hospitals that provide a more complex and specialised range of services.

The bar charts of state- and territory-based total usage have been designed to provide a snapshot for 2015, showing the range of use within and between peer groups. Individual hospitals are encouraged to review their rankings in the context of these graphs. If their use is high compared with other hospitals in their state or territory, it is recommended that they explore the possible reasons. In some cases, the characteristics of the local patient mix may explain high use of particular antibacterial classes (for example, use of glycopeptides in areas where rates of infection with methicillin-resistant *Staphylococcus aureus* are high). If reasons for patterns of use are not obvious, a targeted audit is recommended. The audit tools developed by the National Centre for Antimicrobial Stewardship for NAPS are useful for targeted audits.

Variations between the states and territories continue for some antibacterial classes. For example, gentamicin usage rates in South Australia are approximately four times those of Victoria. This may reflect differences in local prescribing policies.

In November 2014, significant changes were made to Australian surgical prophylaxis guidelines – in particular, the dose of cefazolin doubled from 1 to 2 grams, which may have contributed to the increase in usage rates of cefazolin from 131 to 138 DDDs per 1000 OBDs from 2014 to 2015. Another contributor may be continuing high rates of inappropriate prescribing of cefalexin (39.2%), particularly for surgical prophylaxis, urinary tract infections and pneumonia, as identified in the 2015 Hospital NAPS.[11]

The current methods used by NAUSP limit international comparisons and benchmarking to some extent, and voluntary participation in the program means that it is not possible to generate population-based denominator data.

NAUSP continues to provide data that inform both local and national AMS initiatives. Hospitals use NAUSP data to target resources for auditing and education, and to follow up outcomes of previous interventions, at an institutional and local health district level. National, and state and territory data are useful for informing policy development, benchmarking with overseas surveillance programs, checking year-by-year changes in prescribing practices, and measuring improvements following AMS interventions.

Enhancements to the NAUSP system – phase one of which was introduced in 2016 – will be completed in early 2017. The enhancements provide for data entry via an online portal, and allow contributors to validate their own data and produce a variety of reports.

Appendix 1 What is a defined daily dose?

A defined daily dose (DDD) is the average daily adult maintenance dose of a medicine for its main indication.[17] DDDs for most antibacterial medicines are included in the J01 class of the World Health Organization's uniform classification index of medicines. The DDD is widely accepted in international surveillance programs because it enables comparison of antibacterial use within and between countries. Antibacterial use in hospitals is usually measured as a rate: the DDD divided by a denominator of clinical activity within the hospital, such as the number of occupied bed days (OBDs) or the number of patient days.

Sales or prescription data about medicines use in the community can be shown as DDDs per 1000 inhabitants per day, to give a population estimate for use of a medicine (or group of medicines). For example, 10 DDDs per 1000 inhabitants per day means that, on a given day, 1% of the population received a medicine (or group of medicines). This estimate is useful for medicines that treat chronic illnesses for which the DDD and the average prescribed daily dose (PDD) are similar.

What are some other measures of medicine use?

The DDD may or may not be the same as a medicine's PDD for a particular person (based on individual characteristics such as weight and kidney function), or its recommended daily dose (RDD) as found in guidelines. For example, the DDD for ampicillin is 2000 mg, a PDD could be 750–3000 mg (depending on the indication, severity of infection and kidney function), and, in one guideline, the RDD to treat a liver abcess is 8000 mg.[10,17]

An individual annual estimate of use can be shown as DDDs per inhabitant per year. This gives an estimate of the number of days for which an individual received the medicine (or group of medicines) per year. For example, 10 DDDs per inhabitant per year implies that, on average during that year, each inhabitant received 10 days of treatment with the medicine (or group of medicines).

Hospital inpatient data can be shown as DDDs per 100 bed days to give a hospital-wide estimate of the rate of use of a medicine (or group of medicines). This allows benchmarking because the rate is independent of hospital size. However, different hospitals and, indeed, different countries define bed days differently. For accuracy, bed day figures should be adjusted to beds that are occupied.

An alternative to the DDD is days of therapy (DOT). The DOT is the sum of days in which each medicine is given.[18] Measuring DOT requires individual patient data to sum the total duration of all medicines given (therefore, it does not reflect the dose of individual medicines).[19]

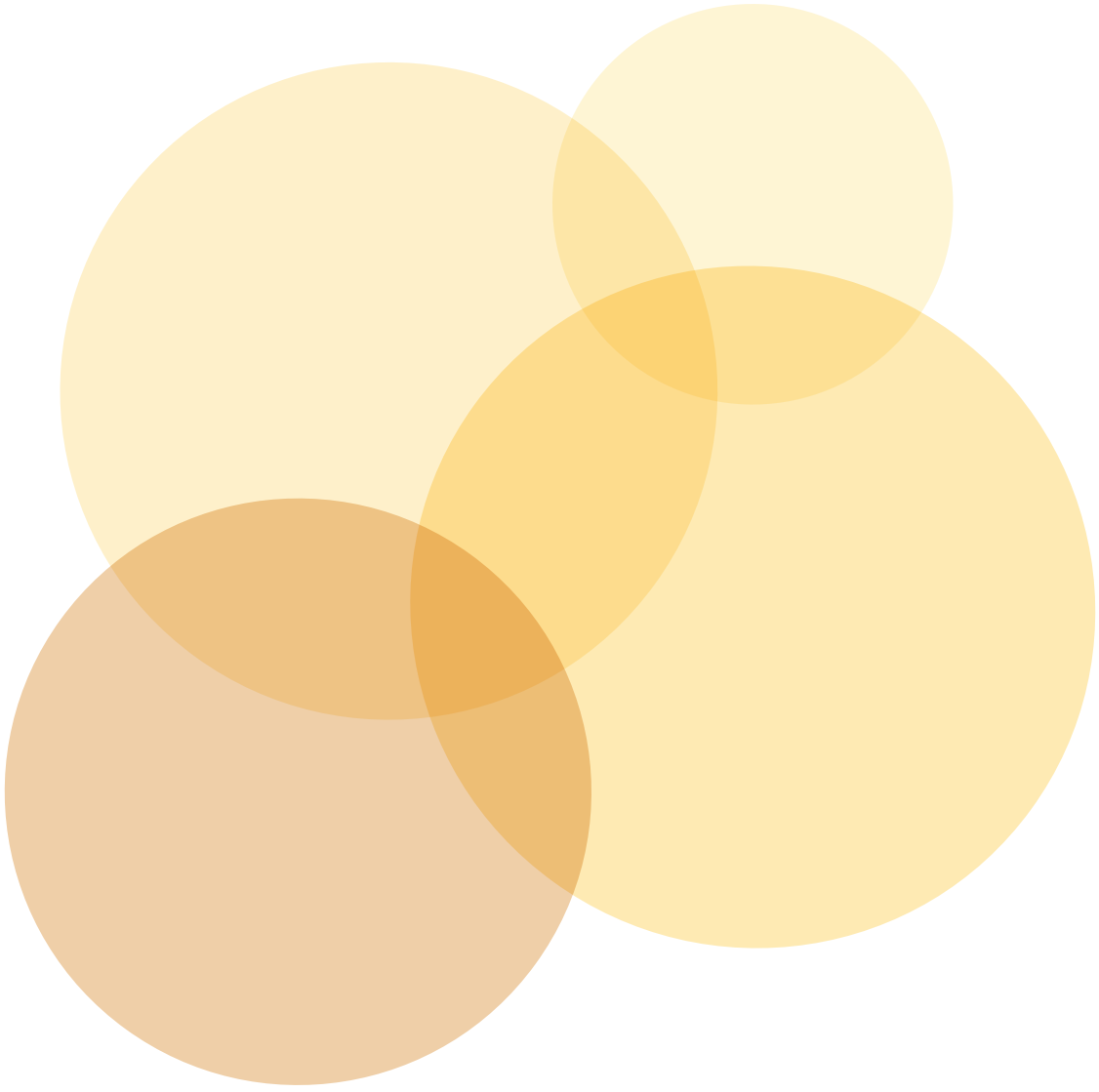
One comparative analysis measured overall antibacterial use by DDD or DOT for 50 antibacterials prescribed for adults discharged from 130 United States hospitals during the 12 months ending 31 July 2003.[19] For antibacterials for which the dose given was similar to the DDD, estimates of use based on the DDD and the DOT were similar (for example, linezolid). In contrast, for antibacterials for which the dose given was larger than the DDD, estimates of use based on the DDD were larger than estimates of use based on the DOT (for example, cefipime). Similarly, for antibacterials for which the dose given was smaller than the DDD, estimates of use based on the DDD were smaller than estimates of use based on the DOT (for example, ceftriaxone).

Another comparative analysis showed the same threefold increase in the DDD and the DOT for antifungal use in a paediatrics and obstetrics–gynaecology hospital over the same 10-year period.[20]

What are some limitations of the DDD?

A DDD does not:

- Account for
  - variation between patients in hospital (e.g. adults, children)
  - hospital infection rates
  - casemix (for example, diagnosis, disease severity); for example, the relative proportions of erythromycin use as an antibacterial and for gastric motility are unknown.
- Measure the dose given or an individual's exposure to a medicine (or group of medicines). For some antibacterials, DDDs do not align with common hospital PDDs: a DDD is usually calculated for oral treatment and is often lower than a PDD for intravenous treatment. For example, the DDD for oral flucloxacillin is 2000 mg, but a PDD used for intravenous flucloxacillin in hospitals can be fourfold higher, at 8000 mg
- Measure appropriate prescribing. For example, prescribing a broad-spectrum antibacterial such as piperacillin–tazobactam to treat intra-abdominal sepsis is 1 DDD. A more common choice to prescribe a combination of three older antibacterials such as amoxicillin, gentamicin and metronidazole is 5 DDDs.



Appendix 2 Contributor information

Table A1 Hospitals contributing to the National Antimicrobial Utilisation Surveillance Program, 2015

State or territory	Hospital
Australian Capital Territory	Canberra Hospital
New South Wales	Armidale Hospital, Auburn Hospital, Bankstown Hospital, Bathurst Base Hospital, Bega District Hospital, Belmont Hospital, Blacktown Hospital, Bowral Hospital, Broken Hill Health Service, Campbelltown Hospital, Canterbury Hospital, Cessnock District Hospital, Coffs Harbour Hospital, Concord Hospital, Dubbo Base Hospital, Fairfield Hospital, Gosford Hospital, Goulburn Base Hospital, Grafton Base Hospital, Griffith Base Hospital, Hornsby Ku-Ring-Gai Hospital, John Hunter Hospital, Kempsey District Hospital, Lismore Base Hospital, Liverpool Hospital, Maitland Hospital, Manly Hospital, Manning Hospital[a], Mona Vale Hospital, Mount Druitt Hospital, Muswellbrook District Hospital, Nepean Hospital, Calvary Mater Hospital Newcastle, Newcastle Mater Oncology, Orange Health Service, Port Macquarie Base Hospital, Prince of Wales Hospital, Royal North Shore Hospital, Royal Prince Alfred Hospital, Ryde Hospital, Scott Memorial Hospital Scone, Shellharbour Hospital, Shoalhaven Hospital, St George Hospital, St Vincent's Hospital, Sutherland Hospital, Tamworth Hospital, Tweed Hospital, Wagga Base Hospital, Westmead Hospital, Wollongong Hospital, Wyong Hospital
Northern Territory	Royal Darwin Hospital
Queensland	Allamanda Private Hospital[a], Atherton Hospital, Bundaberg Hospital, Caboolture Hospital, Cairns Base Hospital, Caloundra Health Service, Gladstone Hospital, Gold Coast University Hospital, Greenslopes Hospital, Gympie Health Service, Hervey Bay Hospital, Innisfail Hospital, Ipswich Hospital, Kingaroy Hospital, Logan Hospital, Mackay Base Hospital, Mareeba Hospital, Maryborough Hospital, Mater Hospital Brisbane, Mater Mothers' Hospital, Mater Private Hospital, Mater Redland Private Hospital, Nambour General Hospital, Princess Alexandra Hospital, Queen Elizabeth II Hospital, Redcliffe Hospital, Redland Hospital, Robina Hospital, Rockhampton Hospital, Royal Brisbane and Women's Hospital, St Andrew's Private Hospital, Sunshine Coast Private Hospital, Prince Charles Hospital, Toowoomba Hospital, Townsville Hospital, Warwick Hospital, Wesley Hospital
South Australia	Ashford Hospital, Calvary Central Districts Hospital[a], Calvary Hospital, Flinders Medical Centre, Flinders Private Hospital, Gawler Health Service, Lyell McEwin Hospital, Memorial Hospital, Modbury Hospital, Mount Gambier Hospital, Noarlunga Hospital, Port Augusta Hospital, Port Pirie Hospital, Queen Elizabeth Hospital, Repatriation General Hospital, Riverland Regional Health Service (Berri), Royal Adelaide Hospital, St Andrew's Hospital, Wakefield Hospital, Whyalla Hospital, Women's and Children's Hospital

Table A1 (continued)

State or territory	Hospital
Tasmania	Hobart Private Hospital, Launceston General Hospital, Mersey Community Hospital, Northwest Regional Hospital, Royal Hobart Hospital
Victoria	Albury Wodonga Health – Albury, Albury Wodonga Health – Wodonga, Alfred Hospital, Angliss Hospital, Austin Hospital, Ballarat Base Hospital, Bendigo Health[a], Box Hill Hospital, Cabrini Private Hospital (Brighton), Cabrini Private Hospital (Malvern), Casey Hospital, Dandenong Hospital, Frankston Hospital, Geelong Hospital, Maroondah Hospital, Mercy Hospital for Women, Monash Medical Centre (Clayton), Monash Medical Centre (Moorabbin), Royal Melbourne Hospital, Sandringham Hospital, St Vincent's Hospital, St Vincent's Private Hospital (East Melbourne), St Vincent's Private Hospital (Fitzroy), The Northern Hospital[a], Warrnambool Base Hospital, West Gippsland Hospital, Western Health (Footscray), Western Health (Sunshine), Werribee Mercy Hospital
Western Australia	Albany Hospital, Armadale Health Service, Bunbury Regional Hospital, Fiona Stanley Hospital[a], Fremantle Hospital, Joondalup Health Campus, King Edward Memorial Hospital, Osborne Park Hospital, Rockingham Hospital, Royal Perth Hospital, Sir Charles Gairdner Hospital, St John of God Hospital (Murdoch), St John of God Hospital (Subiaco)

a Sites contributed between 6 and 12 months of data for the 2015 reporting period.

Appendix 3 WHO Anatomical Therapeutic Classification and defined daily doses for antibacterial agents included in NAUSP analyses

ATC classification	Generic name	DDD (g)	Route
J01AA	Tetracyclines		
J01AA02	Doxycycline	0.1	O, P
J01AA08	Minocycline	0.2	O, P
J01AA12	Tigecycline	0.1	P
J01B	Amphenicols		
J01BA01	Chloramphenicol	3	O, P
J01C	β-lactam antibacterials, penicillins		
J01CA	Penicillins with extended spectrum		
J01CA01	Ampicillin	2	O, P
J01CA04	Amoxycillin	1	O, P
J01CE	β-lactamase-sensitive penicillins		
J01CE01	Benzylpenicillin	3.6	P
J01CE02	Phenoxymethylpenicillin	2	O
J01CE08	Benzathine benzylpenicillin	3.6	P
J01CE09	Procaine benzylpenicillin	0.6	P
J01CF	β-lactamase-resistant penicillins		
J01CF01	Dicloxacillin	2	O, P
J01CF05	Flucloxacillin	2	O, P
J01CR	Combinations of penicillins, including β-lactamase inhibitors		
	Without antipseudomonal activity		
J01CR02	Amoxicillin and enzyme inhibitor	1	O
J01CR02	Amoxicillin and enzyme inhibitor	3	P
	With antipseudomonal activity		
J01CR03	Ticarcillin and enzyme inhibitor	15	P
J01CR05	Piperacillin and enzyme inhibitor	14	P
J01D	Other β-lactam antibacterials		
J01DB	First-generation cephalosporins		
J01DB01	Cefalexin	2	O
J01DB03	Cefalotin	4	P
J01DB04	Cefazolin	3	P

ATC classification	Generic name	DDD (g)	Route
J01DC	Second-generation cephalosporins		
J01DC01	Cefoxitin	6	P
J01DC02	Cefuroxime	0.5	O
J01DC04	Cefaclor	1	O
J01DD	Third-generation cephalosporins		
J01DD01	Cefotaxime	4	P
J01DD02	Ceftazidime	4	P
J01DD04	Ceftriaxone	2	P
J01DE	Fourth-generation cephalosporins		
J01DE01	Cefepime	2	P
J01DH	Carbapenems		
J01DH02	Meropenem	2	P
J01DH51	Imipenem and enzyme inhibitor	2	P
J01DH03	Ertapenem	1	P
J01DH04	Doripenem	1.5	P
J01DF	Monobactams		
J01DF01	Aztreonam	4	P
J01DI	Other cephalosporins		
J01DI02	Ceftaroline	1.2	P
J01E	Sulfonamides and trimethoprim		
J01EA01	Trimethoprim	0.4	O, P
J01EE01	Sulfamethoxazole and trimethoprim	1.92	O, P
J01F	Macrolides, lincosamides and streptogramins		
J01FA	Macrolides		
J01FA01	Erythromycin	1	O, P
J01FA01	Erythromycin ethylsuccinate	2	O
J01FA06	Roxithromycin	0.3	O
J01FA09	Clarithromycin	0.5	O
J01FA10	Azithromycin	0.3	O
J01FA10	Azithromycin	0.5	P
J01FF	Lincosamides		
J01FF01	Clindamycin	1.2	O
J01FF01	Clindamycin	1.8	P
J01FF02	Lincomycin	1.8	P
J01FG	Streptogramins		
J01FG01	Pristinamycin	2	O

ATC classification	Generic name	DDD (g)	Route
J01FG02	Quinupristin/dalfopristin	1.5	P
J01GB	Aminoglycoside antibacterials		
J01GB01	Tobramycin	0.24ww	P
J01GB01	Tobramycin	0.3	Inh solution
J01GB01	Tobramycin	0.112	Inh powder
J01GB03	Gentamicin	0.24	P
J01GB05	Neomycin	1	O
J01GB06	Amikacin	1	P
J01MA	Quinolone antibacterials		
J01MA02	Ciprofloxacin	1	O
J01MA02	Ciprofloxacin	0.5	P
J01MA06	Norfloxacin	0.8	O
J01MA14	Moxifloxacin	0.4	O, P
J01X	Other antibacterials		
J01XA	Glycopeptide antibacterials		
J01XA01	Vancomycin	2	O, P
J01XA02	Teicoplanin	0.4	P
J01XB	Polymyxins		
J01XB01	Colistin	3MU	P, Inh
J01XC	Steroid antibacterials		
J01XC01	Fusidic acid	1.5	O, P
J01XD	Imidazole derivatives		
J01XD01	Metronidazole	1.5	P
P01AB01	Metronidazole	2	O, R
P01AB02	Tinidazole	2	O
J01XX	Other antibacterials		
J01XX01	Fosfomycin	3	O
J01XX01	Fosfomycin	8	P
J01XX08	Linezolid	1.2	O, P
J01XX09	Daptomycin	0.28	P
J04	Antimycobacterials		
J04AB03	Rifampicin	0.6	O, P

ATC = Anatomical Therapeutic Classification; DDD = defined daily dose; Inh = inhalation; O = oral; P = parenteral; R = rectal
Source: WHO (2017)[21]

Glossary

Term	Definition
aggregate total-hospital antibacterial usage rate	The total number of defined daily doses of antibacterials divided by the total hospital occupancy measured in occupied-bed days.
antimicrobials	Medicines used to treat or prevent infections caused by microbes, including antibacterial, antifungal, antiviral and antiparasitic medicines. In this report, the term 'antimicrobial' is used to refer to data on all, or almost all, classes of antimicrobials. Because this report is confined to reporting on use of systemic antibacterials in Australian hospitals, the term 'antibacterial' is used when referring to the output of analyses of the NAUSP data, and when comparisons are made with data reported by other countries.
mean total-hospital antibacterial usage rate	The mean antibacterial usage rate for all hospitals, calculated using the total rate for individual hospitals.
median total-hospital antibacterial usage rate	The median antibacterial usage rate for all hospitals, calculated using the total rate for individual hospitals.
occupied-bed day	The sum of the length of stay for each acute adult inpatient separated during the reporting period who remained in hospital overnight (adapted from the definition of the Australian Institute of Health and Welfare). Day patients, outpatients, hospital-in-the-home, and psychiatric and rehabilitation units are excluded.
usage rate	The number of defined daily doses (DDDs) used per 1000 occupied-bed days (OBDs). Data for outpatient areas, including hospital-in-the-home, day treatment centres, day surgery and dialysis clinics, are excluded. The rate is calculated as follows: $\text{Usage rate} = \frac{\text{Number of DDDs/time period}}{\text{OBDs/time period}} \times 1000$

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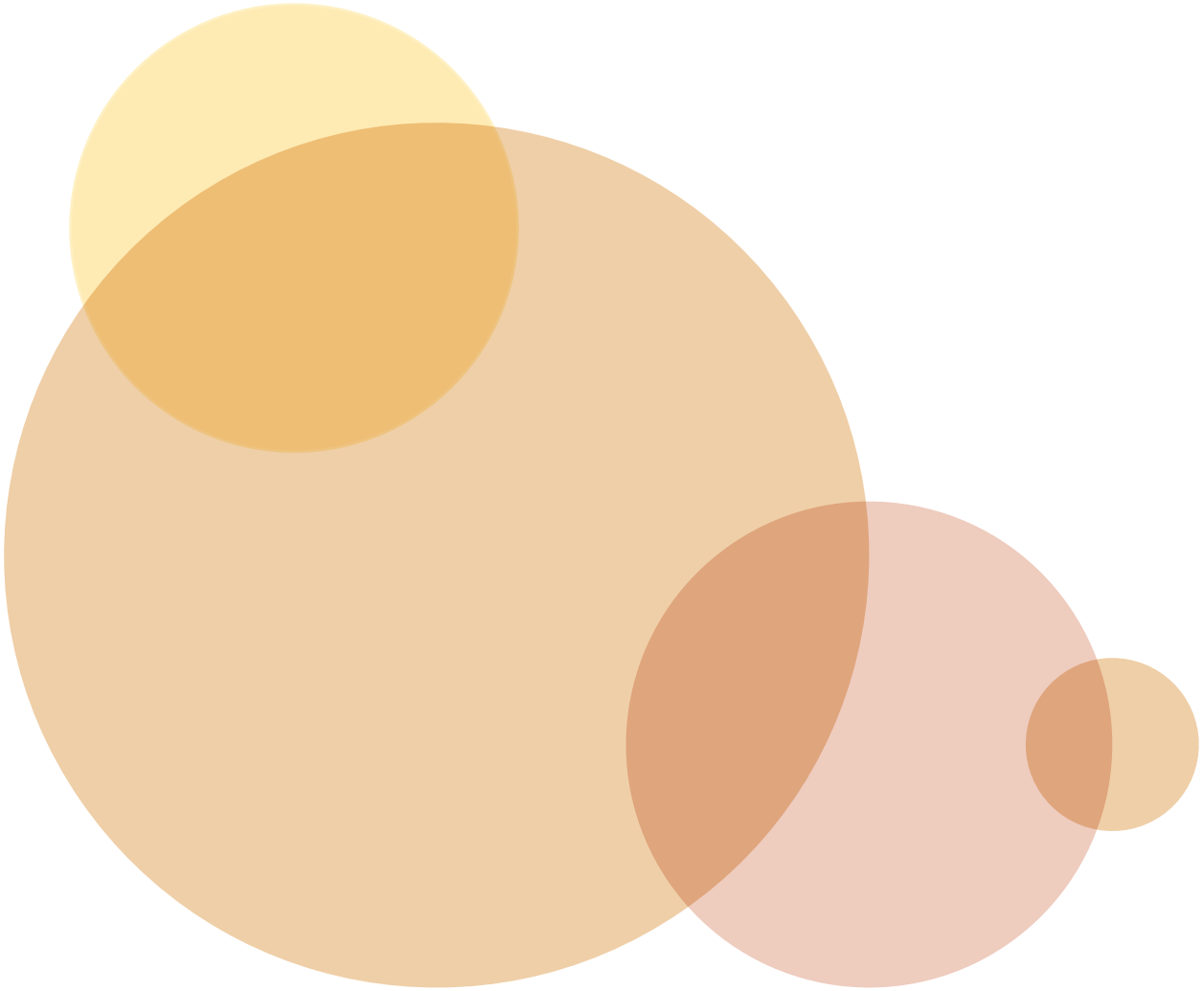
Additional NAUSP data are available at www.sahealth.sa.gov.au/nausp.

The NAUSP team and the Commission thank all hospitals that voluntarily provide monthly data on antimicrobial use.



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