AUSTRALIAN COMMISSION ON SAFETY AND QUALITY IN HEALTH CARE

AURA
Antimicrobial Use and Resistance in Australia

January 2018

Antimicrobial Use in Australian Hospitals

2016 annual report of the National Antimicrobial Utilisation Surveillance Program

Government of South Australia
SA Health

NAUSP
National Antimicrobial Utilisation Surveillance Program

Published by the Australian Commission on Safety and Quality in Health Care

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ISBN: 978-1-925665-19-2

The Commission's preference is that you attribute this publication (and any material sourced from it) using the following citation:

> SA Health, Australian Commission on Safety and Quality in Health Care. Antimicrobial use in Australian hospitals: 2016 annual report of the National Antimicrobial Utilisation Surveillance Program. Sydney: ACSQHC; 2018.

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Abbreviations

Term	Definition
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 of Health and Ageing
WHO	World Health Organization

Summary

Antibacterial use in Australian hospitals continues to fall as part of the national response to antimicrobial resistance. Total-hospital antibacterial use has reduced by 12.6% overall from 2010 to 2016. Reducing volume of antimicrobial use is an indirect indicator of increased appropriateness of use. This ongoing decline has been supported by the implementation of the National Safety and Quality Health Service (NSQHS) Standard Preventing and Controlling Healthcare-Associated Infection in Australian public and private hospitals.

The Preventing and Controlling Healthcare-Associated Infection Standard reduces the risks of patients acquiring preventable healthcare-associated infections, through implementation of key strategies including clinical governance, risk identification and management, infection prevention and control systems, antimicrobial stewardship (AMS) and surveillance activities.

Usage rates of systemic antifungal agents are reported for the first time in this report.

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 52 in 2008 to 169 hospitals (143 public and 26 private) in 2016. All Principal Referral Hospitals and 88% (93/106) of Public Acute Group A and B hospitals participated in the program in 2016.

Key findings of analyses of the 2016 data from the National Antimicrobial Utilisation Surveillance Program (NAUSP) include the following:

- For January–December 2016, the aggregate total-hospital antibacterial usage rate for all NAUSP contributor hospitals (*n* = 169) was 891.5 DDDs per 1,000 OBDs; this is a 2.7% fall from 2015, and an 8.5% fall compared with 2012, likely reflecting effectiveness AMS programs associated with implementation of the NSQHS Standards

- The median annual antimicrobial usage rate in 2016 was 922 DDDs per 1,000 OBDs, and the mean usage rate across the 169 institutions was 938 DDDs per 1,000 OBDs (range 269–2,065 DDDs per 1,000 OBDs); among the 91 contributors who have submitted data for five years or more, average usage rates have declined by 6.3% since 2012, and 0.8% between 2015 and 2016

- As expected, due to the complexity of patients cared for, usage rates in intensive care units (ICUs) are higher than total-hospital usage rates for most antibacterial classes

- Aggregate ICU usage rates have declined, with an 8.5% reduction since 2012, and notable reductions in use of aminoglycosides, β-lactamase-resistant penicillins, carbapenems, glycopeptides, macrolides and metronidazole; while it is not possible to link NAUSP data to clinical outcome, it is assumed that the decline reflects a move to more appropriate use of antibacterials and does not compromise patient outcomes

- Twenty antibacterials accounted for 93.5% of all antibacterials used in public and private hospitals in 2016, on a defined daily doses (DDDs) per 1,000 occupied bed days (OBDs) basis

- Six antibacterials – amoxicillin–clavulanate, cefazolin, flucloxacillin, amoxicillin, doxycycline and piperacillin–tazobactam – represented 55% of antibacterials used; a similar usage pattern was reported in the 2015 NAUSP annual report[2]

- Consistent decreases in usage rates over the last five years are apparent for aminoglycosides, penicillin–β-lactamase inhibitor combinations (amoxicillin–clavulanate only), fluoroquinolones, macrolides, metronidazole and trimethoprim; at the same time, usage rates of tetracyclines and trimethoprim–sulfamethoxazole have increased which may be due to substitution of tetracyclines for macrolides and trimethoprim–sulfamethoxazole for fluoroquinolones

- Fluconazole was the most commonly used antifungal agent in NAUSP contributor hospitals in 2016, and triazole antifungals (fluconazole, itraconazole, posaconazole, voriconazole) accounted for almost 90% of total usage for the past five years; although usage rates of echinocandins (anidulafungin, caspofungin, micafungin) are low, usage increased from 3.8% to 5.6% of total antifungal use from 2012 to 2016

- ICU usage rates of antifungals are quadruple the rates in other hospital settings; international comparative data for usage of antifungal agents are scarce, but available data show that Australian total-hospital usage rates are lower than in the Netherlands.

During 2017–18, the Australian Commission on Safety and Quality in Health Care (the Commission) will continue to work with the South Australian Department of Health and Ageing (SA Health) to enhance the capacity of NAUSP in its support of AMS programs in Australian hospitals. Planned enhancements include developing a method to collect relevant usage data from paediatric hospitals, publishing six-monthly usage and benchmarking reports for ICUs, and expanding the range of specialised clinical settings for which usage data analyses are routinely available (e.g. haematology, oncology).

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 contributes to meeting the requirements for accreditation against the NSQHS) Standard Preventing and Controlling Healthcare-Associated Infection.[1]

NAUSP directly supports implementation of the Australian Government's first National Antimicrobial Resistance Strategy[3] and initiatives to improve the appropriate use of antimicrobials. 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.

Introduction

In Australian healthcare settings, patients are often treated in close proximity to each other. They undergo invasive procedures, have medical devices inserted, and received broad-spectrum antibacterials and immunosuppression therapies. These conditions create ideal opportunities for adaptation and spread of pathogenic infectious agents, including resistant strains.

Healthcare-associated infections are the most common hospital-acquired complication. Such infections cause considerable harm to patients. Infectious microorganisms evolve over time, and continue to present major clinical management challenges. Currently, the main concern is the emergence and transmission of organisms resistant to antimicrobials.

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 (WHO) Global Action Plan on Antimicrobial Resistance.[3] 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. The Implementation Plan that supports the strategy was released in November 2016.[4]

The National Antimicrobial Utilisation Surveillance Program (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.

Surveillance programs such as NAUSP support improved understanding of the use of antimicrobials in hospitals. This supports achievement of the objectives of the national strategy by enabling implementation of antimicrobial stewardship (AMS) practices that improve the appropriate use of antimicrobials.

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 Australian Department of Health and Ageing (SA Health). Development and implementation of NAUSP have been an ongoing collaboration between SA Health and the Commission since 2013.

NAUSP does not collect data on either appropriateness of prescribing or clinical outcomes, so capacity to comment on those issues is limited. The AURA Surveillance System includes data on appropriateness of prescribing that are collected via the National Antimicrobial Prescribing Survey (NAPS) conducted by the National Centre for Antimicrobial Stewardship (NCAS). It is important to note that the appropriate mix and volume of antimicrobials used in a hospital is influenced by casemix – that is, the types of patients for which care is provided.

Since it began in July 2004, NAUSP has diversified and grown into a national program involving all states and territories and hospitals from the public and private sectors. Trend and benchmarking data, both for individual hospitals and aggregated at jurisdictional level, 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 on a voluntary basis. The number of contributing 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 the NSQHS Standard Preventing and Controlling Healthcare-Associated Infection.[2]

This is the fourth annual report of NAUSP. It includes analyses of national data on antimicrobial use in 169 public and private adult acute care hospitals in 2016. All Principal Referral Hospitals, and 88% of Public Acute Group A and Public Acute Group B hospitals now participate in the program. The number of private hospitals participating in NAUSP is slowly increasing.

All Australian states and territories were represented in NAUSP in 2016; 35 hospitals have contributed continuously since July 2004, and 13 South Australian hospitals have contributed continuously since the program began locally in 2001. Figure 1 and Tables 1 and 2 show the growth in the number of hospitals participating in NAUSP since 2004.

The number of hospitals participating, and contributing data to aggregated annual reports, has varied over this period. Not all contributor hospitals enrolled in the program have contributed data to the annual rates used in this report. The number of hospitals for which data were used to generate annual rates for this report varies from that in previous reports due to the following factors:

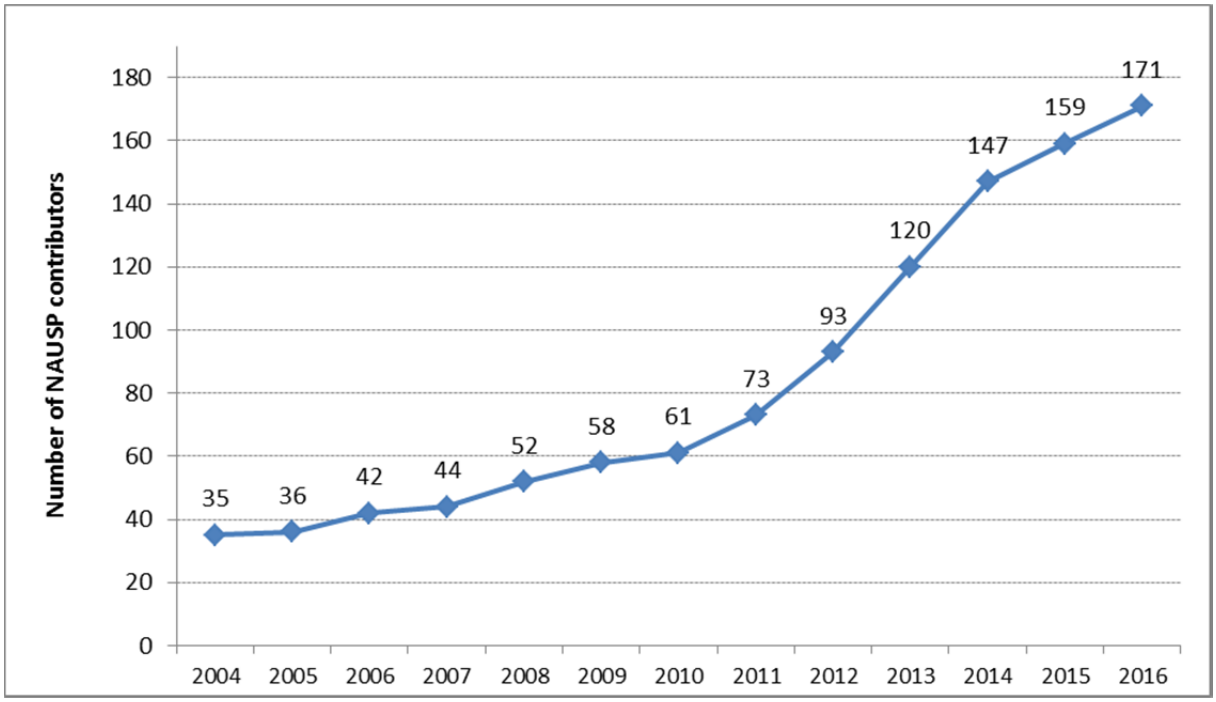
- Provision of retrospective data by new contributors
- Omission of two contributors from the 2016 cohort while data anomalies were corrected
- Inclusion of some contributors for which data were previously omitted for annual reports
- Relocation and name change of a private hospital
- Inclusion of data from a previously un-peered hospital with that of an existing NAUSP contributor.

Tables 1 and 2 provide information on the cohort of hospitals included in analyses for this 2016 annual report and data used for trend analysis.

This report includes historical comparisons over five and 10 years, where possible, and comprises data only from the 2016 cohort. Interstate and intrastate data are presented, along with comparisons of antimicrobial usage rates between hospital peer groups for selected antibacterial and antifungal classes.

The utility of surveillance is enhanced as more data become available. This allows hospitals to benchmark against their own historical usage, but also against similar facilities, and allows AMS teams to provide more informed advice to prescribers.

Figure 1: Number of public and private hospitals that have contributed to NAUSP, 2004–2016*



* The data on the number of contributors for each year may vary from previous reports because the data in those reports related to contributor hospitals included in the cohort for analyses, rather than the total number of contributors. In 2014 and 2015, a specialised unit of one hospital was counted as a separate contributor.

Table 1: Annual number of contributor hospitals (public and private) included in the cohort for analyses, by peer group, 2004–2016*†

Year	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	Total
2004	15	7	4	3	0	2	4	0	**35**
2005	15	8	4	3	0	2	4	0	**36**
2006	17	10	6	3	0	2	4	0	**42**
2007	18	10	7	3	0	2	4	0	**44**
2008	20	12	9	3	0	4	4	0	**52**
2009	20	15	11	3	0	4	4	0	**57**
2010	20	17	11	3	0	5	4	0	**60**
2011	22	22	12	3	1	6	5	1	**72**
2012	27	32	15	3	2	6	5	1	**91**
2013	29	42	25	4	2	6	7	3	**118**
2014	29	53	32	10	3	7	7	4	**145**
2015	30	55	36	13	4	7	7	5	**157**
2016	30	56	37	16	4	10	8	8	**169**

* Hospitals that contributed to NAUSP during the period 2004–2016 have been assigned to peer groups using the 2015 Australian Institute of Health and Welfare classifications.[5]

† The number of hospitals in each group may vary from those in previous reports due to new contributors providing retrospective data. Some contributors were omitted from the 2016 cohort due to data anomalies and some contributors previously omitted in annual reports were included. A private hospital relocated and changed names and data from a previously un-peered hospital were able to be included with an existing NAUSP contributor.

Table 2: Public and private hospitals that contributed to the 2016 NAUSP cohort for analyses, by state and territory, 2004–2016*

Year	NSW and ACT	Vic	Qld and NT	SA	WA	Tas	Total
2004	7	4	1	19	3	1	**35**
2005	7	5	1	19	3	1	**36**
2006	11	7	1	19	3	1	**42**
2007	13	7	1	19	3	1	**44**
2008	18	8	3	19	3	1	**52**
2009	20	8	3	19	3	4	**57**
2010	22	9	3	19	3	4	**60**
2011	25	13	7	19	4	4	**72**
2012	30	14	19	19	5	4	**91**
2013	39	18	29	19	9	4	**118**
2014	48	25	36	20	11	5	**145**
2015	52	29	36	21	14	5	**157**
2016	55	30	41	21	17	5	**169**

* The number of hospitals may vary from those in previous reports due to new contributors providing retrospective data. Some contributors were omitted from the 2016 cohort due to data anomalies and some contributors previously omitted in annual reports were included. A private hospital relocated and changed names and data from a previously un-peered hospital were able to be included with an existing NAUSP contributor.

Methods

This section describes the contributors to NAUSP, and details of the data and analyses.

Contributing hospitals

Public and private hospitals contribute data voluntarily to NAUSP on an ongoing basis throughout each year.

As hospitals join the program, retrospective data may be added to the database. 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 Australian Institute of Health and Welfare (AIHW) criteria used to categorise hospitals were amended in November 2015 to include private hospital peer groups. Historically, private hospitals had been assigned by NAUSP to an appropriate AIHW public hospital peer group for analyses in annual reports, and for routine quarterly reporting. This convention will continue until private hospital representation increases sufficiently to allow reporting by 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.

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 a peer group by NAUSP for the analyses based on hospital size and activity.

The participating hospitals for 2016 were from the following AIHW peer groups (percentage representation in each hospital peer group is shown in brackets):

- Principal Referral Hospital – 30 contributors (100%)
- Specialist Women's Hospital – 4 contributors (67%)
- Public Acute Group A Hospital – 56 contributors (90%)
- Public Acute Group B Hospital – 37 contributors (84%)
- Public Acute Group C Hospital – 16 contributors (11%)
- Private Acute Group A Hospital – 10 contributors (45%)
- Private Acute Group B Hospital – 8 contributors (22%)
- Private Acute Group C Hospital – 8 contributors (16%).

The numbers of contributing hospitals, and the number reporting intensive care unit (ICU) data, 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.

Data elements

Pharmacy departments of participating hospitals supply NAUSP with aggregate monthly quantities of antimicrobial products 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 and converted to standardised usage metrics – these are based on the WHO definition of defined daily dose (DDD). The DDD for any medicine is the average maintenance dose per day for an average adult for the main indication of the medicine. NAUSP does not collect paediatric usage data because this unit of measurement is only applicable for adults.

Usage is then converted to a standard rate used in comparable surveillance programs – DDDs per 1,000 OBDs. 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 2 for more information). At present, NAUSP uses published WHO DDDs to enable comparisons with international surveillance programs.

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.[6-8] 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.

Values calculated from raw data submitted to NAUSP include:

- The DDDs of the antimicrobial
- The aggregate number of grams of the antimicrobial used for a month
- Monthly antimicrobial usage rates (as DDDs per 1,000 OBDs)
- Three- or five-month moving averages of the usage rates.

Data quality

Since the commencement of the NAUSP web-based application (the NAUSP Portal) in May 2016, NAUSP participants validate data during the automated submission process.

Alerts are generated automatically when quantities fall outside a usual or expected range. This enables validation of data at an early stage of data submission. Rolling data quality assurance activities are performed by NAUSP officers monthly and during production of the annual report. Denominator data that are used to calculate usage rates are reviewed by the NAUSP team at least twice a year to confirm that numerator and denominator data are consistent. 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.

Other validation processes include:

- Confirming that mapping (aliasing) of antimicrobials to the NAUSP-defined formulation within the portal is performed correctly by NAUSP pharmacists
- Checking for incorrect parameter settings for automated usage and OBD reports generated by contributors.

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 (excluding some inhalations), antimycobacterials (except rifampicin), antiparasitics, and infusor packs of antibacterials for use outside of 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 usage 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 to individuals and wards such as psychiatric, rehabilitation, dialysis and day surgery units to allow comparison with European surveillance programs that report only acute inpatient usage data.

Data classification, restrictions and limitations

Data provided to NAUSP do not include the indication for which antimicrobials are used, or any patient-level data. Although some contributing hospitals provide data on ward-by-ward antimicrobial consumption, data for specialist areas (with the exception of ICUs) have not generally been available. Expansion of the program (implemented in March 2017) will allow analyses of usage for a limited number of specialties.

This report presents usage rates for the most commonly used antibacterials and antibacterial classes. A full 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 in Appendix 2. This report also includes antifungal usage rates for the first time.

The NAUSP cohort has strong participation by large public hospitals, where AMS activities are generally well established. In 2015, NAUSP removed restrictions on participation that were based on minimum bed numbers. Participating hospitals are required to meet the criteria for categorisation into one of eight 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 and antifungal quantities and OBDs supplied by individual contributors. Minor discrepancies between annual reports may occur as a result of data submitted retrospectively by contributing hospitals.

Statistical analysis

Statistical analyses of changes in usage rates of antimicrobial classes over time were assessed using joinpoint regression analysis.

Joinpoint regression is a statistical modelling technique that explains the relationship between two variables by means of segmented linear regression where several different lines are connected together at 'joinpoints'.

Overview of antibacterial usage rates, 2016

This section includes an overview of contributing hospitals, annual usage rates for antibacterial classes, the top 20 antibacterials used in contributing hospitals, and comparisons by state and territory.

Contributing hospitals

Table 3 shows the number of public and private hospitals that contributed to NAUSP in 2016, by state and territory, and AIHW peer group classification.

Table 3: Public and private hospitals that contributed to NAUSP, by state and territory, and hospital peer group*, 2016

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	Total
NSW and ACT	12	22	15	5	0	1	0	0	55
Vic	6	11	7	0	1	2	1	2	30
Qld and NT	6	13	7	5	1	4	1	4	41
SA	2	4	4	3	1	2	4	1	21
WA	3	4	3	3	1	1	2	0	17
Tas	1	2	1	0	0	0	0	1	5
Total	**30**	**56**	**37**	**16**	**4**	**10**	**8**	**8**	**169**

* AIHW (2015)[5]

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 169 contributor hospitals across Australia, as shown in Table 3.

For January–December 2016, the aggregate total-hospital antibacterial usage rate for all NAUSP contributor hospitals (*n* = 169) was 891.5 DDDs per 1,000 OBDs (see Figure 2a). This is a 2.7% fall from 2015, when the aggregate total-hospital antibacterial usage rate was 916.5 DDD per 1,000 OBDs (*n* = 159). The median annual usage rate in 2016 was 922 DDDs per 1,000 OBDs, and the mean usage rate across the 169 institutions was 938 DDDs per 1,000 OBDs (range 269–2,065 DDDs per 1,000 OBDs).

As shown in Table 4, decreases in usage rates over the last five years are apparent for aminoglycosides, penicillin–β-lactamase inhibitor combinations (amoxicillin–clavulanate only), extended-spectrum penicillins, fluoroquinolones, macrolides, metronidazole and trimethoprim. These decreases were significant ($p<0.05$) for β-lactamase inhibitor combinations (amoxicillin–clavulanate only), extended-spectrum penicillins and macrolides. At the same time, usage rates of tetracyclines and trimethoprim–sulfamethoxazole have increased.

Table 4: Annual total-hospital antibacterial usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by antibacterial class, 2012–2016

Antibacterial (WHO classification)	2012	2013	2014	2015	2016
	n = 90	*n* = 118	*n* = 143	*n* = 157	*n* = 169
Alimentary antibiotics	0.0	0.0	0.0	0.1	0.3
Aminoglycosides	44.9	41.7	37.5	31.4	28.4
Amphenicols	0.0	0.0	0.0	0.0	0.0
β-lactamase inhibitor combinations	185.0	185.2	180.3	173.7	164.7
β-lactamase-resistant penicillins	84.7	91.8	92.6	90.5	90.0
β-lactamase-sensitive penicillins	26.5	26.9	29.1	33.3	32.0
Carbapenems	20.9	20.0	18.3	17.6	17.2
Extended-spectrum penicillins	106.9	104.6	103.5	93.1	102.5
First-generation cephalosporins	131.8	133.0	129.8	136.6	133.0
Fluoroquinolones	44.4	42.1	37.9	34.0	30.0
Fourth-generation cephalosporins	5.6	5.2	5.5	5.8	5.6
Glycopeptides	31.4	29.1	26.1	24.4	23.7
Lincosamides	13.8	15.1	14.7	13.5	12.7
Macrolides	81.4	72.3	66.8	60.4	52.2
Monobactams	0.4	0.4	0.4	0.3	0.4
Nitrofurans	0.9	0.8	0.9	0.9	1.0
Nitroimidazoles (metronidazole)	47.4	44.2	40.6	37.8	33.9
Other antibacterials (linezolid and daptomycin)	2.4	2.4	2.4	2.4	2.5
Other cephalosporins and penems (ceftaroline, ceftolozane–tazobactam)	0.0	0.0	0.0	0.1	0.1
Polymyxins	0.7	0.9	0.7	0.7	0.6
Rifamycins	6.4	5.6	4.9	4.5	4.4
Second-generation cephalosporins	5.5	5.5	5.5	6.4	6.6
Steroids (fusidic acid)	2.0	1.6	1.3	1.1	1.1
Streptogramins	0.6	0.5	0.5	0.4	0.4
Streptomycins	0.0	0.0	0.0	0.0	0.0
Tetracyclines	44.3	48.1	55.8	66.1	69.5
Third-generation cephalosporins	51.7	48.8	46.8	48.1	46.7
Trimethoprim	19.8	19.4	18.1	16.7	14.3
Trimethoprim–sulfamethoxazole	15.4	16.5	16.1	16.8	17.5
Grand total	**974.7**	**962.0**	**936.2**	**916.5**	**891.5**

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

Note: Rates (DDD/1,000 OBD) may vary slightly from previous reports as a result of retrospective usage data adjustments and number of hospitals contributing to aggregate data.

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–2d show the annual aggregate total-hospital rates of antibacterial use across all peer groups from 2007 to 2016.

Figures 3–5 show the trends in usage rates for three of the AIHW hospital peer groups over the same period: Principal Referral Hospitals, Public Acute Group A Hospitals and Public Acute Group B Hospitals. Data from Public Acute Group C and Specialist Women's Hospitals were not included in these analyses because of the low number of contributors.

Box 1: Antimicrobial usage rates explained

Defined daily dose (DDD): The DDD for any medicine is the average maintenance dose per day for an average adult for the main indication of the medicine.

Occupied bed days (OBD): A measure of hospital activity. One patient admitted for 10 days = 10 OBD; 10 patients admitted overnight = 10 OBD.

Aggregate: The sum of all DDDs used in the state or territory divided by the sum of all OBDs in the state or territory – the overall antimicrobial usage rate for the state or territory.

DDD/1,000 OBD: A measure of the rate of antimicrobial use, referenced to hospital activity and therefore allowing some comparison between hospitals of different sizes.

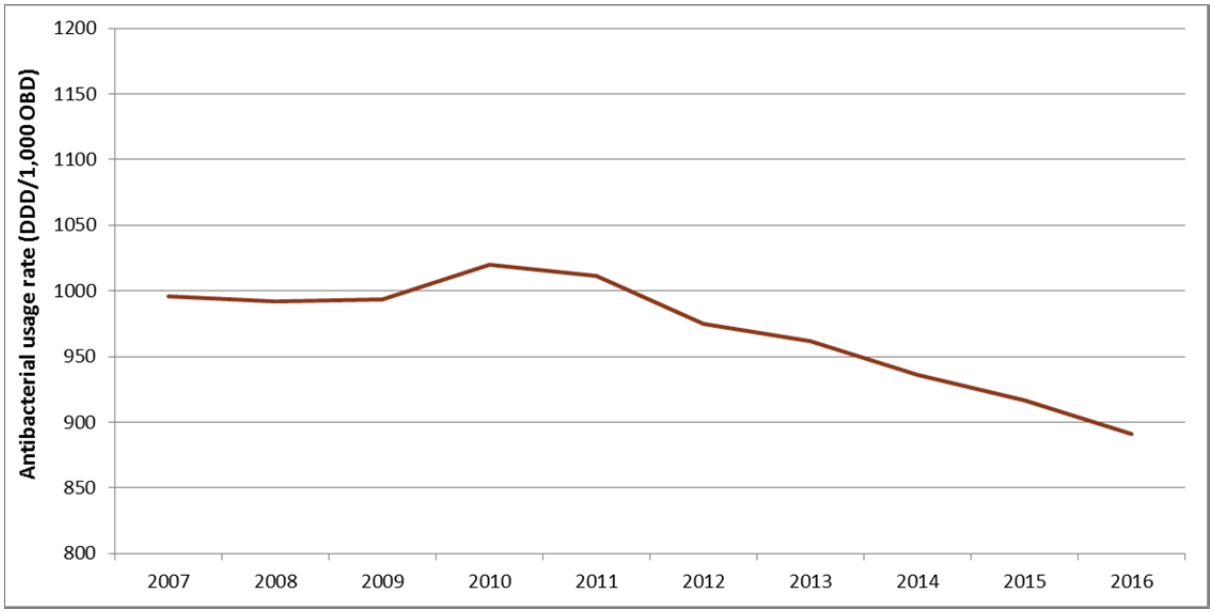
Mean: The average of individual hospitals' DDDs/1,000 OBDs (this is not the same as the aggregate as larger hospitals are over-represented in NAUSP reports in most states and territories.)

Median: The middle value of individual hospitals' usage rates.

Ninety-one contributors have submitted data for five years or more (see Table 1). Since 2012 average usage rates have declined by 6.3% in this group from 965.2 DDDs per 1,000 OBDs to 904.4 DDDs per 1,000 OBDs. Between 2015 and 2016 the decline in usage rates was only 1.7% in this group - from 920.4 DDDs per 1,000 OBDs to 904.4 DDDs per 1,000 OBDs.

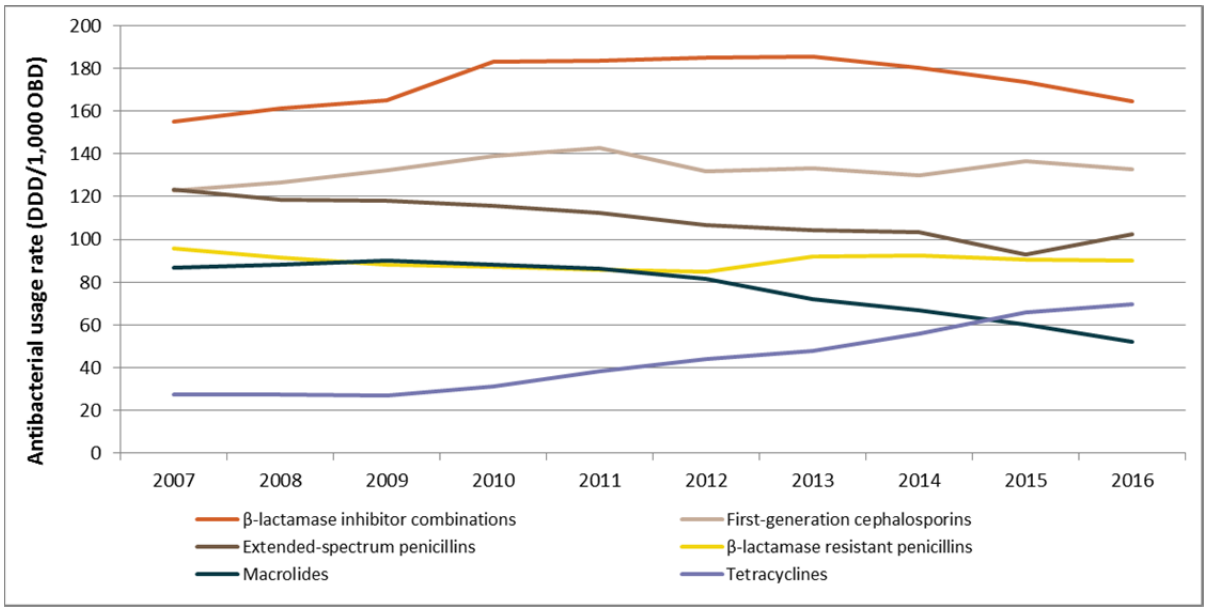
The usage rates of six high-use antibacterial classes are shown in Figures 2b, 3b, 4b and 5b. These antibacterial classes have been highlighted because they represent more than 60% of antibacterials used in NAUSP contributor hospitals. β-lactamase inhibitor combinations are the antibacterial class used most across all peer groups. Figures 2c and 2d, 3c and 3d, 4c and 4d, and 5c and 5d show usage rates for other antibacterial classes. As seen previously, there is wide variation between peer groups in the usage rates and rankings of antibacterials used.

Figure 2a: Annual aggregate total-hospital antibacterial usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, 2007–2016



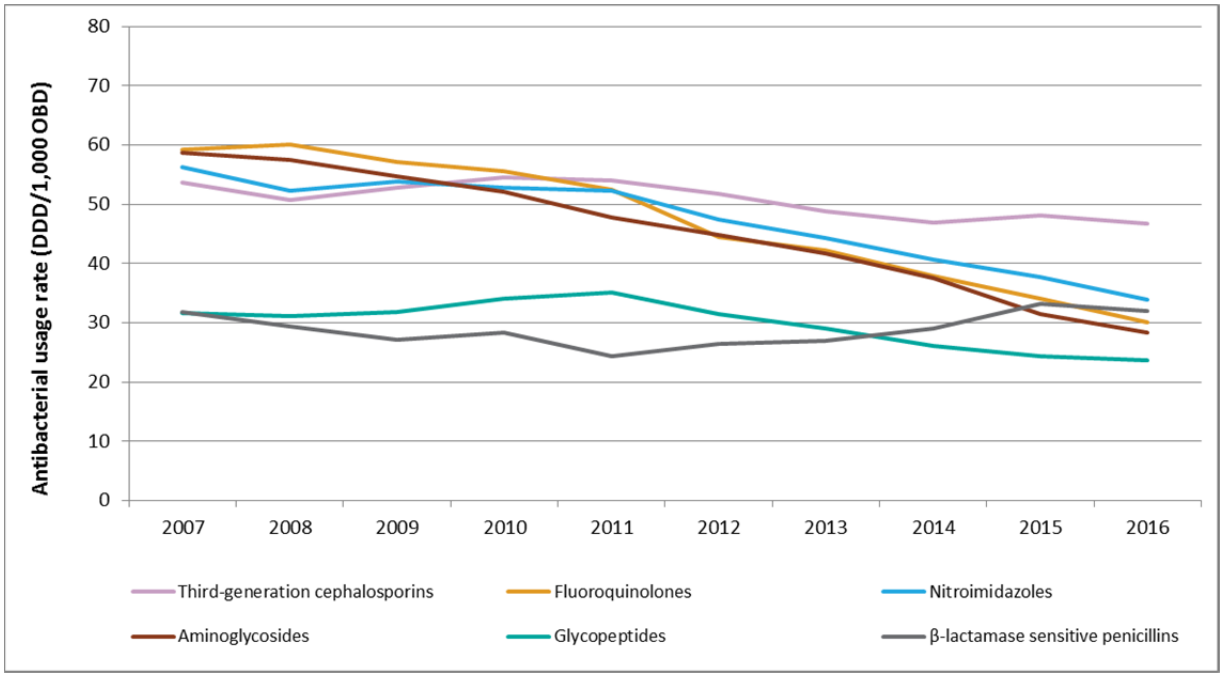
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Note: y-axis truncated to aid visibility of trend

Figure 2b: Annual aggregate total-hospital usage rates (DDD/1,000 OBD) for the six most commonly used antibacterial classes* in NAUSP contributor hospitals, 2007–2016



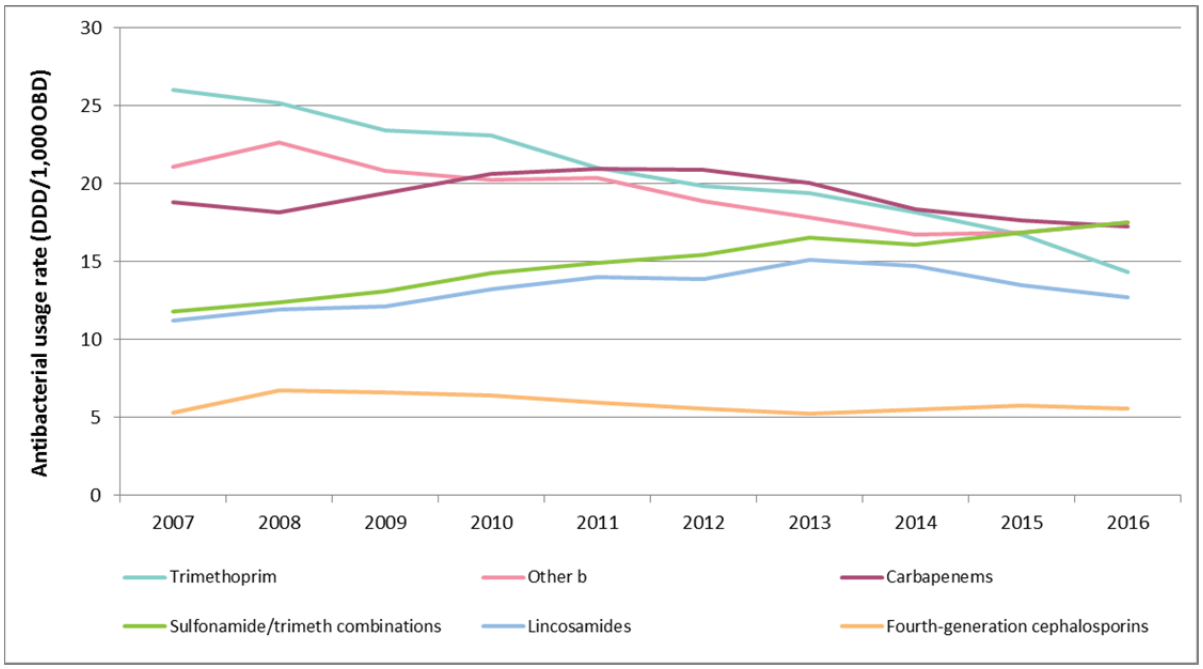
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
* These six antibacterial classes account for more than 60% of antibacterials used in NAUSP contributor hospitals from 2007 to 2016.

Figure 2c: Annual aggregate total-hospital usage rates (DDD/1,000 OBD) for other antibacterial classes* in NAUSP contributor hospitals, 2007–2016



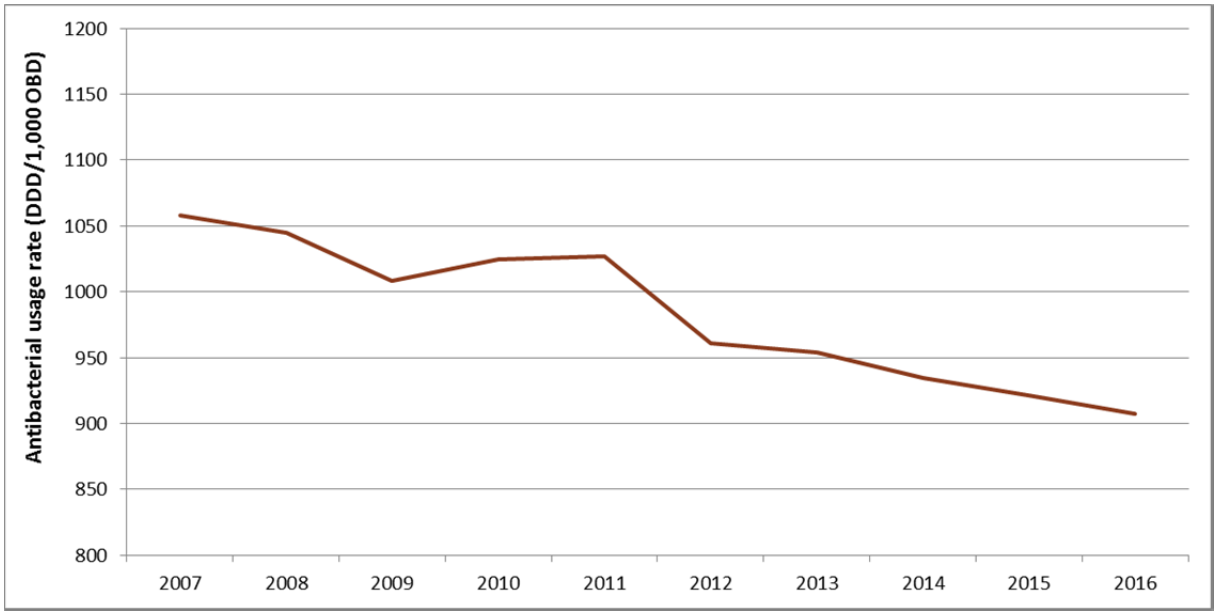
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
* These antibacterial classes combined account for less than 30% of antibacterials used in NAUSP contributor hospitals from 2007 to 2016.

Figure 2d: Annual aggregate total-hospital usage rates (DDD/1,000 OBD) for other antibacterial classes* in NAUSP contributor hospitals, 2007–2016



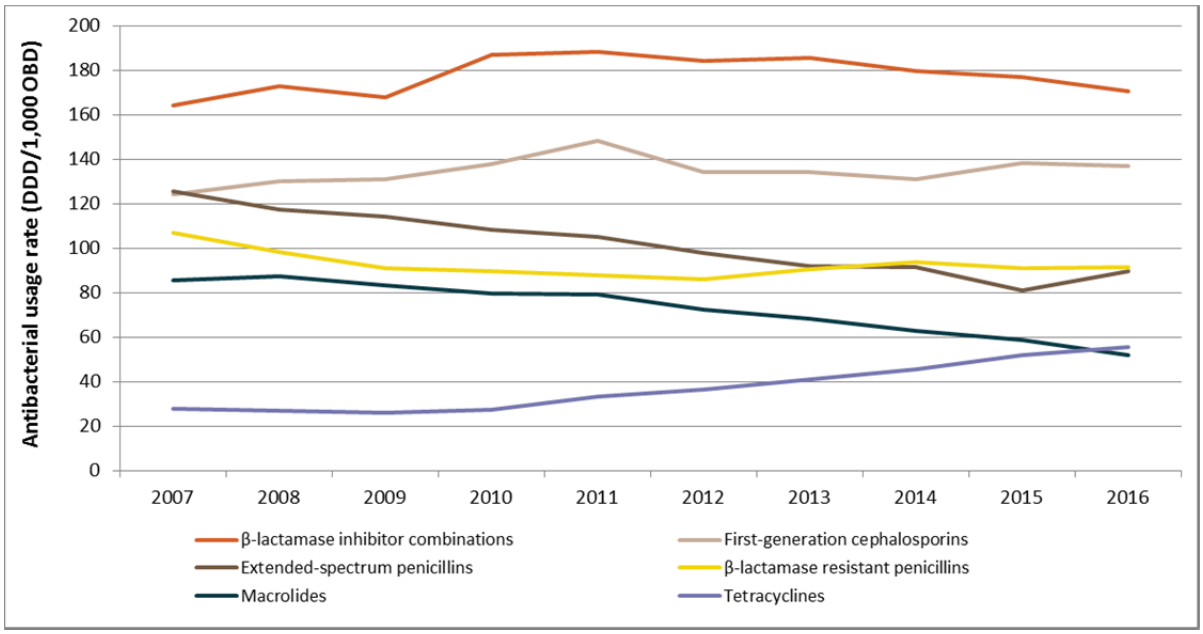
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
* These antibacterial classes combined account for less than 10% of antibacterials used in NAUSP contributor hospitals from 2007 to 2016.
† 'Other' comprises amphenicols, monobactams, nitrofurans, linezolid and daptomycin, ceftaroline, polymyxins, rifamycins, second-generation cephalosporins, fusidic acid, streptogramins and streptomycins.

Figure 3a: Annual aggregate total-hospital antibacterial usage rates (DDD/1,000 OBD) in Principal Referral Hospitals that contributed to NAUSP, 2007–2016



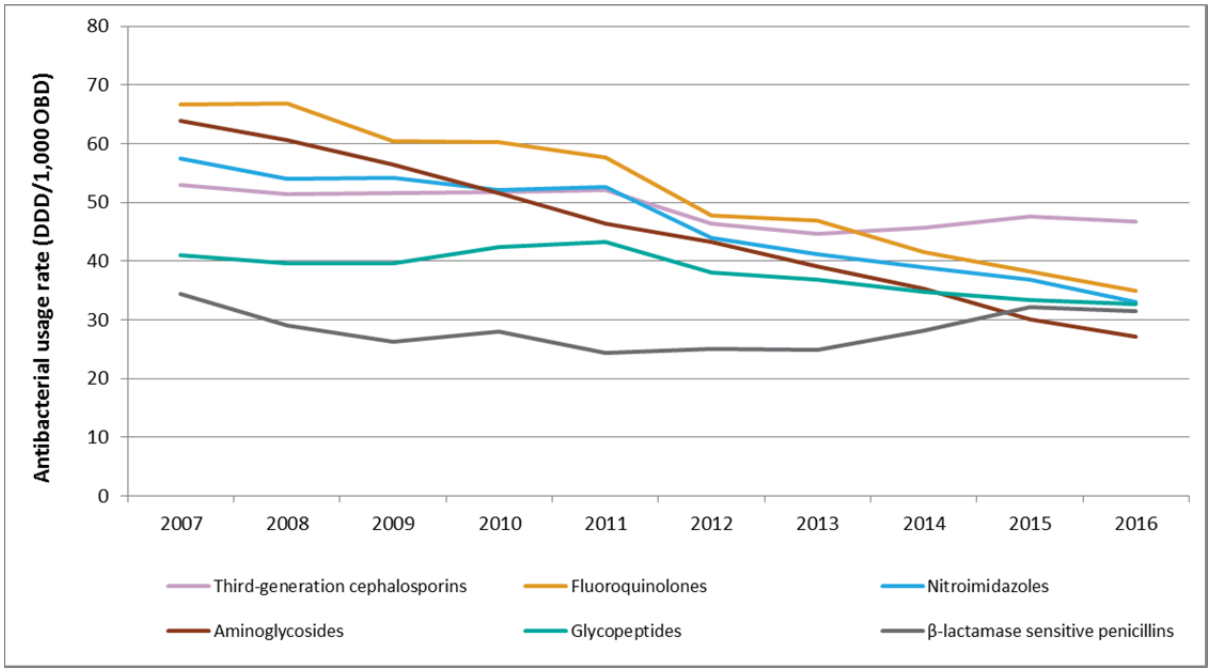
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Note: y-axis truncated to aid visibility of trend

Figure 3b: Annual aggregate total-hospital usage rates (DDD/1,000 OBD) for the six most commonly used antibacterial classes* in Principal Referral Hospitals that contributed to NAUSP, 2007–2016



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
* These six antibacterial classes account for more than 60% of antibacterials used in NAUSP Principal Referral contributor hospitals from 2007 to 2016.

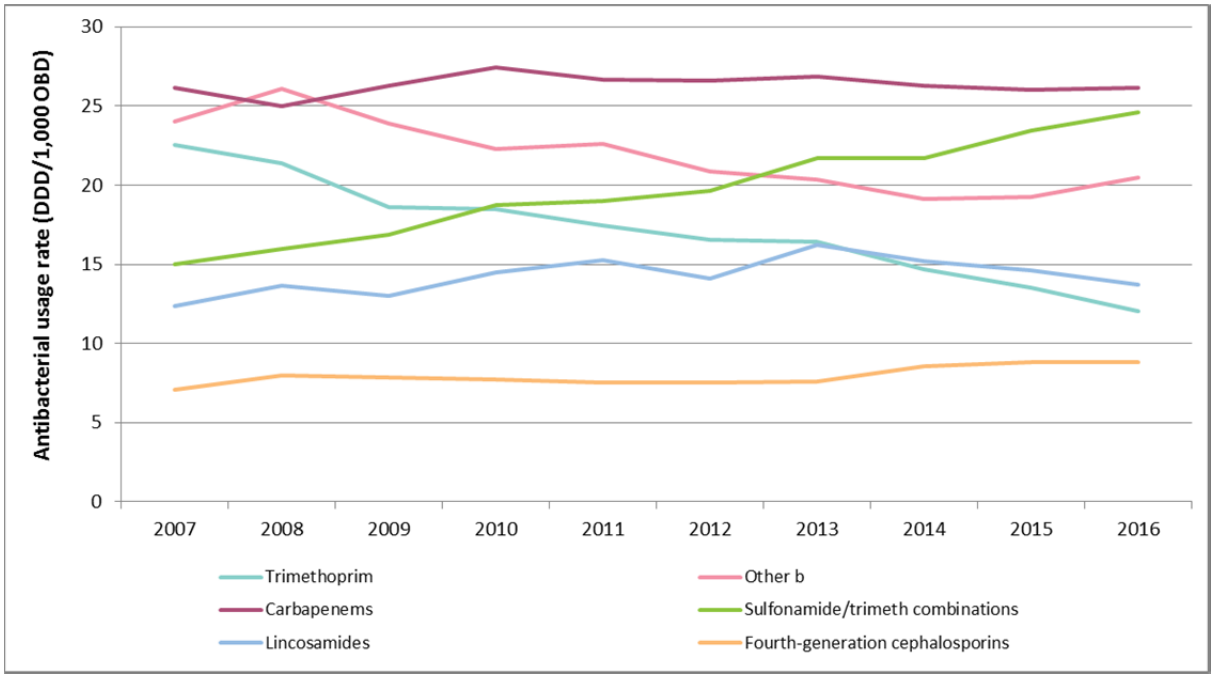
Figure 3c: Annual aggregate total-hospital usage rates (DDD/1,000 OBD) for other antibacterial classes* in Principal Referral Hospitals that contributed to NAUSP, 2007–2016



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

* These antibacterial classes combined account for less than 30% of antibacterials used in NAUSP Principal Referral contributor hospitals from 2007 to 2016.

Figure 3d: Annual aggregate total-hospital usage rates (DDD/1,000 OBD) for other antibacterial classes* in Principal Referral Hospitals that contributed to NAUSP, 2007–2016

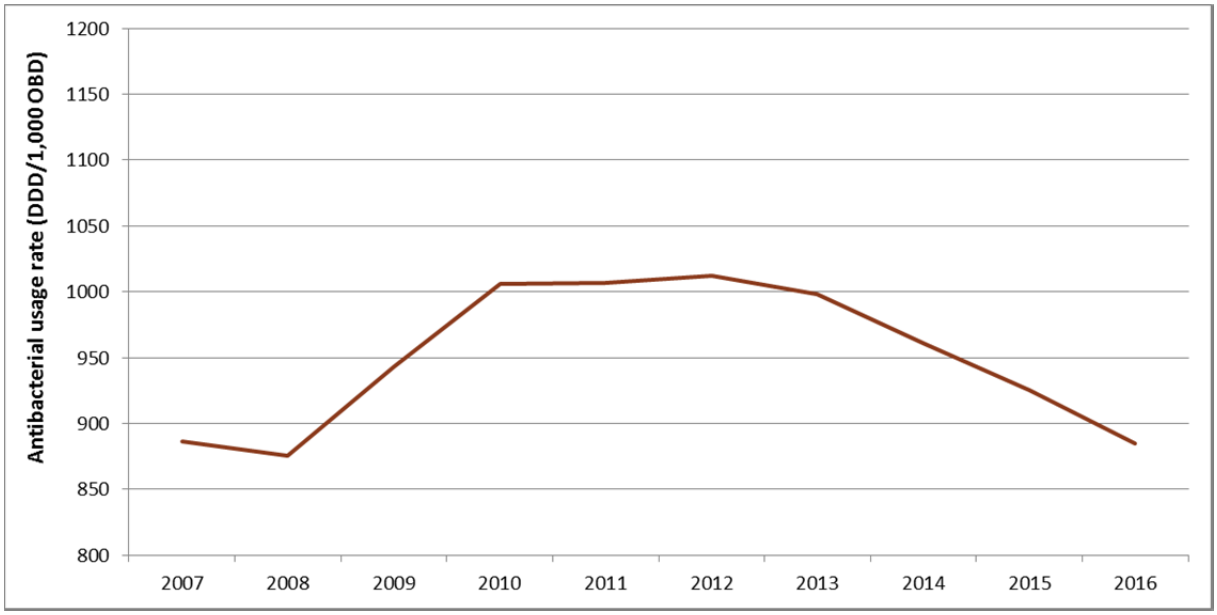


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

* These antibacterial classes combined account for approximately 10% of antibacterials used in NAUSP Principal Referral contributor hospitals from 2007 to 2016.

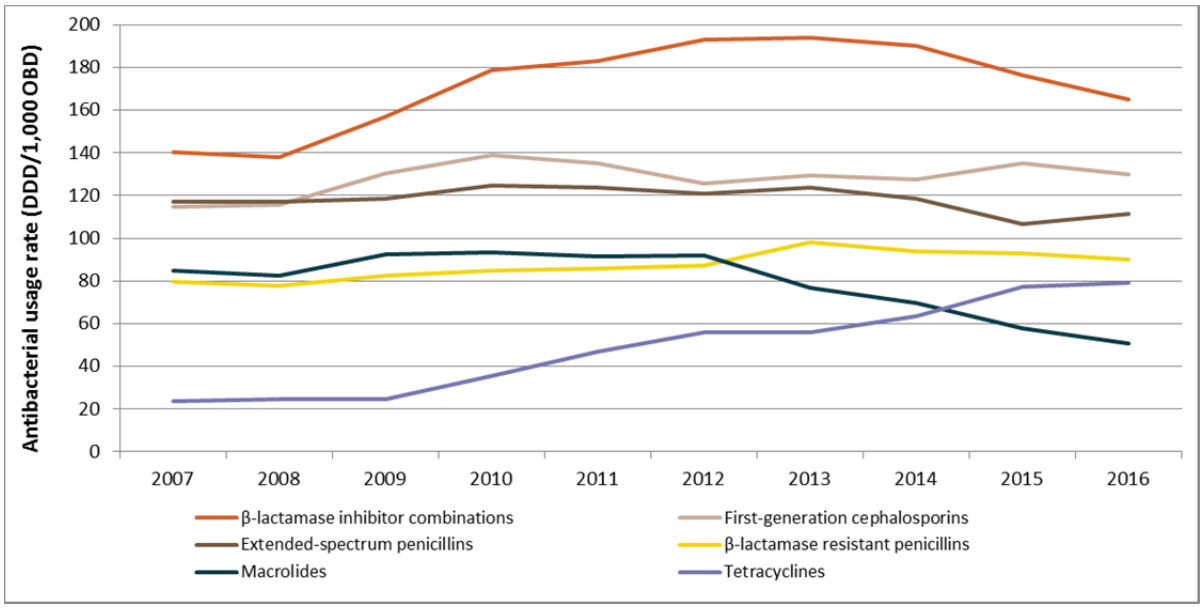
† 'Other' comprises amphenicols, monobactams, nitrofurans, linezolid and daptomycin, ceftaroline, polymyxins, rifamycins, second-generation cephalosporins, fusidic acid, streptogramins and streptomycins.

Figure 4a: Annual aggregate total-hospital antibacterial usage rates (DDD/1,000 OBD) in Public Acute Group A Hospitals that contributed to NAUSP, 2007–2016



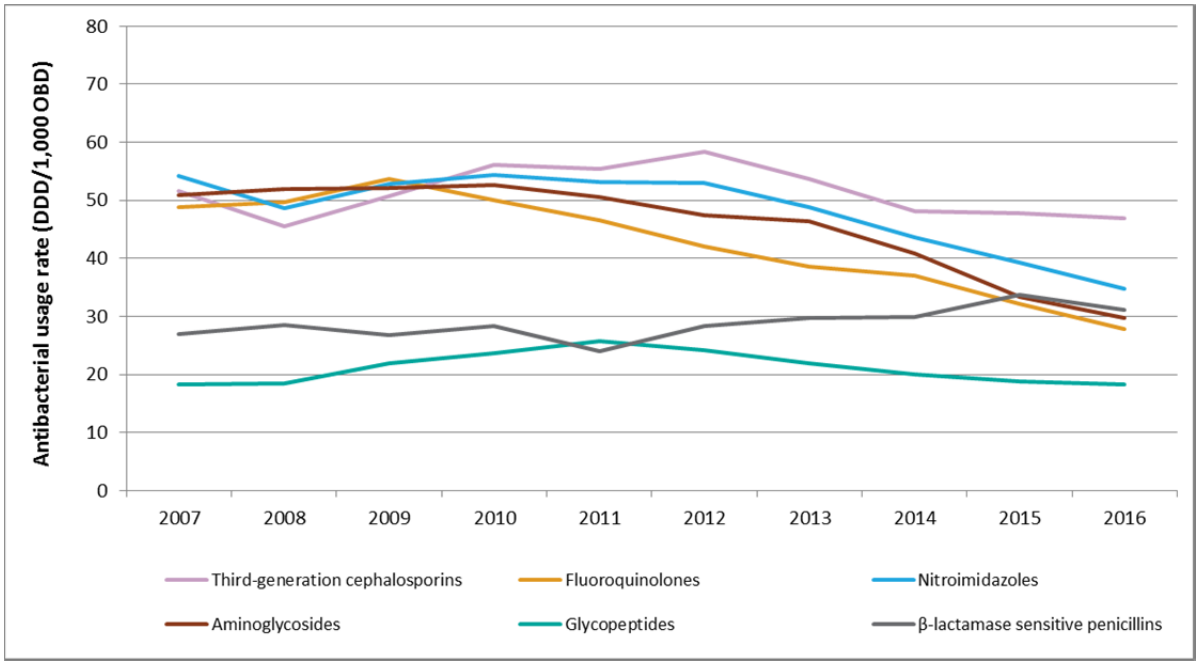
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Note: y-axis truncated to aid visibility of trend

Figure 4b: Annual aggregate total-hospital usage rates (DDD/1,000 OBD) for the six most commonly used antibacterial classes* in Public Acute Group A hospitals that contributed to NAUSP, 2007–2016



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
* These six antibacterial classes account for more than 60% of all antibacterials used in NAUSP Public Acute Group A contributor hospitals from 2007 to 2016.

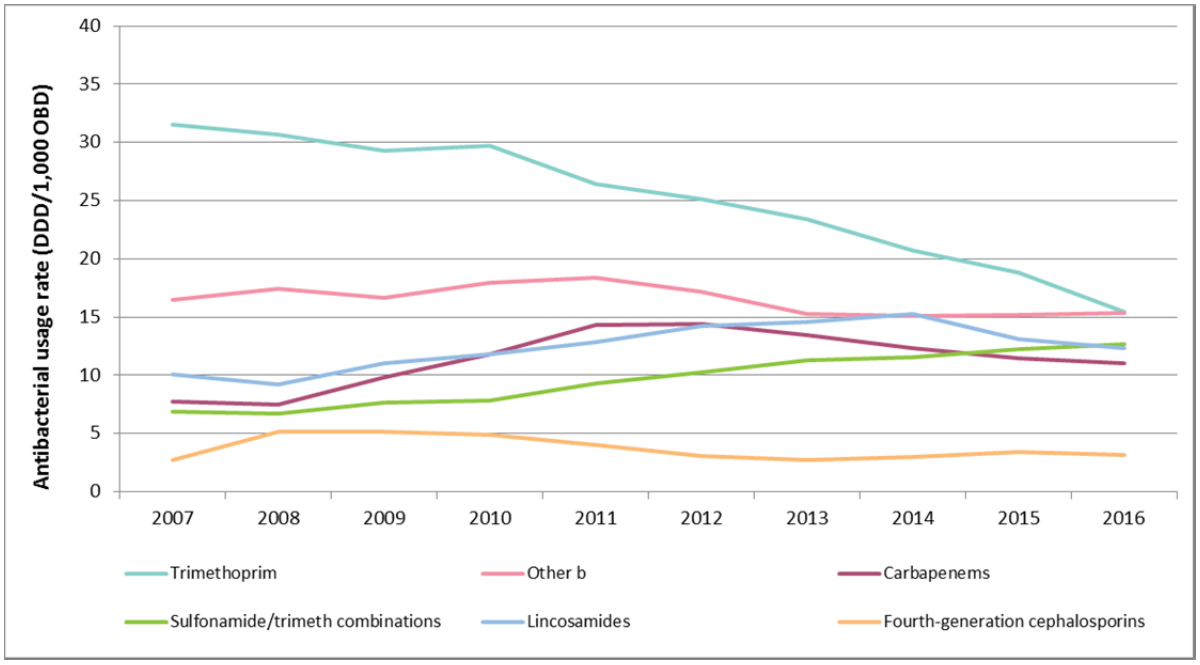
Figure 4c: Annual aggregate total-hospital usage rates (DDD/1,000 OBD) for other antibacterial classes* in Public Acute Group A Hospitals that contributed to NAUSP, 2007–2016



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

* These antibacterial classes combined account for less than 30% of antibacterials used in NAUSP Public Acute Group A contributor hospitals from 2007 to 2016.

Figure 4d: Annual aggregate total-hospital usage rates (DDD/1,000 OBD) for other antibacterial classes* in Public Acute Group A Hospitals that contributed to NAUSP, 2007–2016

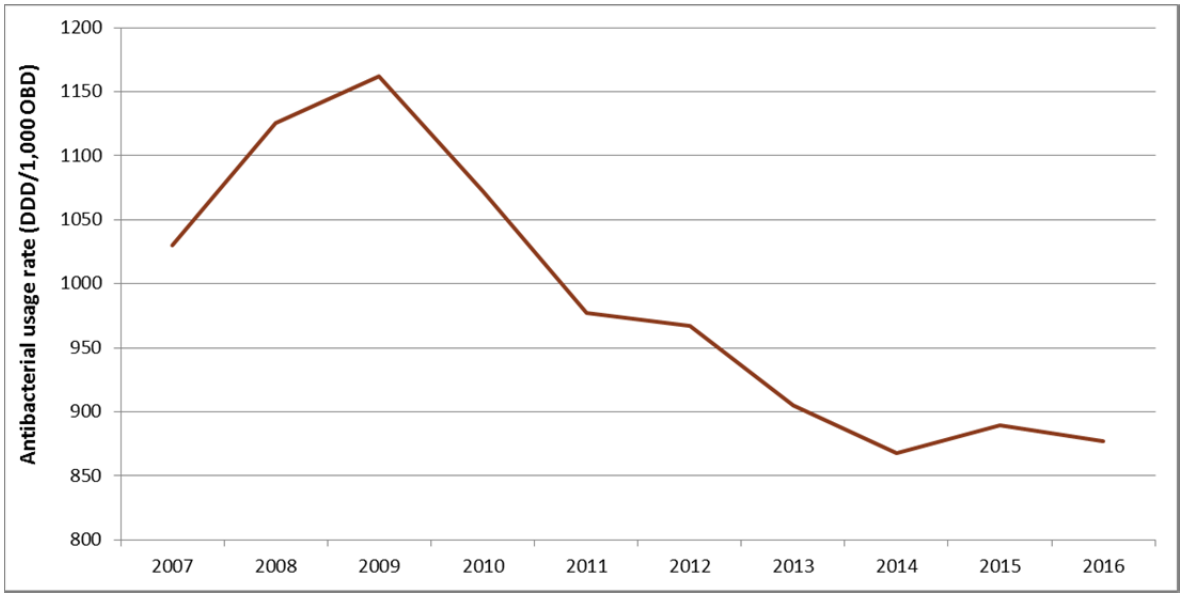


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

* These antibacterial classes combined account for less than 10% of antibacterials used in NAUSP Public Acute Group A contributor hospitals from 2007 to 2016.

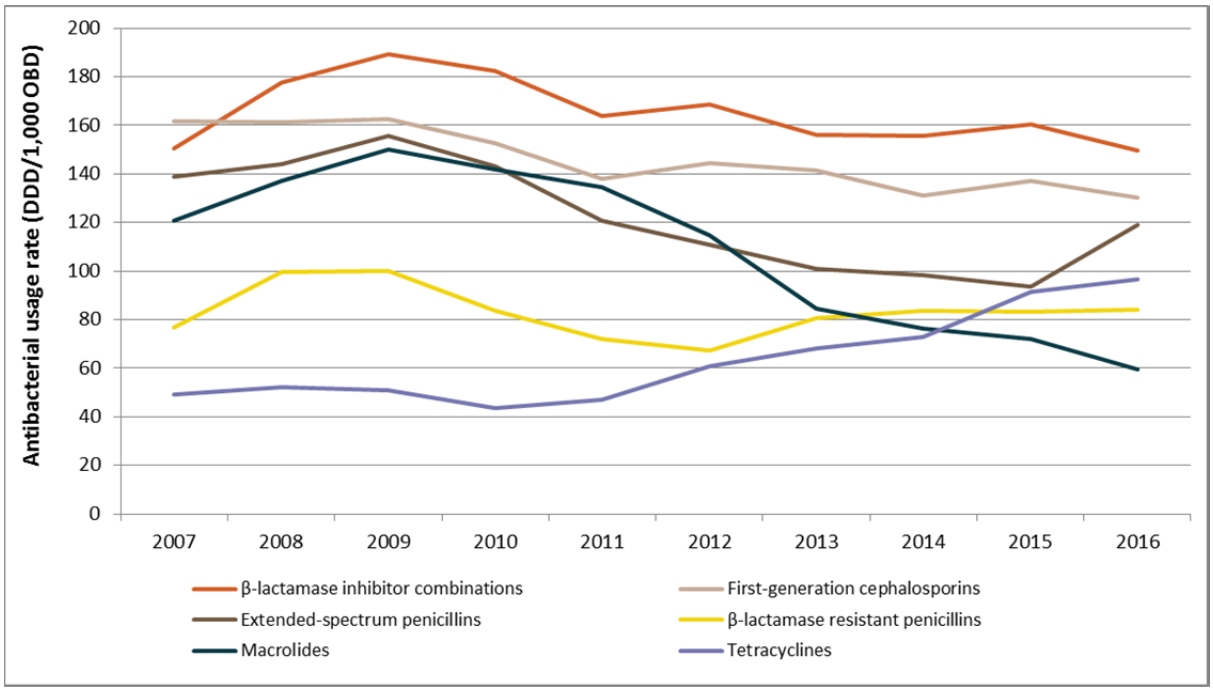
† 'Other' comprises amphenicols, monobactams, nitrofurans, linezolid and daptomycin, ceftaroline, polymyxins, rifamycins, second-generation cephalosporins, fusidic acid, streptogramins and streptomycins.

Figure 5a: Annual aggregate total-hospital antibacterial usage rates (DDD/1,000 OBD) in Public Acute Group B Hospitals that contributed to NAUSP, 2007–2016



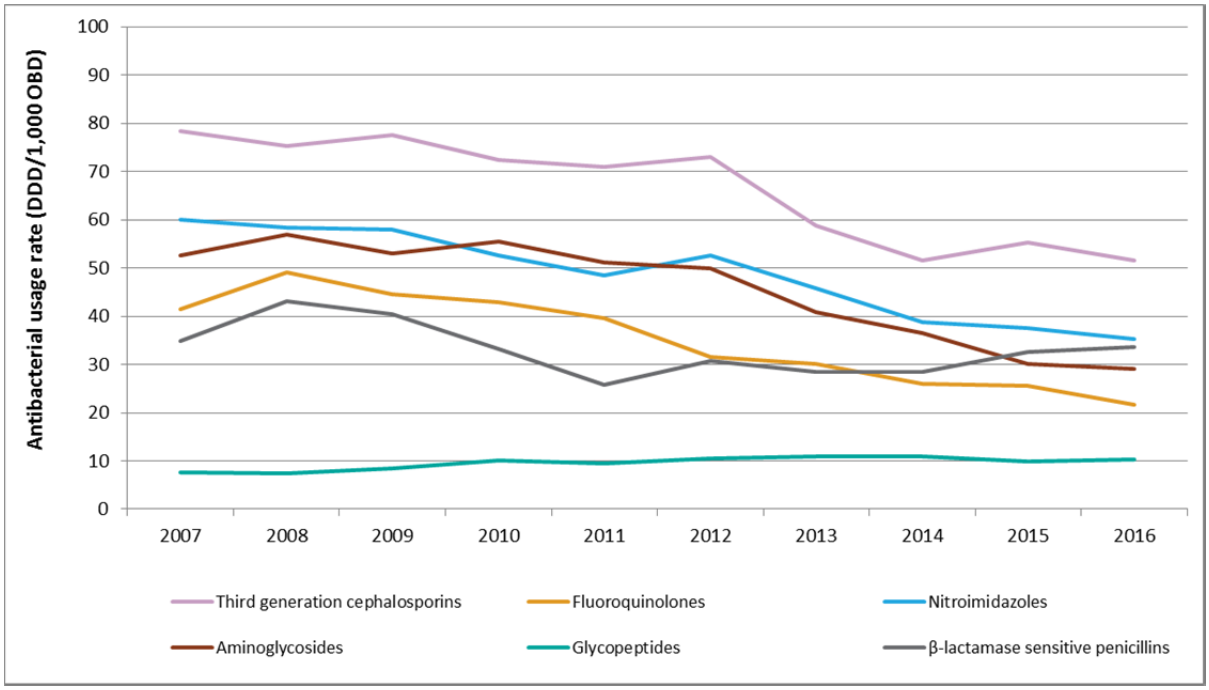
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Note: y-axis truncated to aid visibility of trend

Figure 5b: Annual aggregate total-hospital usage rates (DDD/1,000 OBD) for the six most commonly used antimicrobial classes* in Public Acute Group B Hospitals that contributed to NAUSP, 2007–2016



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
* These six antibacterial classes account for more than 65% of antibacterials used in NAUSP Public Acute Group B contributor hospitals from 2007 to 2016.

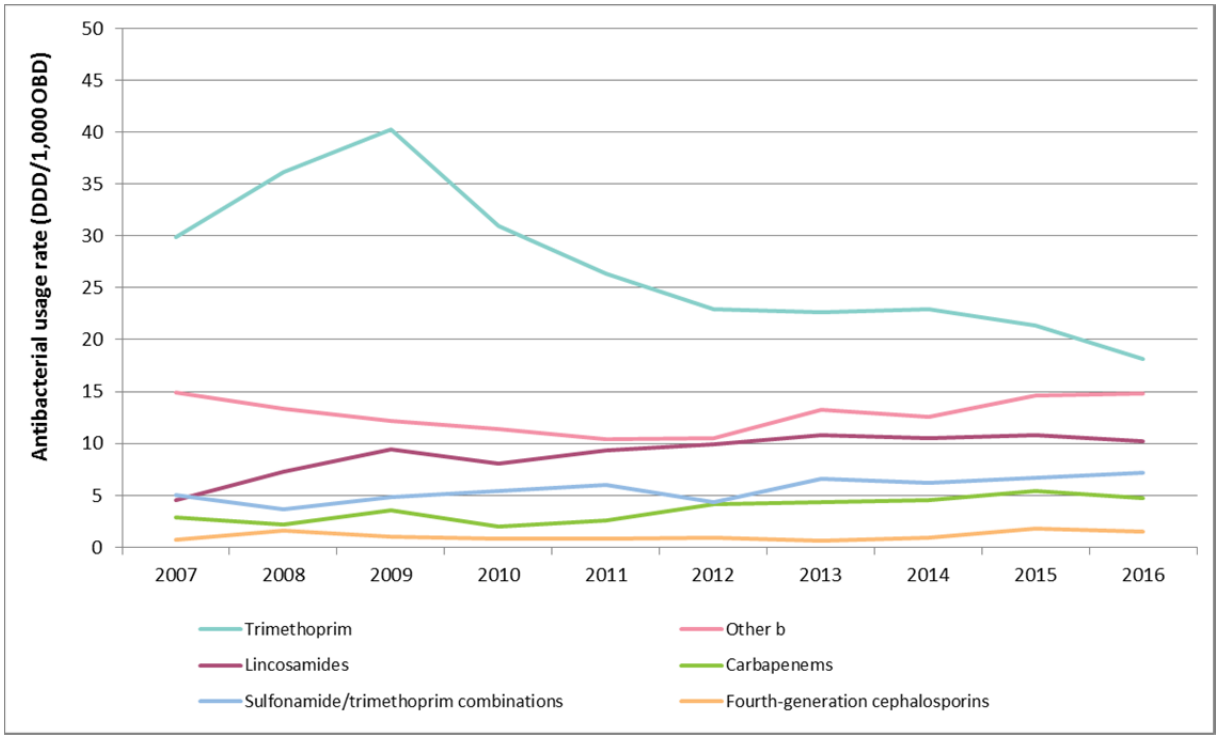
Figure 5c: Annual aggregate total-hospital usage rates (DDD/1,000 OBD) for other antibacterial classes* in Public Acute Group B Hospitals that contributed to NAUSP, 2007–2016



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

* These antibacterial classes combined account for less than 30% of antibacterials used in NAUSP Public Acute Group B contributor hospitals from 2007 to 2016.

Figure 5d: Annual aggregate total-hospital usage rates (DDD/1,000 OBD) for other antibacterial classes* in Public Acute Group B Hospitals that contributed to NAUSP, 2007–2016



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

* These antibacterial classes combined account for less than 7% of antibacterials used in NAUSP Public Acute Group B contributor hospitals from 2007 to 2016.

† 'Other' comprises amphenicols, monobactams, nitrofurans, linezolid and daptomycin, ceftaroline, polymyxins, rifamycins, second-generation cephalosporins, fusidic acid, streptogramins and streptomycins.

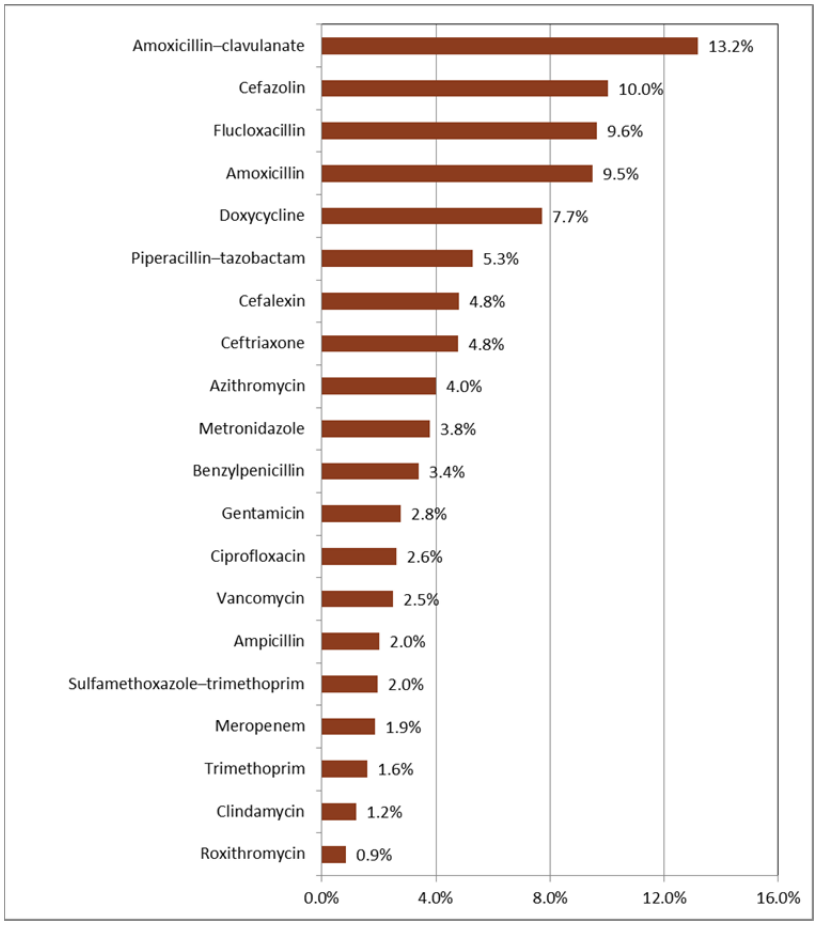
Top 20 antibacterials used in public and private hospitals that contributed to NAUSP in 2016

Twenty antibacterials accounted for 93.5% of all antibacterials used in public and private hospitals that contributed to NAUSP in 2016 on a DDDs per 1,000 OBDs basis (Figure 6). Six antibacterials – amoxicillin–clavulanate, cefazolin, flucloxacillin, amoxicillin, doxycycline and piperacillin–tazobactam – represented 55% of antibacterials used in these hospitals. A similar usage pattern was reported in the 2015 NAUSP annual report.[1] Ten antibacterials accounted for 73% of use.

A slight change in the ranking occurred in 2016 compared with 2015, with flucloxacillin replacing amoxicillin in third position, and piperacillin–tazobactam replacing cefalexin within the top six. Comparatively high flucloxacillin use is largely because the WHO DDD for flucloxacillin is only one-quarter of the usual parenteral adult dose used in Australia; most hospital use is parenteral.

'Highly reserved antibacterials' accounted for very small percentages of total antibacterial use – for example, linezolid (0.12%), daptomycin (0.15%) and colistin (0.07%).

Figure 6: Top 20 antibacterials as a percentage of all antibacterials used in NAUSP contributor hospitals, 2016



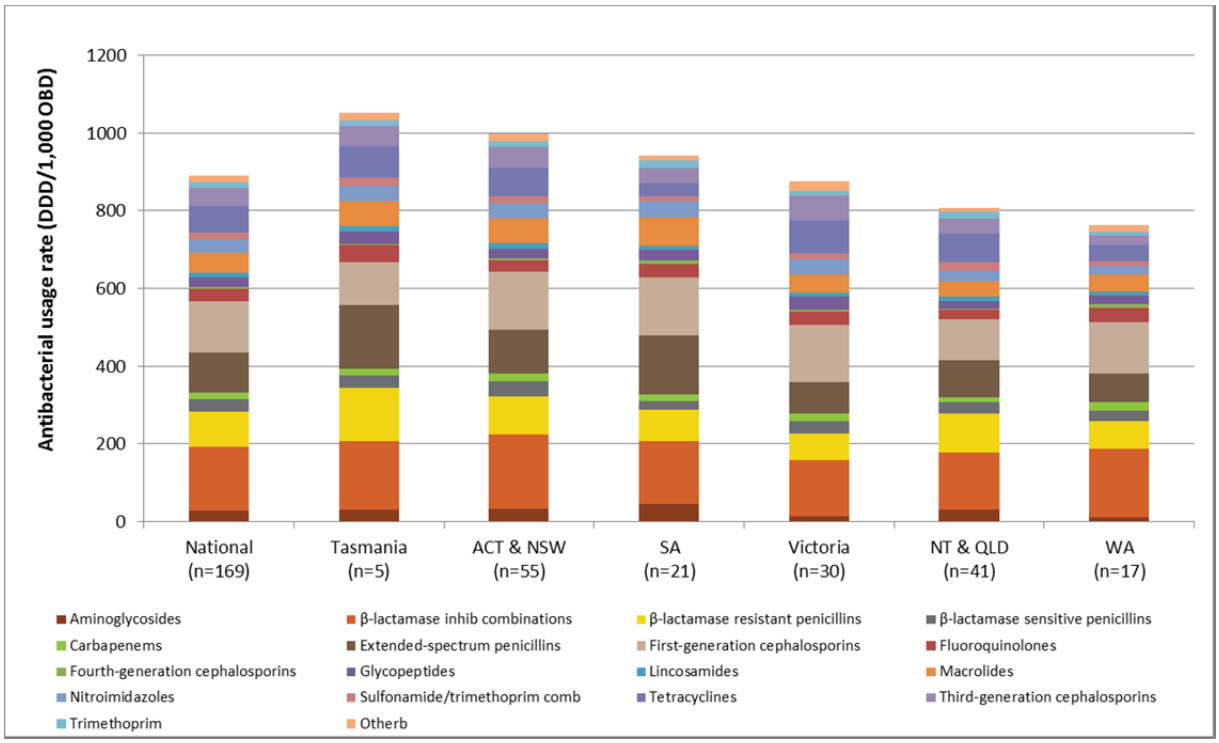
These findings are similar to those from the National Antimicrobial Prescribing Survey (NAPS) 2015[9] which found that cefazolin, ceftriaxone, metronidazole, amoxicillin–clavulanate and piperacillin–tazobactam were the most commonly prescribed antibacterials in participating hospitals in 2015. The difference in order reflects the difference between methodologies used by NAUSP and NAPS.

Comparison of antibacterial usage rates by state and territory

Total-hospital antibacterial usage rates for NAUSP contributors for 2016 are shown by state and territory in Figure 7. There was no change in ranking of total-hospital antibacterial use by state and territory from 2015 to 2016.

Aggregate usage rates for Tasmania fell noticeably in 2016 compared with 2015. Usage rates of β-lactamase inhibitor combinations, extended-spectrum penicillins, first-generation cephalosporins, macrolides, nitroimidazoles, and tetracyclines fell by more than 10 DDDs per 1,000 OBDs per year. There were no increases of note in other classes.

Figure 7: Aggregate total-hospital antibacterial usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, 2016



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

* '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.

Surveillance of six major antibacterial classes by state and territory

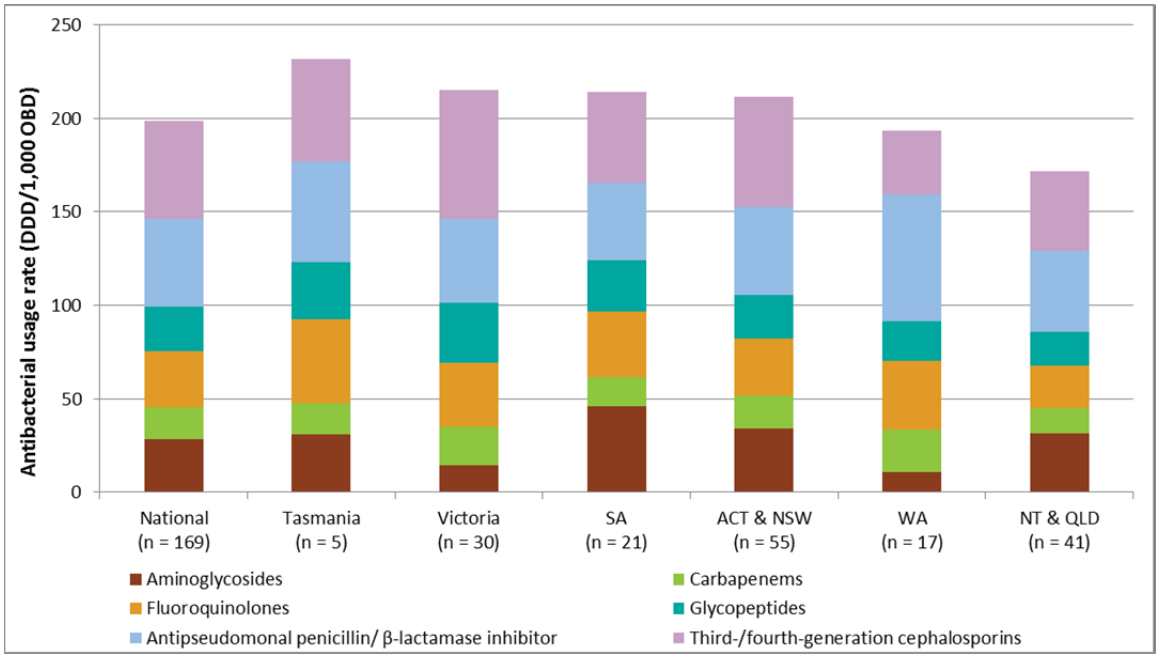
For more than a decade NAUSP has produced reports for contributor hospitals highlighting six antibacterial classes which are high-priority targets of AMS programs. Reasons for targeting these antibacterial classes include their potential impact on the development of antimicrobial resistance[10], and the potential for inappropriate prescribing, high cost and unfavourable side-effect profiles (for example, for aminoglycosides) with these antibacterials.

The six classes of antibacterials used in Australian hospitals that are of major importance 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 2016 was 199 DDDs per 1,000 OBDs. The mean was 206 DDDs per 1,000 OBDs (range 172–232). The classes for which use varied most between states and territories in 2016 were aminoglycosides and antipseudomonal penicillin–β-lactamase inhibitor combinations. Figure 8 shows aggregated usage rates of these antibacterial classes by state and territory, and nationally.

Figure 8: Aggregate total-hospital usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals for six major antibacterial classes, by state and territory, 2016



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

The six major antibacterial classes listed above accounted for 22% of antimicrobial use in 2016. This figure varies only slightly between states and territories, and was not significantly different to that in 2015.

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.

Table 5 shows antibacterial usage rates in NAUSP contributor hospitals for each state and territory.

Table 5: Total-hospital antibacterial usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2016

	n	Aggregate	Mean	Median	Range
National	169	892	938	922	269–2,065
NSW and ACT	55	999	1,095	1,061	700–2,051
Vic	30	875	861	891	269–1,294
Qld and NT	41	808	896	786	442–2,065
SA	21	942	870	800	436–1,509
WA	17	764	766	797	391–1,191
Tas	5	1,051	898	923	605–1,185

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

See Appendix 1 for a list of hospitals that contributed data for the 2016 analyses.

New South Wales and Australian Capital Territory

New South Wales and the Australian Capital Territory had the most contributors to NAUSP in 2016 (*n* = 55). The cohort comprised 12 Principal Referral, 22 Public Acute Group A, 15 Public Acute Group B and five Public Acute Group C Hospitals, and one Private Acute Group A Hospital. Data from two ACT hospitals are included in the analysis.

During 2016, the mean total-hospital antibacterial usage rate for NSW and the Australian Capital Territory was 1,095 DDDs per 1,000 OBDs (range 700–2,051; median 1,061; Figure 9). In comparison, the mean rate in 2015 was 1,079 DDDs per 1,000 OBDs (range 416–1,792; median 1,026).

Victoria

In Victoria, 30 hospitals contributed to NAUSP during 2016 – six Principal Referral, 11 Public Acute Group A and seven Public Acute Group B Hospitals, one Specialist Women's Hospital, and five private hospitals. There are not yet any Victorian Public Acute Group C contributors to NAUSP.

The mean total-hospital antibacterial usage rate was 861 DDDs per 1,000 OBDs (range 269–1,294; median 891; Figure 13). In comparison, in 2015, the total-hospital antibacterial usage rate was 887 DDDs per 1,000 OBDs (range 322–1,524; median 893).

Queensland and Northern Territory

In 2016, 41 hospitals contributed to NAUSP from Queensland and the Northern Territory. The cohort comprised six Principal Referral, 13 Public Acute Group A, seven Public Acute Group B and five Public Acute Group C Hospitals, one Specialist Women's Hospital, and nine private hospitals. Data from two NT hospitals are included in the analysis.

During 2016, the mean total-hospital antibacterial usage rate for Queensland and the Northern Territory was 896 DDDs per 1,000 OBDs (range 442–2,065; median 786; Figure 10). In comparison, the 2015 mean total-hospital antibacterial usage rate for Queensland hospitals was 916 DDDs per 1,000 OBDs (range 378–1808; median 849).

South Australia

A total of 21 hospitals from South Australia contributed to NAUSP in 2016 – two Principal Referral, four Public Acute Group A, four Public Acute Group B and three Public Acute Group C Hospitals, one Specialist Women's Hospital, and seven private hospitals.

The mean total-hospital antibacterial usage rate for South Australia was 870 DDDs per 1,000 OBDs (range 436–1,509; median 800; Figure 11). In comparison, in 2015, the total-hospital antibacterial usage rate was 873 DDDs per 1,000 OBDs (range 314–1,445; median 850).

Western Australia

Seventeen hospitals from Western Australia contributed to NAUSP in 2016. The cohort comprised three Principal Referral, four Public Acute Group A, three Public Acute Group B and three Public Acute Group C Hospitals, one Specialist Women's Hospital, and three private hospitals.

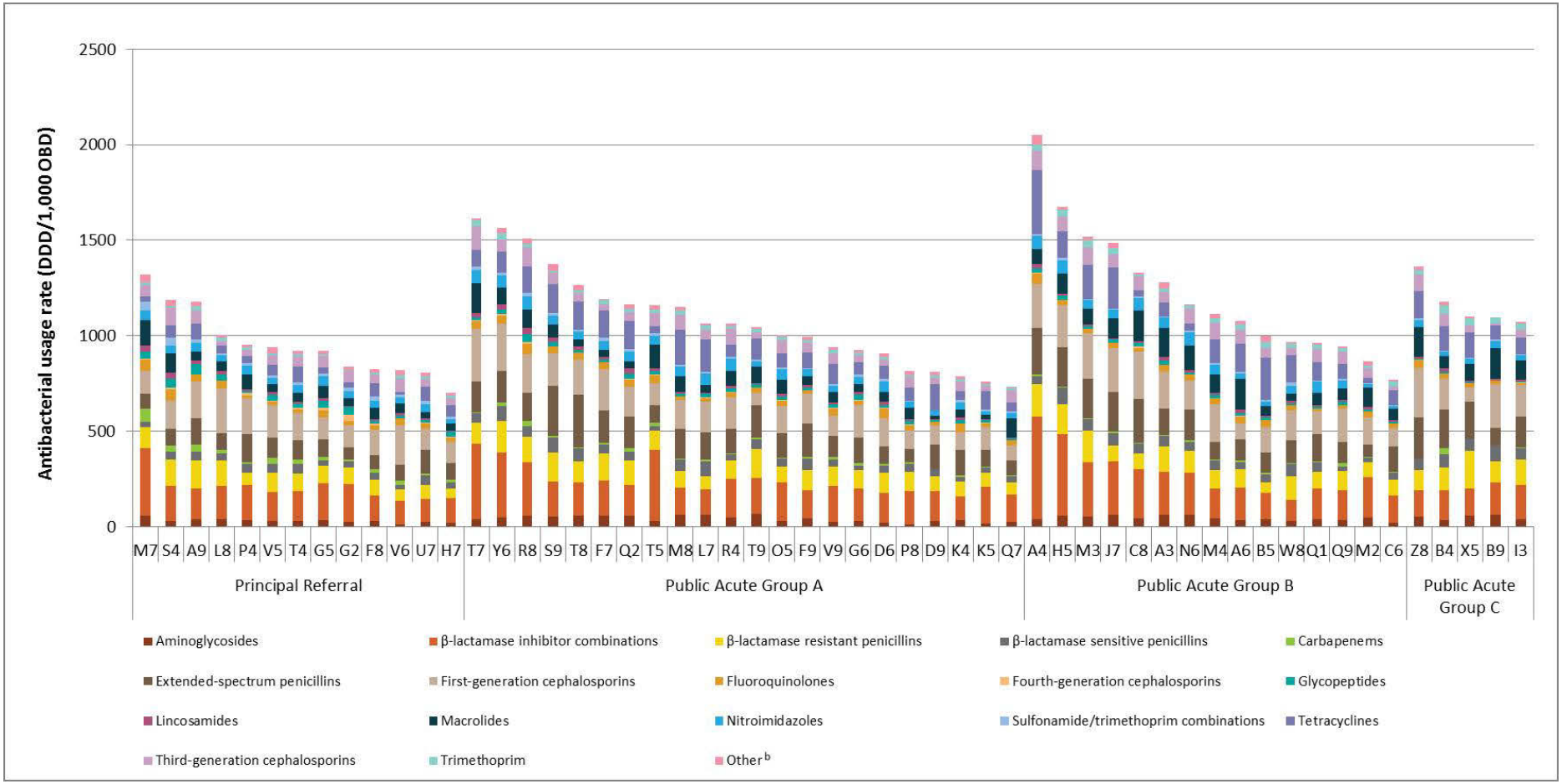
The mean total-hospital antibacterial usage rate in Western Australia was 766 DDDs per 1,000 OBDs (range 391–1,191; median 797; Figure 14). In comparison, in 2015, the total-hospital antibacterial usage rate was 763 DDDs per 1,000 OBDs (range 392–1,139; median 788).

Tasmania

Five Tasmanian hospitals contributed to NAUSP in 2016 – 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 898 DDDs per 1,000 OBDs (range 605–1,185; median 923; Figure 12). In comparison, in 2015, the total-hospital antibacterial usage rate was 1,220 DDDs per 1,000 OBDs (range 1,183–1,254; median 1,207). Data from two Tasmanian hospitals showed usage rates were approximately halved from the previous year. During 2016, the AMS teams at these hospitals focused on antibiotic usage in intra-abdominal infections and respiratory indications.

Figure 9: Total-hospital antibacterial usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by peer group*, New South Wales and Australian Capital Territory, 2016

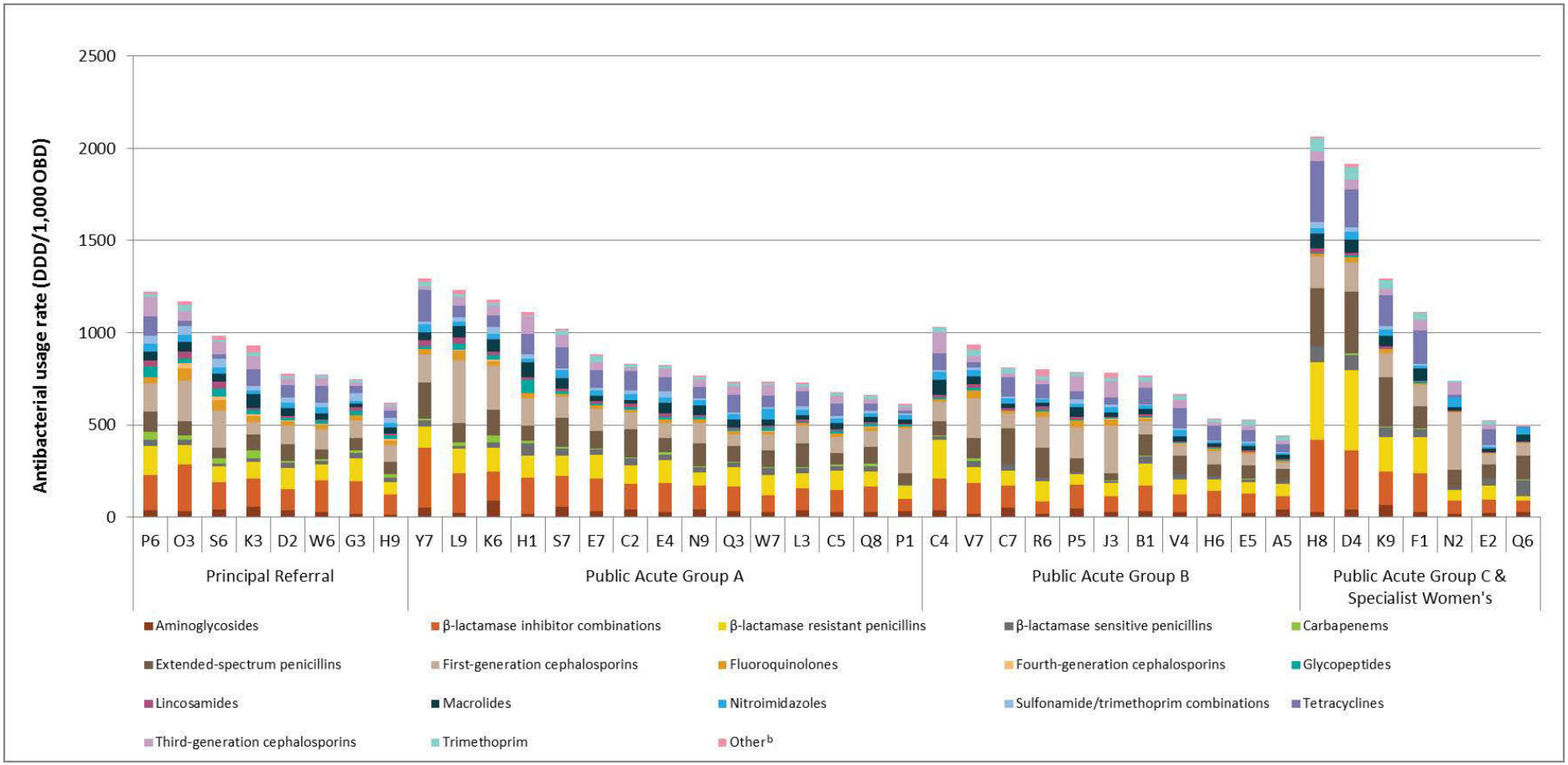


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

* Data from one NSW private hospital are benchmarked with the Principal Referral Hospital cohort.

† '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 10: Total-hospital antibacterial usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by peer group*, Queensland and Northern Territory, 2016

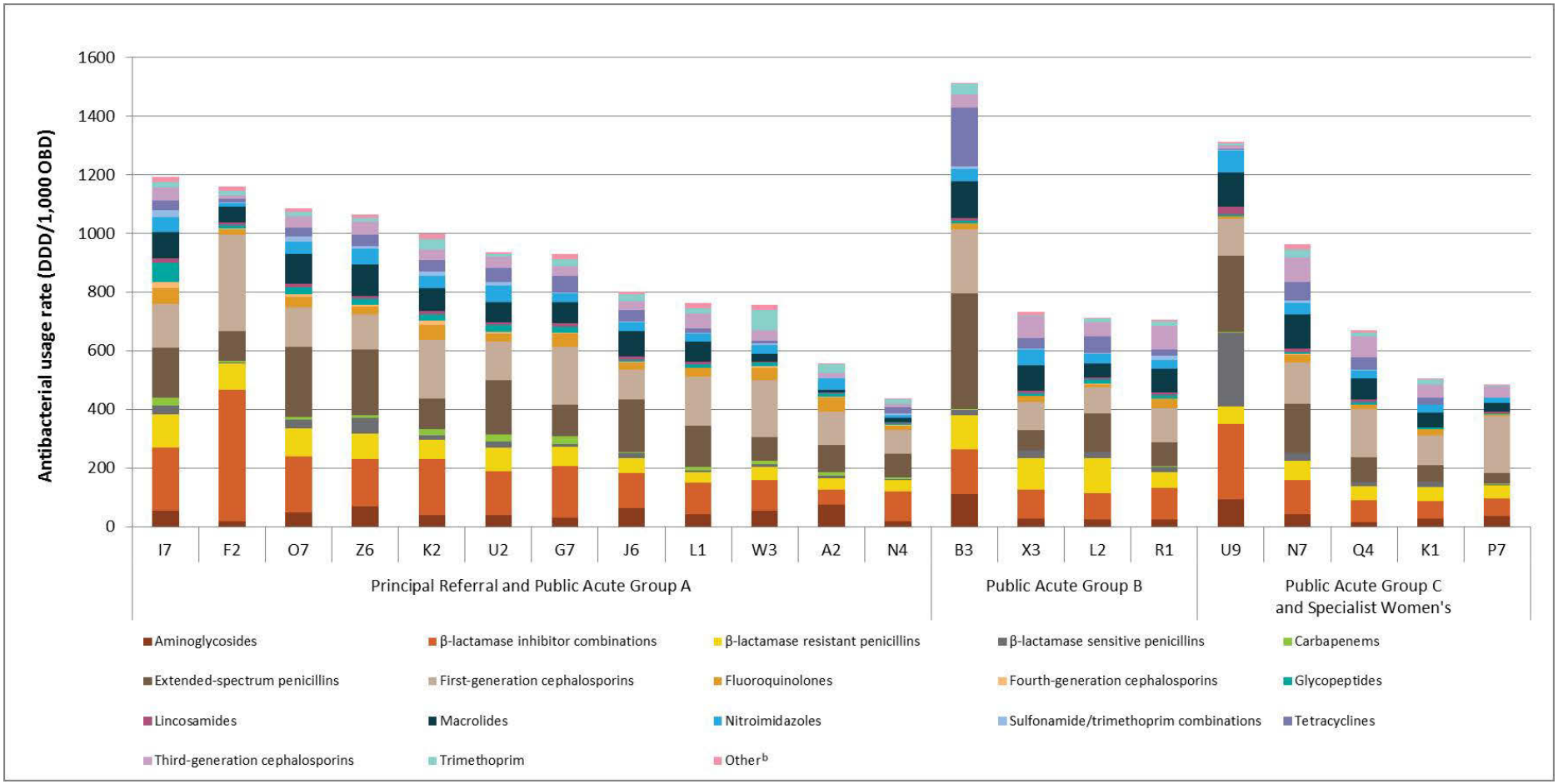


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

* Nine private hospitals are included in the Principal Referral, Public Acute Group A, Public Acute Group B and Public Acute Group C Hospital peer groups.

† '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 11: Total-hospital antibacterial usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by peer group*, South Australia, 2016

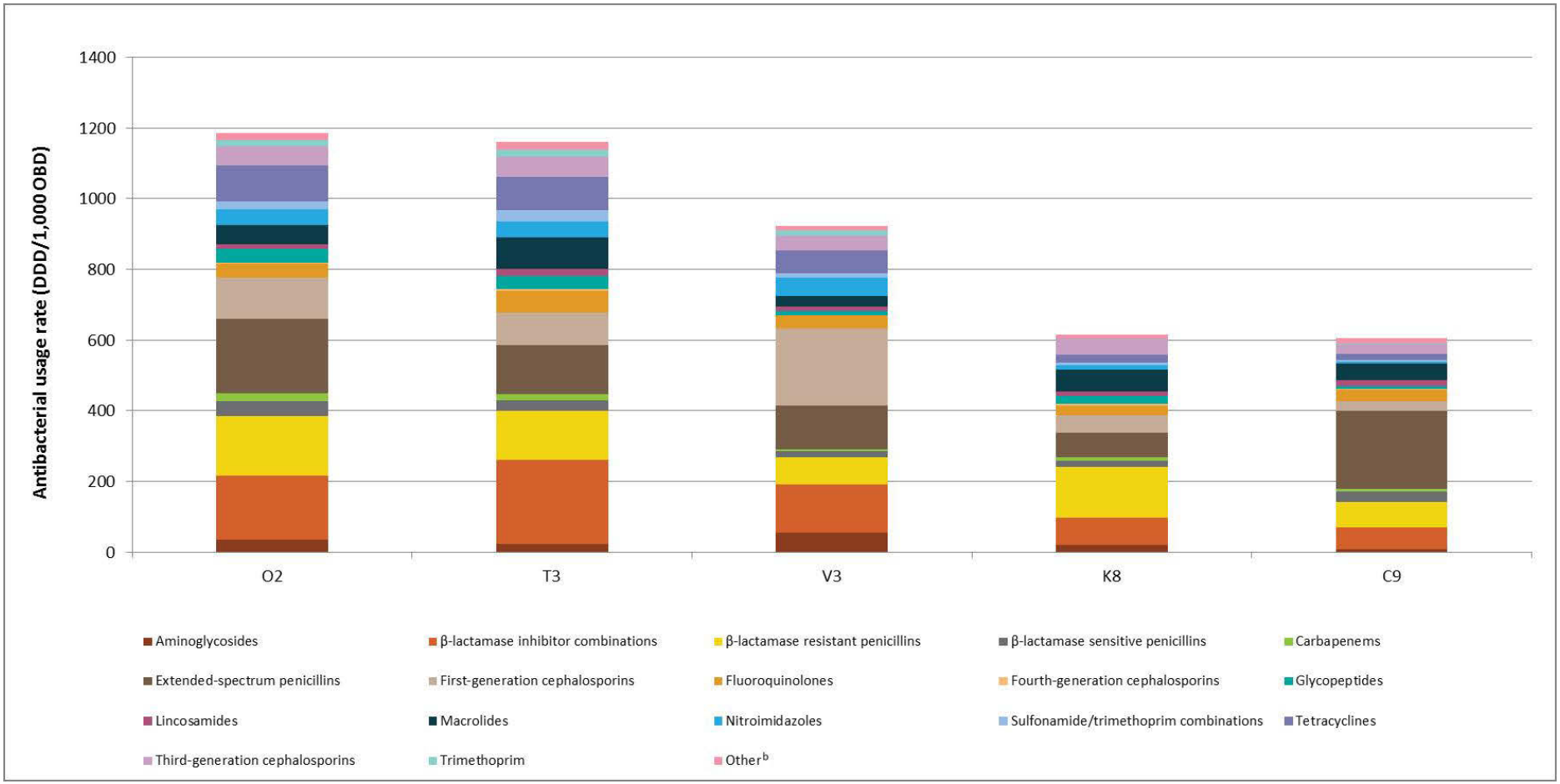


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

* Seven private hospitals are included in Principal Referral, Public Acute Group A and Public Acute Group C Hospital peer groups.

† 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/1,000 OBD) in NAUSP contributor hospitals, by peer group*, Tasmania, 2016

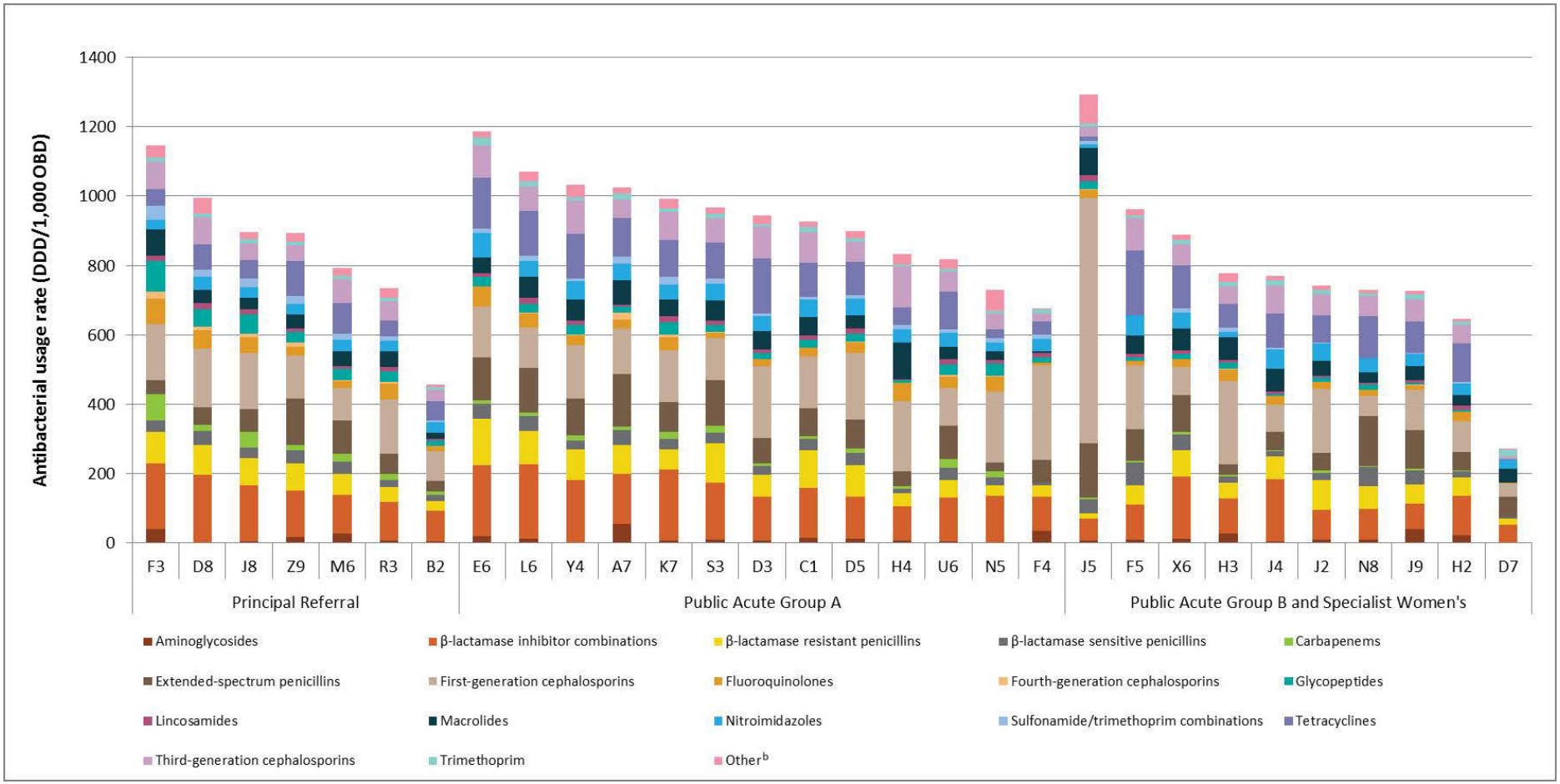


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

* Principal Referral, Public Acute Group A, Public Acute Group B and Public Acute Group C Hospitals from Tasmania contributed to NAUSP in 2016. Presentation by peer group would lead to identification due to the low number of Tasmanian NAUSP contributor hospitals.

† '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/1,000 OBD) in NAUSP contributor hospitals, by peer group*,Victoria, 2016

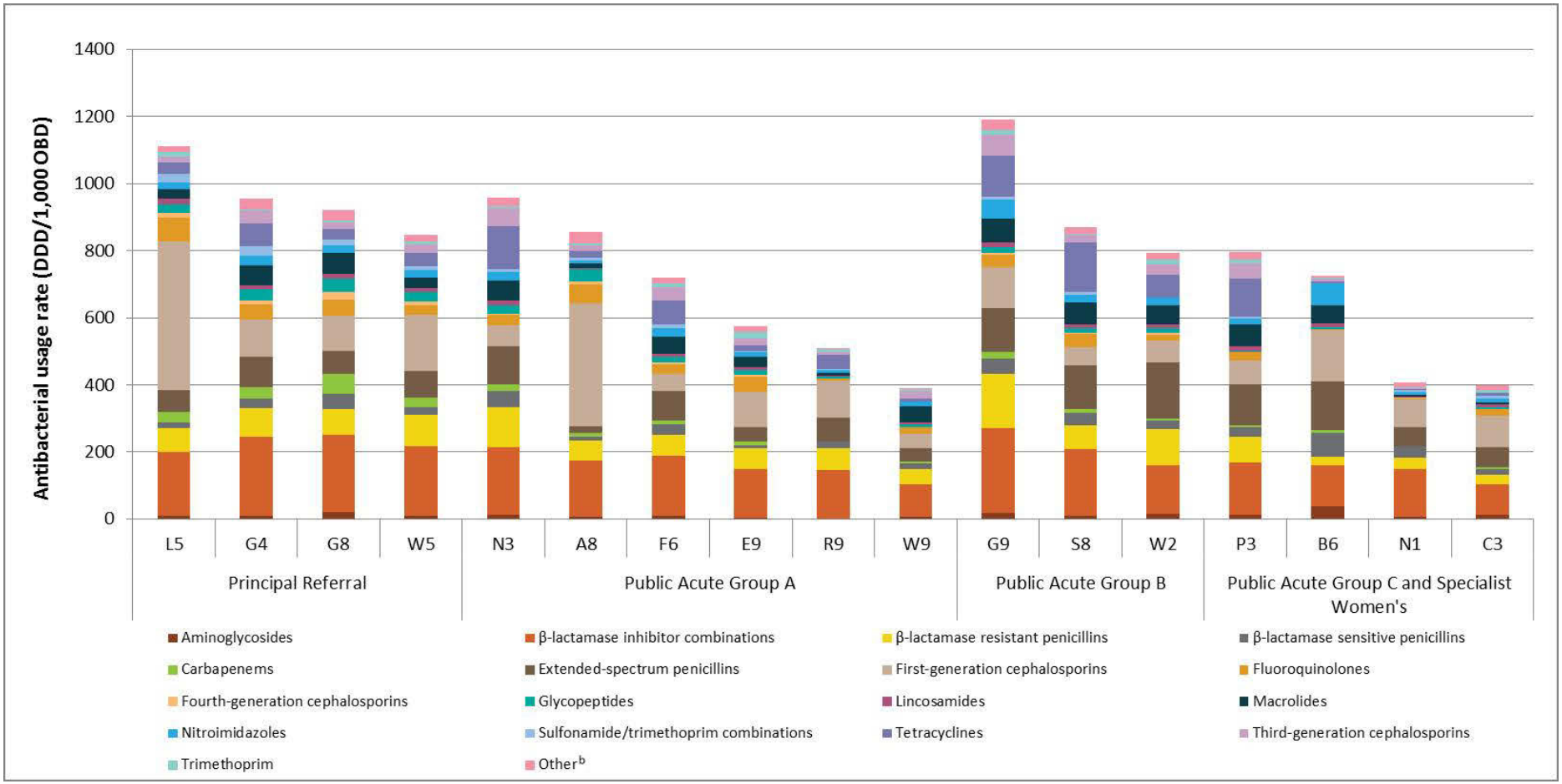


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

* Five private hospitals are included in the Principal Referral, Public Acute Group A and Public Acute Group B Hospital peer groups.

† '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/1,000 OBD) in NAUSP contributor hospitals, Western Australia, 2016*



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

* Three private hospitals are included in the Principal Referral and Public Acute Group A Hospital peer groups.

† 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.

Annual hospital antibacterial usage rates by antibacterial class, 2012–2016

Antibacterial classes are categorised into therapeutic groups using the WHO Anatomical Therapeutic Classification (ATC) system (see Appendix 2). The ATC 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. Changes in usage rates may also reflect simple variations between WHO-defined DDDs and current doses used in Australian hospital clinical practice. For example, cefazolin doses of 2 grams every six to eight hours are indicated for a range of indications[11] (ATC DDD is 3 grams), and vancomycin doses are often required to be greater than the 2 gram ATC DDD.[12]

Total-hospital and intensive care unit usage rates

Annual total-hospital usage rate data from NAUSP contributors, aggregated by year and antibacterial class, for the five years to December 2016 shows declining usage rates for aminoglycosides, carbapenems, glycopeptides, macrolides and metronidazole. In contrast, consistent, although often small, increases in aggregated annual usage rates were seen for trimethoprim–sulfamethoxazole, tetracyclines and first-generation cephalosporins (see Table 4).

Usage rates in ICUs are higher than total-hospital usage rates for most antibacterial classes (see Table 6). Aggregate ICU usage rates have also declined, with an 8.5% reduction since 2012. Notable reductions in use have occurred for aminoglycosides, β-lactamase-resistant penicillins, carbapenems, glycopeptides, macrolides and metronidazole.

In 2016 the mean ICU usage rate for Principal Referral Hospitals and private hospitals assigned to that peer group for the analyses (n = 34) was 1,487 DDDs per 1,000 OBDs (range 859–2,246; median 1,458; Figure 15). In Public Acute Group A and B Hospitals and private hospitals assigned to the Group A peer group for the analyses (n = 45), the mean ICU usage rate was 1,512 DDDs per 1,000 OBDs (range 598–2,446; median 1,464; Figure 16).

Analyses of the six antibacterial classes with the greatest potential to fuel multi-drug resistance show a mean of 700 DDDs per 1,000 OBDs (range 283–1,174; median 701) in Principal Referral Hospitals, and a mean of 639 DDDs per 1,000 OBDs (range 214–1,315; median 652) in Public Acute Group A and B Hospitals (Figures 17 and 18).

Table 6: Annual intensive care unit antibacterial usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by antibacterial class, 2012–2016

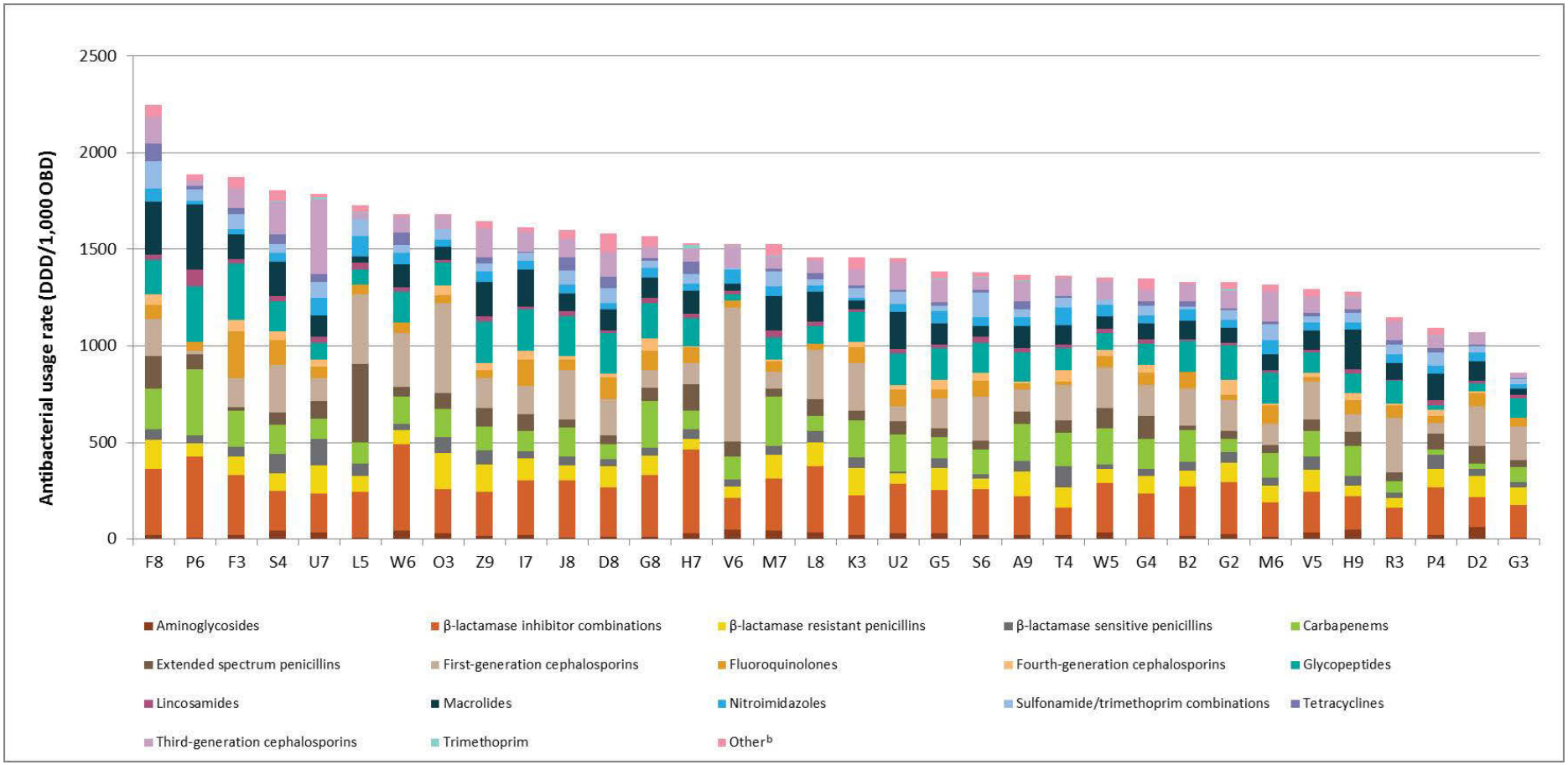
Antibacterial class (WHO Classification)	2012 (*n* = 55)	2013 (*n* = 63)	2014 (*n* = 67)	2015 (*n* = 73)	2016 (*n* = 79)
Alimentary antibiotics	0.0	0.0	0.0	0.0	0.1
Aminoglycosides	44.1	35.2	34.2	29.8	26.5
Amphenicols	0.0	0.0	0.0	0.0	0.0
β-lactamase inhibitor combinations	259.1	258.7	260.7	259.9	261.3
β-lactamase-resistant penicillins	111.7	106.0	115.4	107.9	100.9
β-lactamase-sensitive penicillins	47.3	48.8	49.0	48.9	49.6
Carbapenems	138.0	144.0	132.2	128.7	124.3
Extended-spectrum penicillins	102.1	89.0	84.0	82.2	84.7
First-generation cephalosporins	120.2	123.3	128.7	144.3	150.1
Fluoroquinolones	100.3	90.7	80.3	70.4	71.0
Fourth-generation cephalosporins	21.8	19.1	24.1	24.0	25.3
Glycopeptides	170.7	164.6	146.2	138.7	135.5
Lincosamides	23.4	24.4	23.3	22.0	22.8
Macrolides	171.8	162.4	156.7	143.6	139.0
Monobactams	1.1	0.9	1.0	1.6	0.8
Nitrofurans	0.2	0.5	0.3	0.3	0.2
Nitroimidazoles (metronidazole)	74.5	64.5	58.3	58.4	51.7
Other antibacterials (linezolid and daptomycin)	13.3	11.9	13.1	12.4	12.7
Other cephalosporins and penems (ceftaroline, ceftolozane–tazobactam)	0.0	0.1	0.4	0.5	0.6
Polymyxins	3.2	4.2	2.8	3.3	2.5
Rifamycins	7.0	8.1	7.9	9.5	9.5
Second-generation cephalosporins	1.0	1.3	1.3	1.9	2.0
Steroids (fusidic acid)	2.0	1.1	1.5	1.5	1.5
Streptogramins	0.3	0.4	0.6	0.2	0.2
Streptomycins	0.0	0.1	0.0	0.1	0.0
Tetracyclines	27.4	26.0	30.2	37.9	41.7
Third-generation cephalosporins	112.8	103.9	101.7	107.9	110.3
Trimethoprim	5.7	4.6	4.1	5.0	4.3
Trimethoprim–sulfamethoxazole	45.1	48.5	45.6	46.9	50.0
Grand total	**1,604.1**	**1,542.4**	**1,503.5**	**1,487.8**	**1,479.1**

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

Note: Numbers 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.

Declining ICU usage rates occurred for aminoglycosides, β-lactamase-resistant penicillins, carbapenems, glycopeptides, macrolides and metronidazole during the last five years. Increases were observed for β-lactamase-sensitive penicillins, first-generation cephalosporins, tetracyclines and trimethoprim–sulfamethoxazole.

Figure 15: Intensive care unit antibacterial usage rates (DDD/1,000 OBD) by NAUSP contributors, Principal Referral Hospitals*, 2016

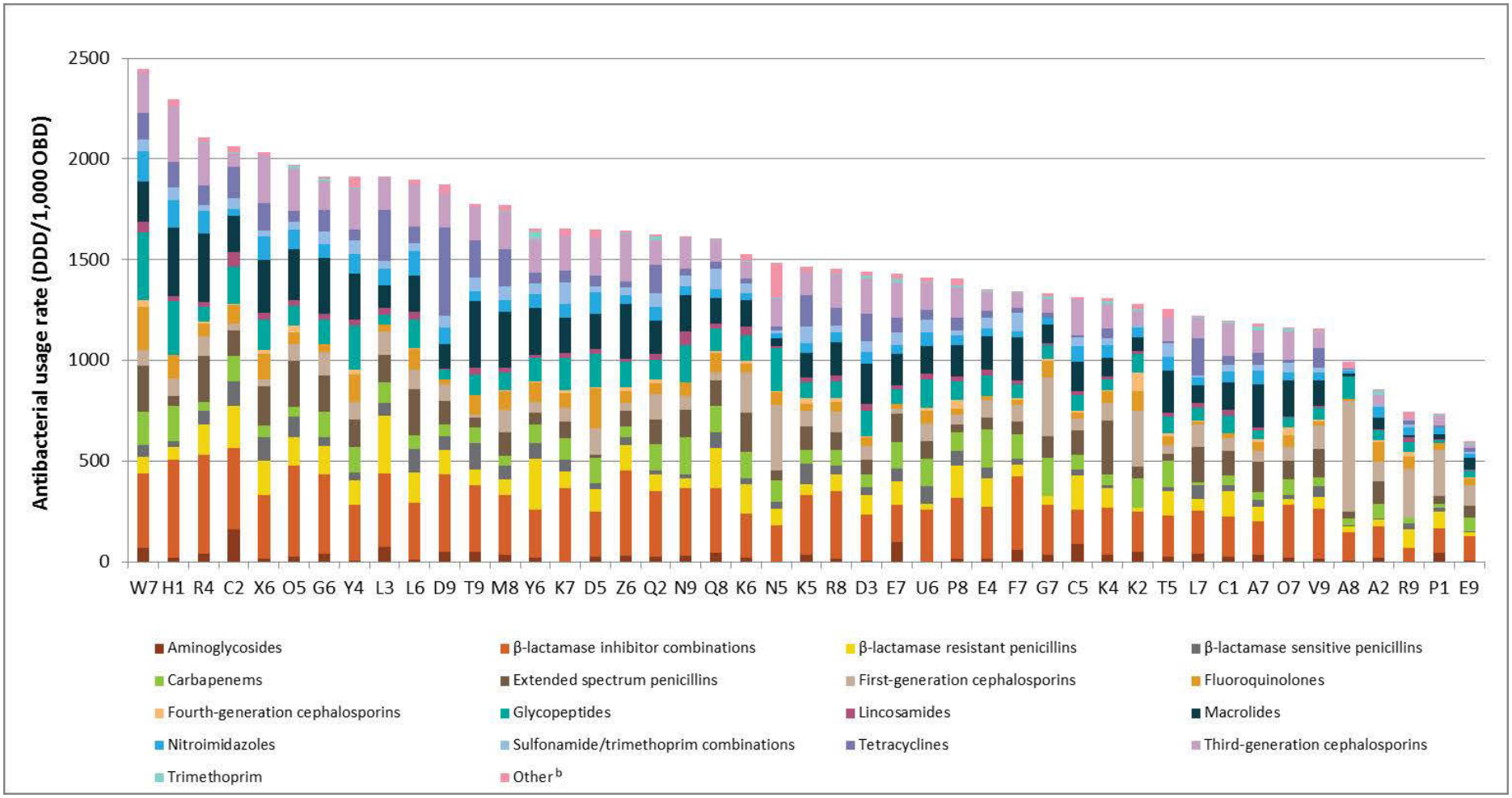


DDD = defined daily dose; ICU = intensive care unit; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

* Four private hospitals are included in these data; one Principal Referral Hospital is unable to supply separate ICU data.

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

Figure 16: Intensive care unit antibacterial usage rates (DDD/1,000 OBD) by NAUSP contributors, Public Acute Group A and B Hospitals*, 2016

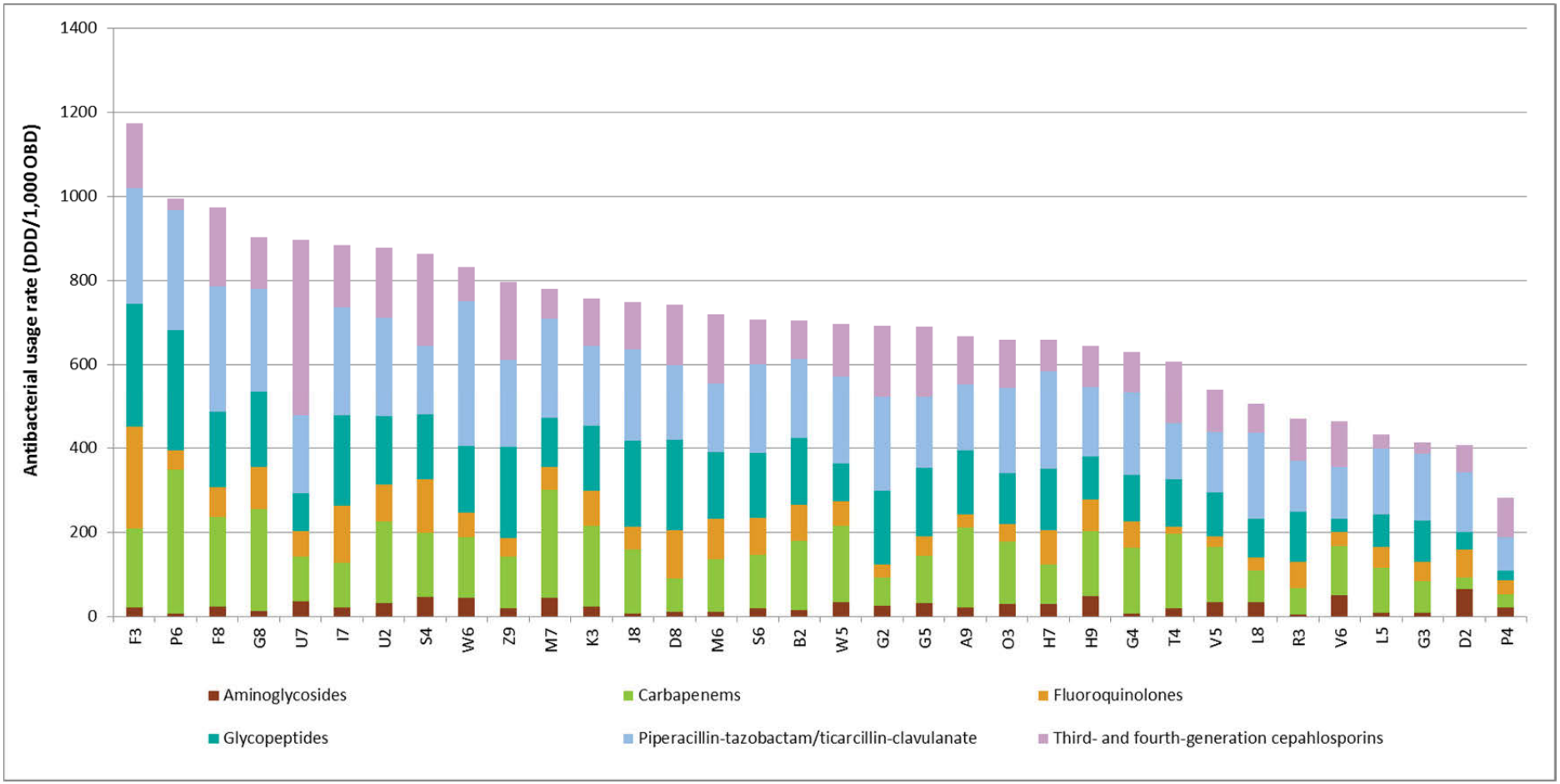


DDD = defined daily dose; ICU = intensive care unit; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

* 45 ICUs made up of 37 Public Acute Group A Hospitals, one Public Acute Group B Hospital and seven private hospitals. Not all contributor hospitals are able to supply separate ICU data.

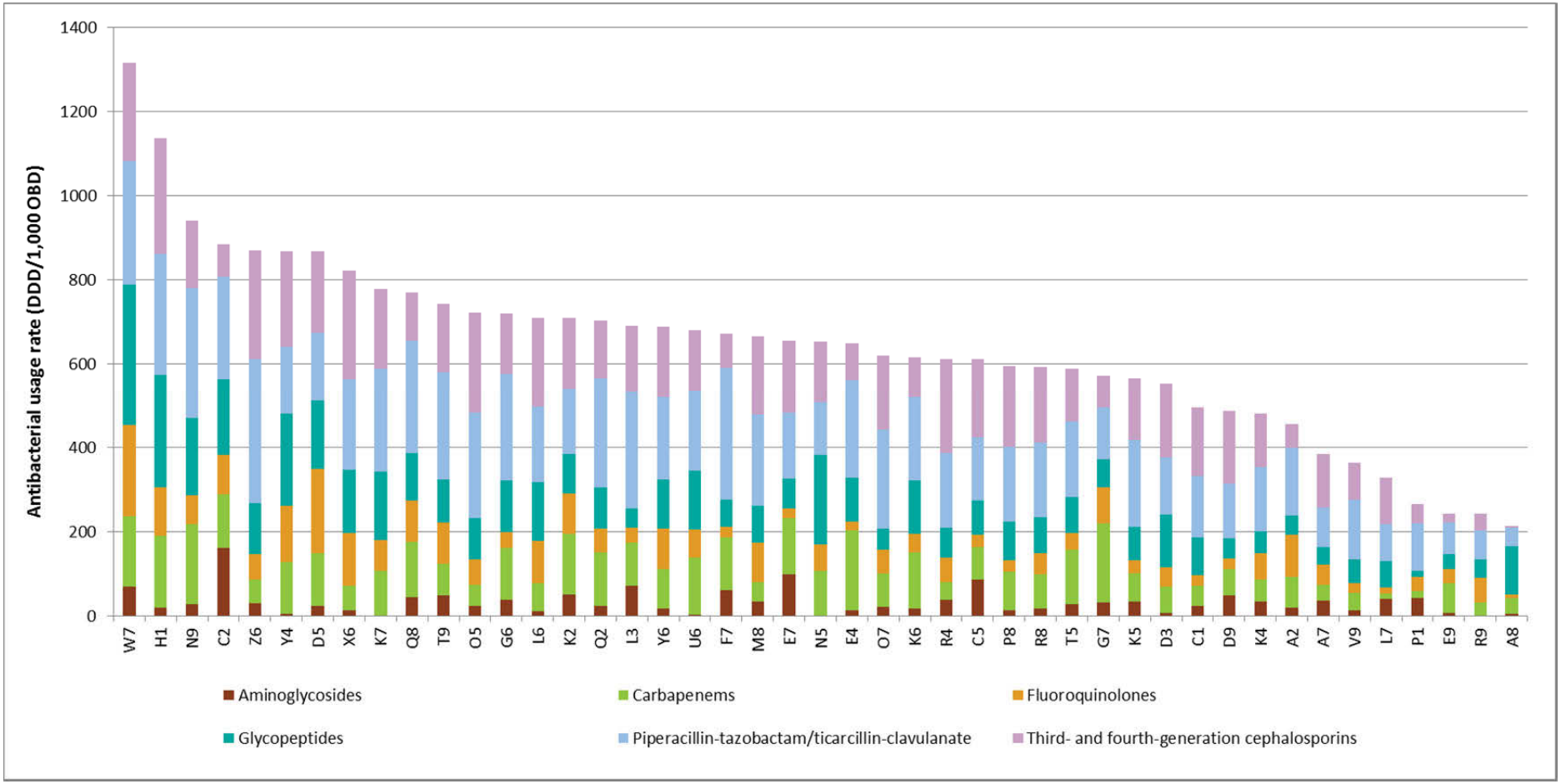
† 'Other' comprises amphenicols, monobactams, nitrofurans, other antibacterials (linezolid and daptomycin), other cephalosporins and penems (ceftaroline), polymyxins, rifamycins, second-generation cephalosporins, steroids (fusidic acid), streptogramins and streptomycins.

Figure 17: Intensive care unit usage rates (DDD/1,000 OBD) for six major antibacterial classes, by NAUSP contributors, Principal Referral Hospitals*, 2016



DDD = defined daily dose; ICU = intensive care unit; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
* Four private hospitals are included in these data; one Principal Referral Hospital is unable to supply separate ICU data.

Figure 18: Intensive care unit usage rates (DDD/1,000 OBD) for six major antibacterial classes, by NAUSP contributors, Public Acute Group A and B Hospitals, 2016



DDD = defined daily dose; ICU = intensive care unit; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
* 45 ICUs made up of 37 Public Acute Group A Hospitals, one Public Acute Group B Hospital and seven private hospitals. Not all contributor hospitals are able to supply separate ICU data.

Usage rates for individual antibacterials, 2012–2016

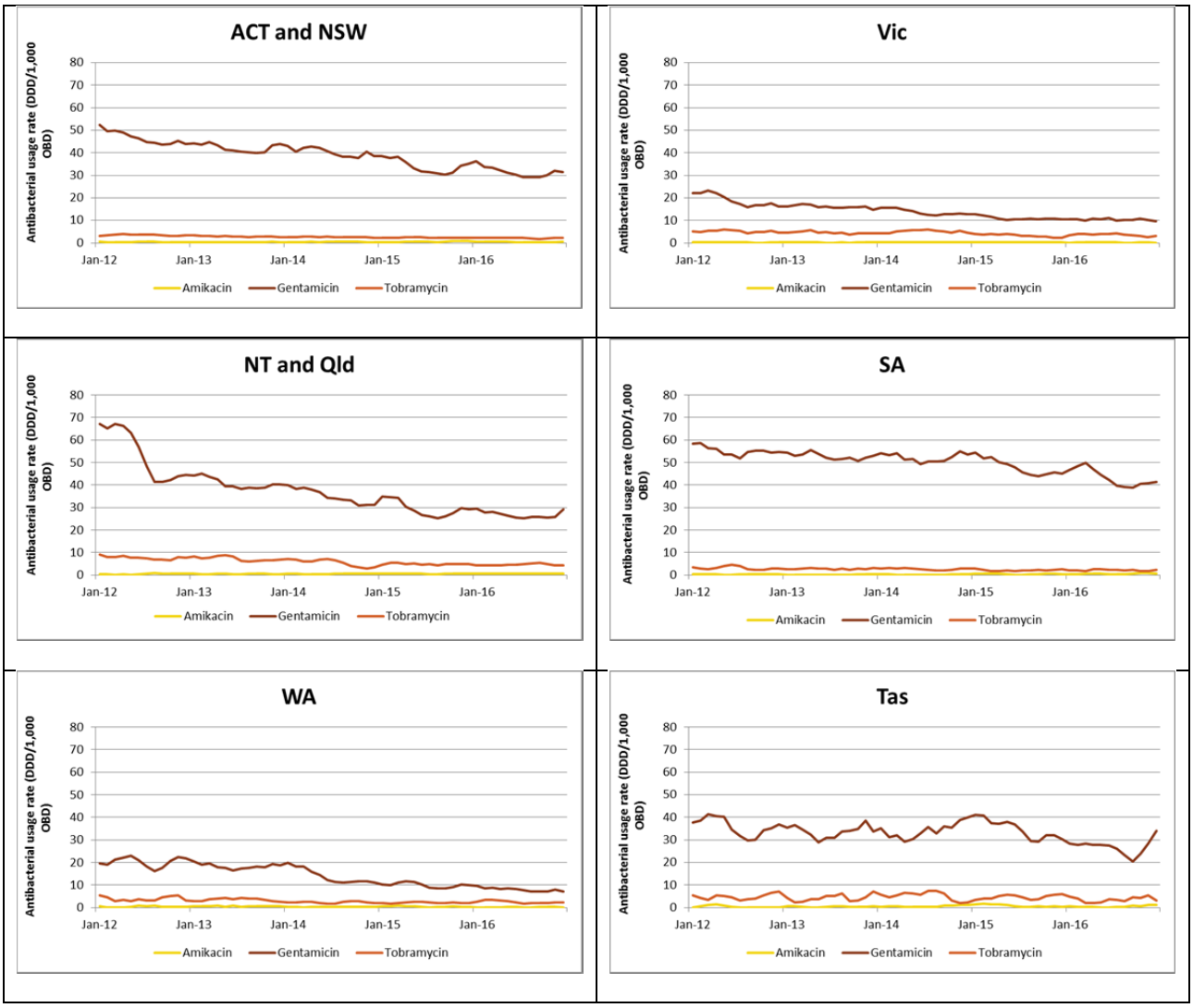
This section summarises usage rates of individual antibacterials and trends over the past five years.

Aminoglycosides – amikacin, gentamicin, tobramycin

Gentamicin is the most commonly used aminoglycoside in NAUSP contributor hospitals. Usage rates decreased from 2012 to 2016, and there are large variations between states and territories (Figure 19). Use of aminoglycosides continues to be 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 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*.

Figure 19: Aminoglycoside usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2012–2016 (3-month moving average)



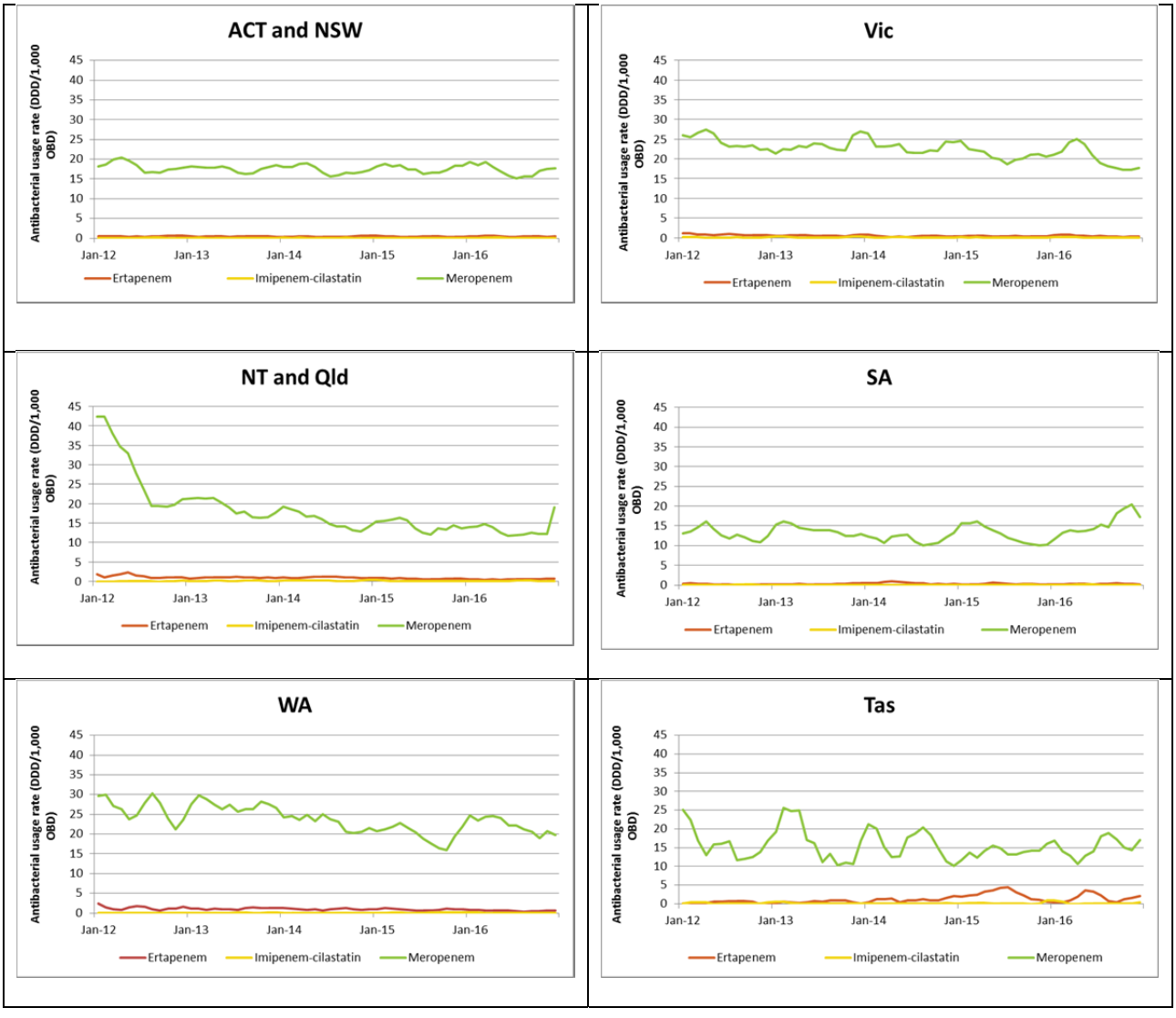
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Carbapenems – ertapenem, imipenem–cilastatin, meropenem

Meropenem is the main carbapenem used in NAUSP contributor hospitals, possibly as a result of the lower incidence of neurotoxicity, superior activity against *Pseudomonas* species and cost benefits compared with other carbapenems.[13] Meropenem has become a key reserve-line antibacterial because it has a role in treating infections with resistance to multiple other classes.

Usage rates of other carbapenems are low, and possibly influenced by prescribing preferences in particular hospitals (Figure 20). Doripenem is rarely used and has not been included in the figures below.

Figure 20: Carbapenem usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2012–2016 (3-month moving average)



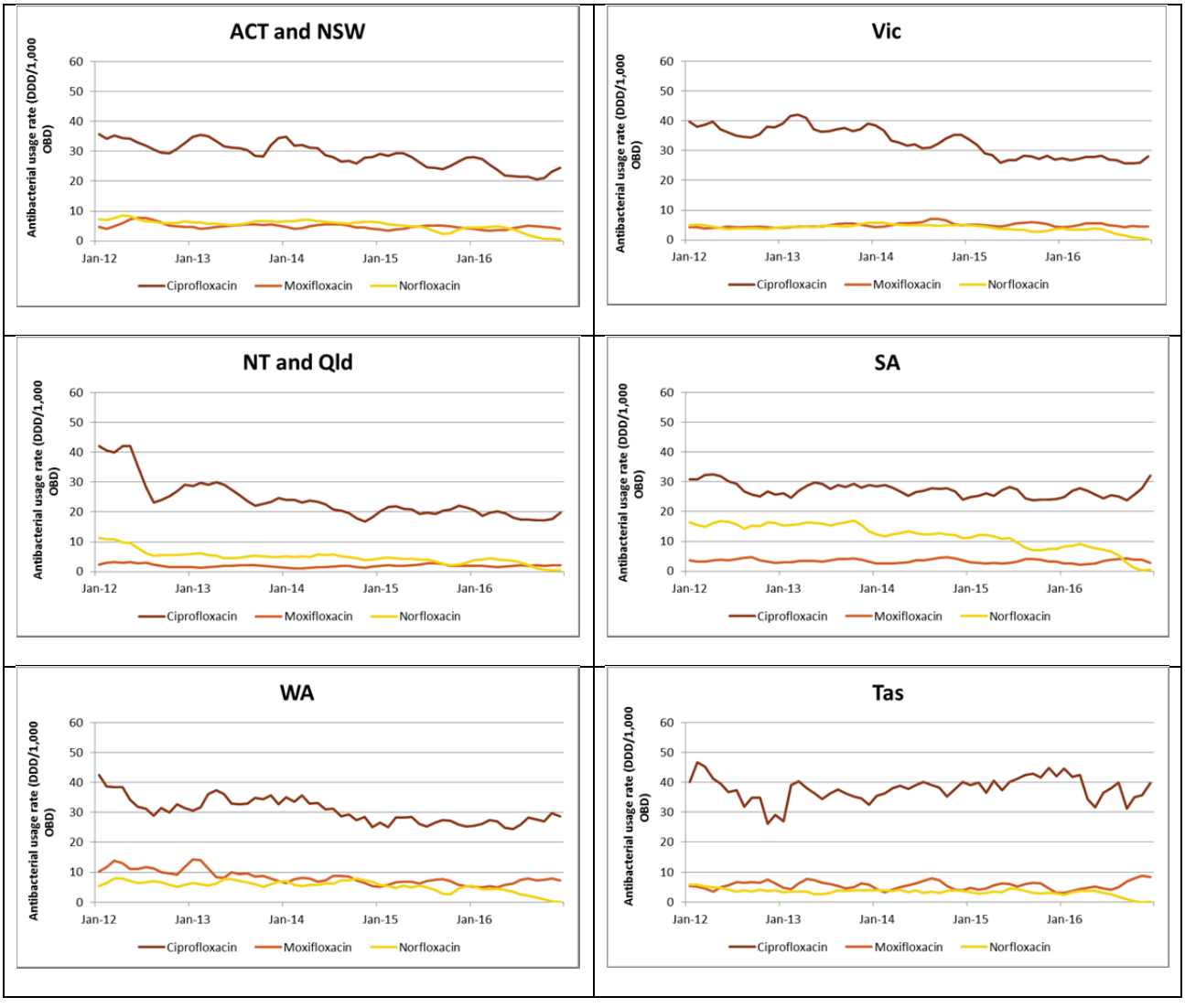
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Fluoroquinolones – ciprofloxacin, moxifloxacin, norfloxacin

Fluoroquinolone usage rates have decreased slightly since 2012 in most states and territories (Figure 21). Ciprofloxacin usage rates have remained stable in South Australia where usage rates have been relatively low since 2012. 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.[11]

Ciprofloxacin is the most frequently used fluoroquinolone; it has higher bioavailability than norfloxacin and it is cheaper than moxifloxacin. Usage rates of moxifloxacin have remained relatively constant because there are a limited number of standard indications. Norfloxacin usage rates declined in 2016, probably related to a nationwide shortage, rather than a specific AMS intervention.

Figure 21: Fluoroquinolone usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2012–2016 (3-month moving average)



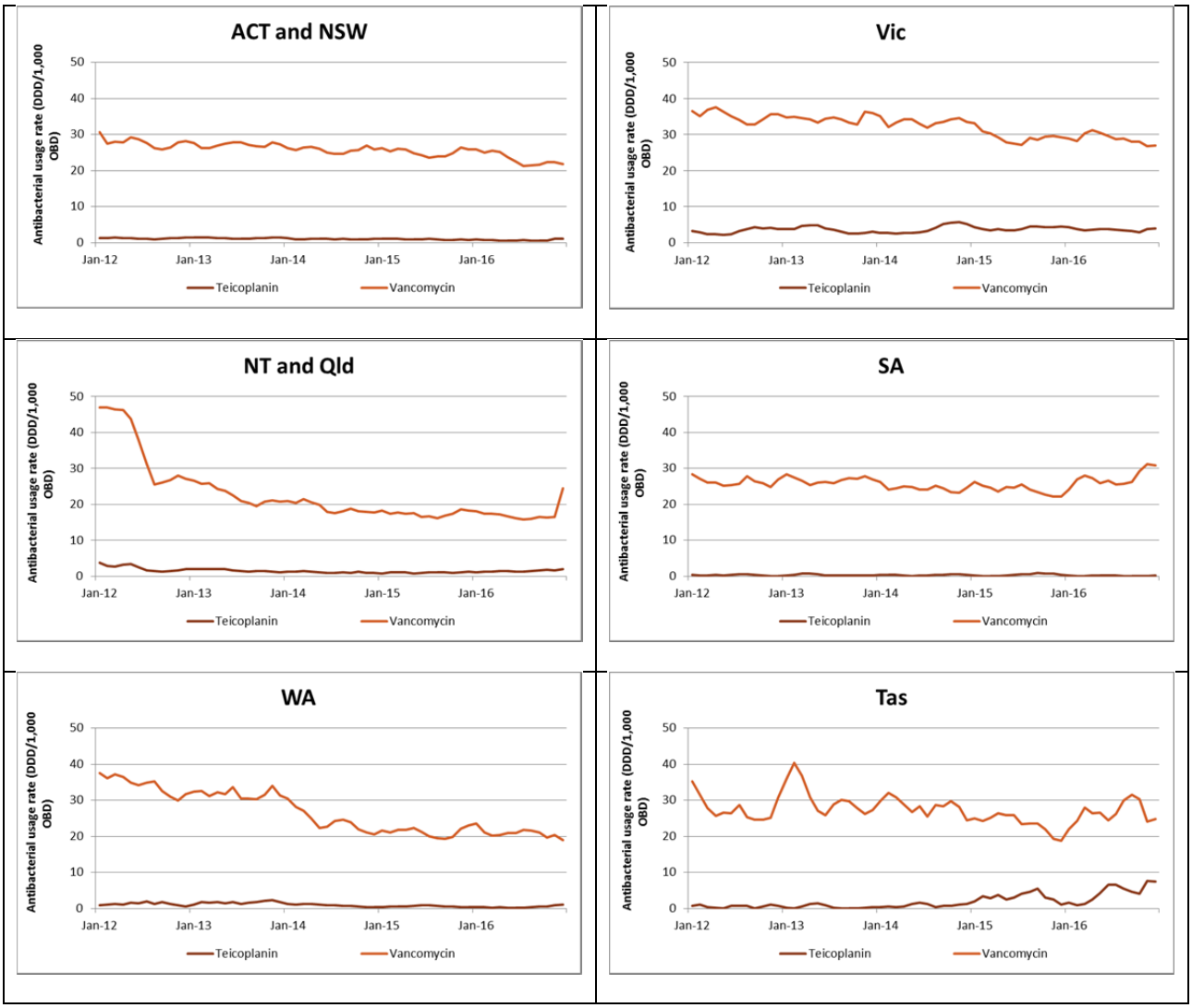
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Glycopeptides – teicoplanin, vancomycin

Teicoplanin and vancomycin are the glycopeptides used in Australia. The newer lipoglycopeptides have not been registered in Australia to date. Since 2012, aggregated vancomycin usage rates have decreased in several states and territories (Figure 22). 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.

Moderate variations in usage rates are apparent between states and territories. In South Australia and Tasmania usage rates appear to have increased in 2016 compared with 2015. This may be due to adoption of dosing guidelines for vancomycin where high initial doses are encouraged to ensure early achievement of therapeutic levels of antibiotic.

Figure 22: Glycopeptide usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2012–2016 (3-month moving average)



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

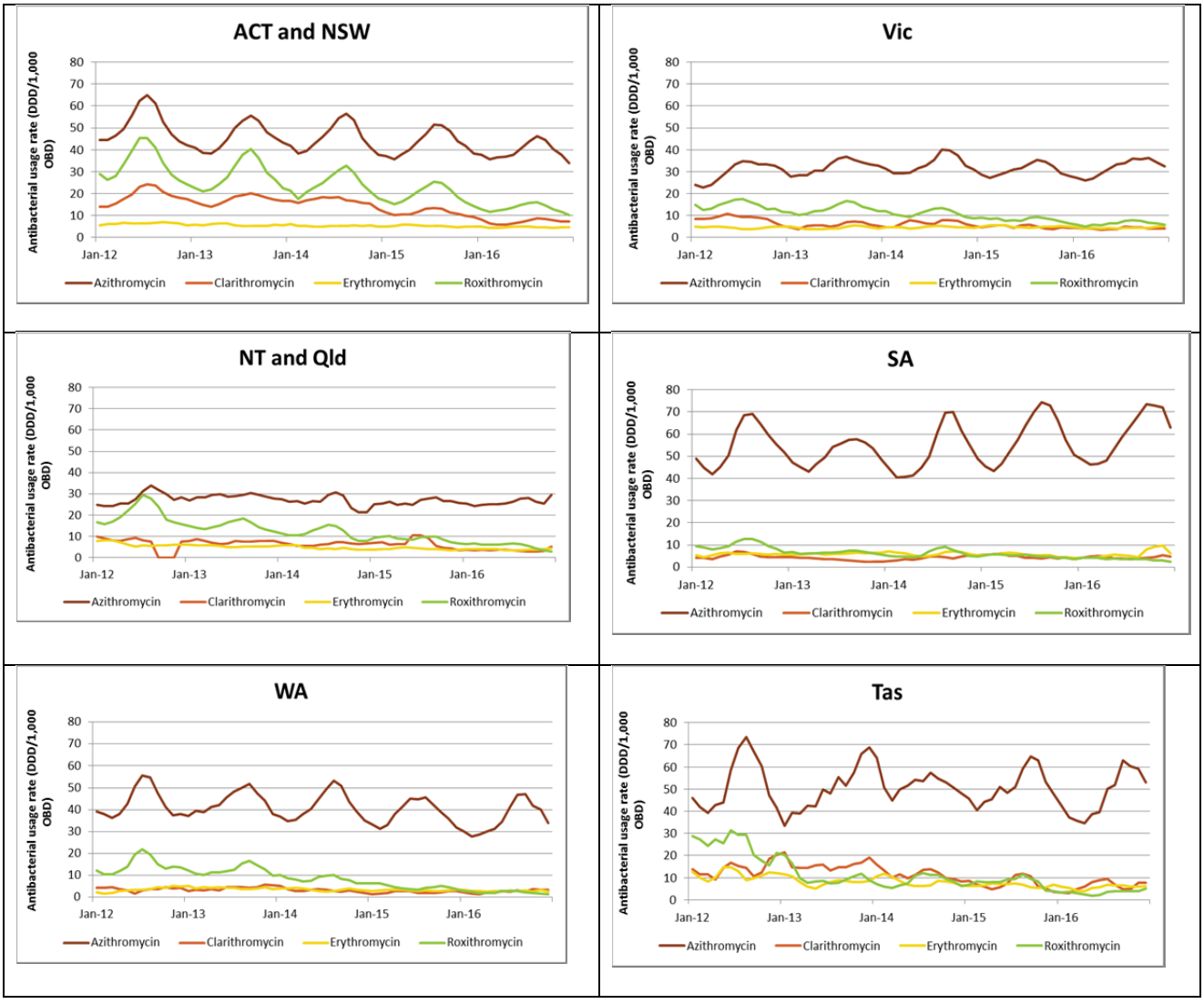
Macrolides – azithromycin, clarithromycin, erythromycin, roxithromycin

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 23). Seasonal variation is much less evident in the Queensland and Northern Territory cohort. Large variations in usage rates occur between states and 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.

Roxithromycin usage rates are highest in New South Wales and the Australian Capital Territory, and there is a seasonal pattern of use as for azithromycin.

Azithromycin is now the main 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 23: Macrolide usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2012–2016 (3-month moving average)



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

Penicillin–β-lactamase inhibitor combinations: amoxicillin–clavulanate, piperacillin–tazobactam, ticarcillin–clavulanate

Two intravenous antipseudomonal penicillin–β-lactamase inhibitor combinations (ticarcillin–clavulanate and piperacillin–tazobactam) 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 broad spectrum makes it suitable for use in people who are critically ill. Piperacillin–tazobactam is used in ICUs for ventilator-associated pneumonia. Outside the ICU setting, it is used for febrile neutropenia and intra-abdominal infections.

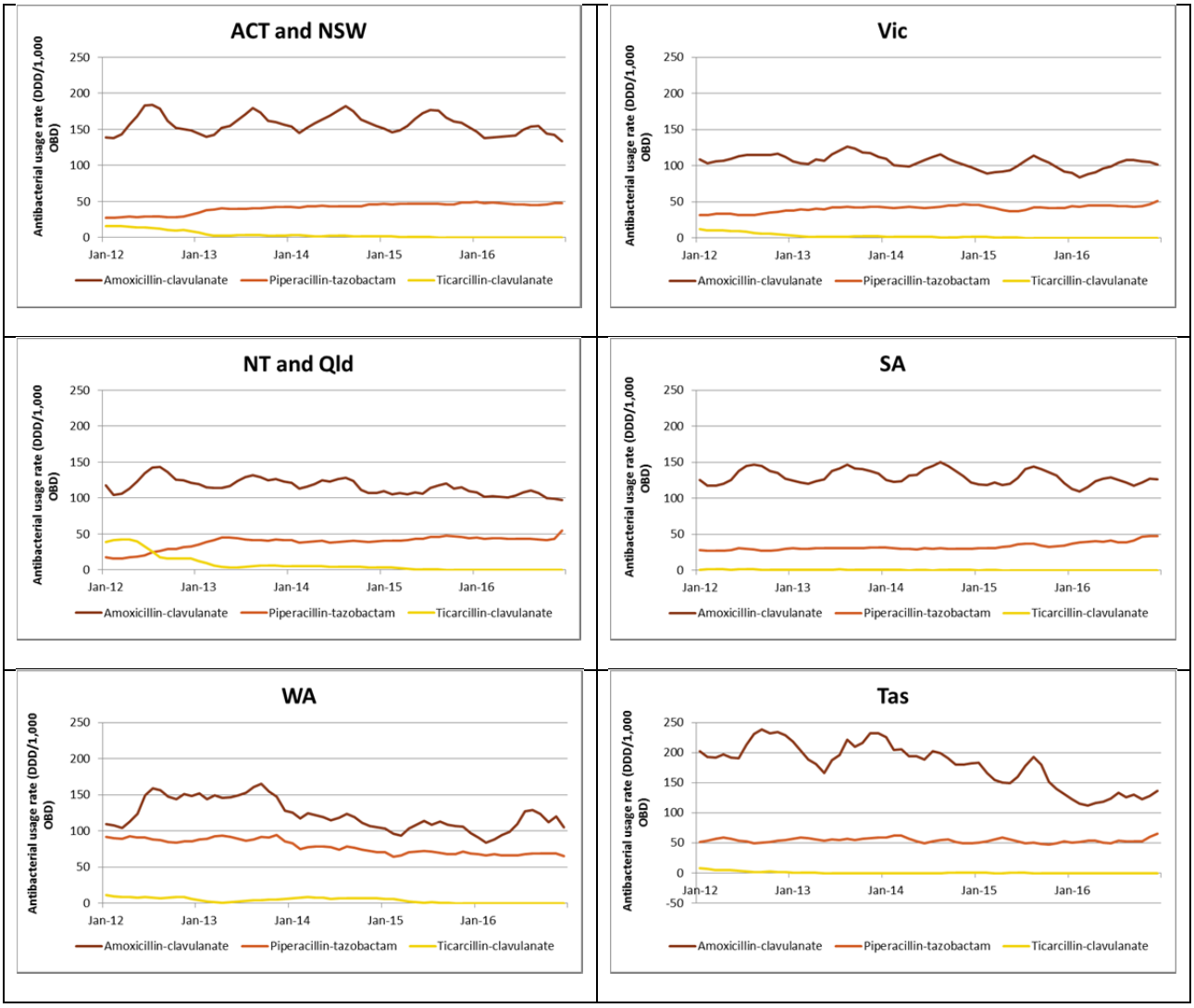
Amoxicillin–clavulanate is not antipseudomonal and before 2017 was only available in oral formulations in Australia. It has a range of indications, including de-escalation from intravenous therapy. Some hospitals began accessing the intravenous formulation in 2015 through the Special Access Scheme[14] for use after gastrointestinal surgery. NAUSP data show that intravenous use accounted for less than 1% of total use in contributor hospitals in 2015 and 2016. It is anticipated that usage will increase in coming years due to intravenous preparations of amoxicillin–clavulanate being approved for use by the Therapeutic Goods Administration in 2017.

Figure 24 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 states and territories with usage rates being 50% higher in Western Australia. Since 2014 usage has remained stable.

Figure 24 also shows some seasonal variation in usage rates for amoxicillin–clavulanate, particularly in New South Wales and the Australian Capital Territory, South Australia and Victoria.

Usage rates of amoxicillin–clavulanate have declined in Tasmania since 2013 and in 2016 were similar to rates in other states and territories.

Figure 24: Penicillin–β-lactamase inhibitor combination usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2012–2016 (3-month moving average)



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

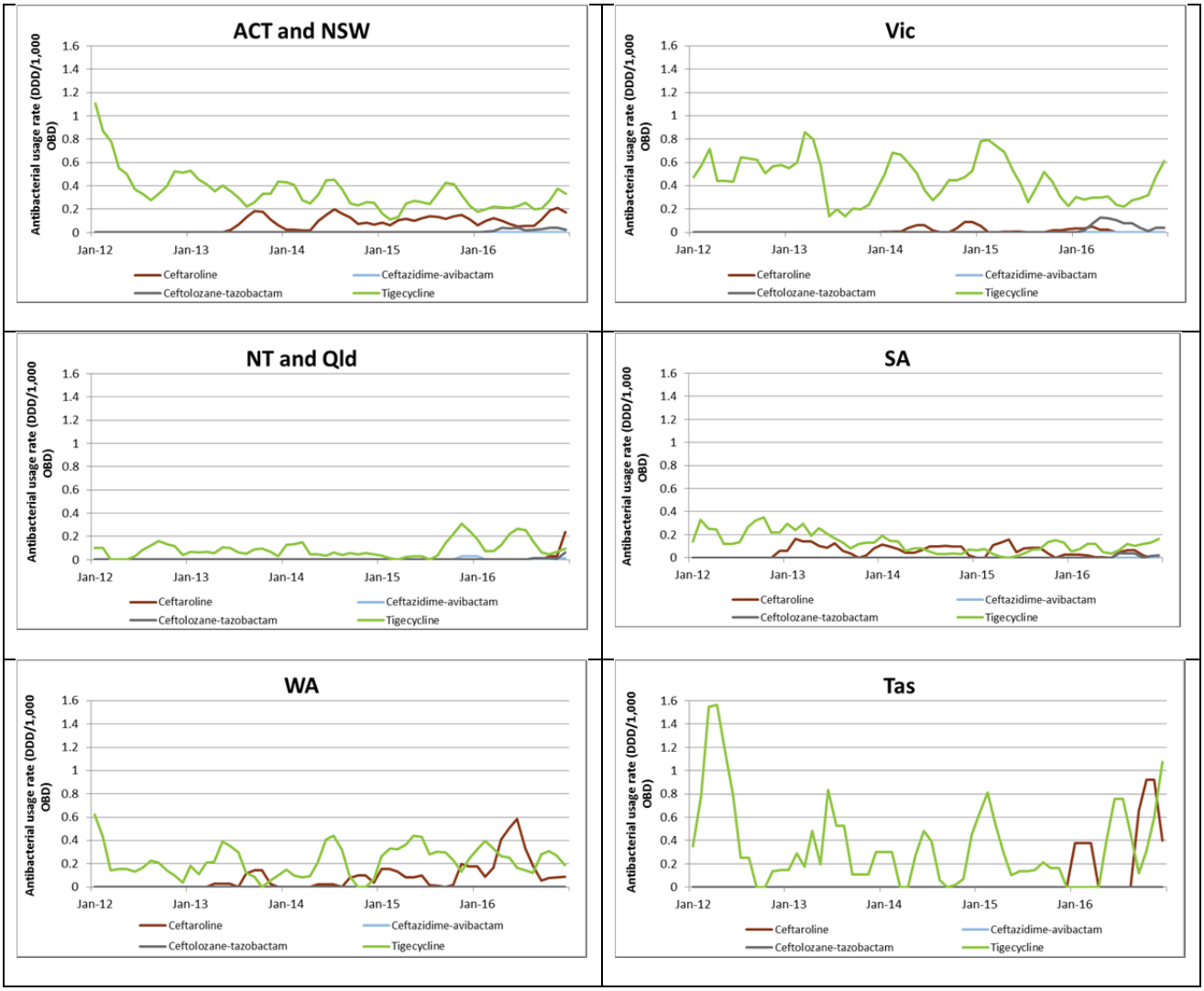
Reserve-line antibacterials (broad spectrum) – ceftaroline, ceftazidime–avibactam, ceftolozane–tazobactam, tigecycline

Usage of the newer antibacterial agents, ceftaroline, ceftazidime–avibactam and ceftolozane–tazobactam, is low and variable between states and territories.

Tigecycline use remains very low in Australian hospitals. Usage of ceftaroline, ceftazidime-avibactam and ceftolozane-tazobactam is minimal.

Figure 25 displays usage of broad-spectrum reserve-line agents. It is likely that these data are derived from only a small number of patients; however, NAUSP does not collect any patient-specific data to verify this.

Figure 25: Broad-spectrum reserve-line antibacterial usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2012–2016 (3-month moving average)



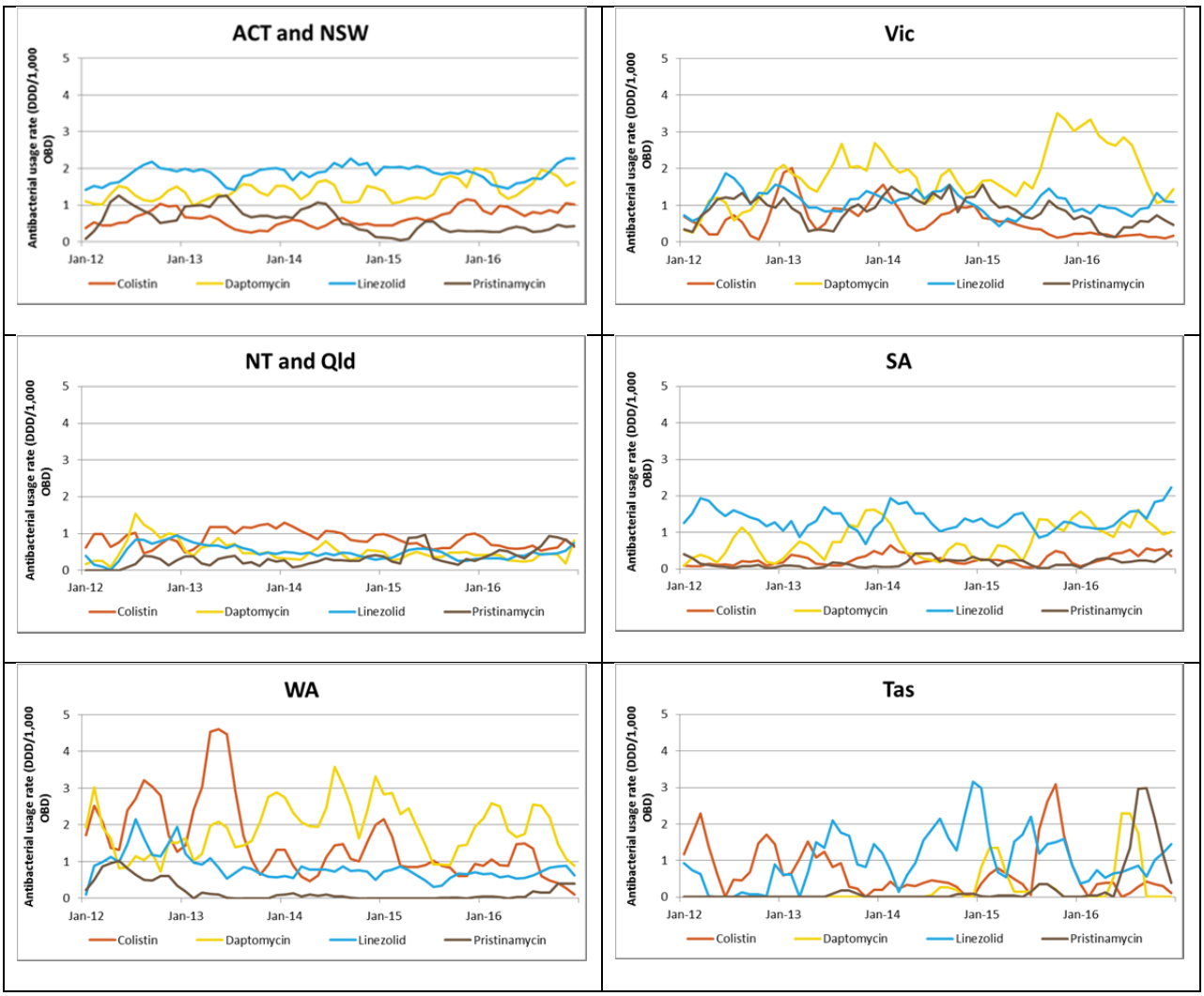
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Reserve-line antibacterials (narrow spectrum) – colistin, daptomycin, linezolid, pristinamycin

Parenteral colistin (methanesulphonate) 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 very low, are increasing. Only 10 hospitals used daptomycin at rates greater than 5 DDDs per 1,000 OBDs per year in the years 2012 to 2016.

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 have not been analysed to determine whether linezolid use can be correlated with the incidence of VRE infections.

Figure 26: Narrow-spectrum reserve-line antibacterial usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2012–2016 (3-month moving average)



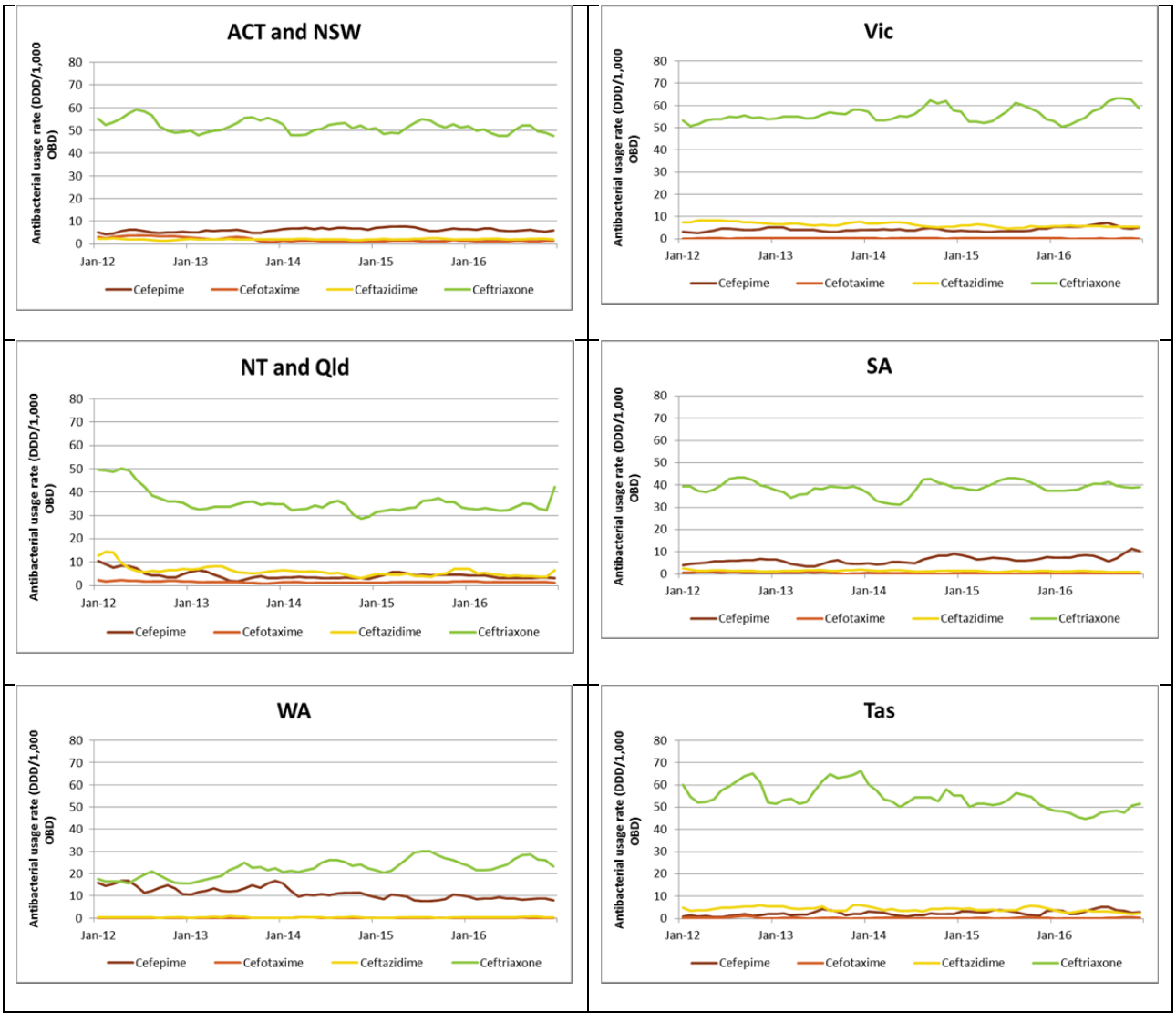
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

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 2012 to 2016.

Ceftriaxone, a third-generation cephalosporin, shows marked seasonal variation, reflecting its use (appropriate or otherwise) in the treatment of lower respiratory infections, which peak in the winter months. This substantiates data from the 2015 NAPS, which revealed that approximately 30% of ceftriaxone prescriptions were inappropriate. Examples of misuse included prescription for diabetic foot infection, bronchiolitis and catheter-associated infection.[9] Usage rates of ceftriaxone are lower in Western Australia than in other states and possibly compensated by higher usage rates of piperacillin–tazobactam for intra-abdominal infections, hospital-acquired pneumonia and undifferentiated sepsis.

Figure 27: Cephalosporin usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2012–2016 (3-month moving average)



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

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 can be supported by usage data.

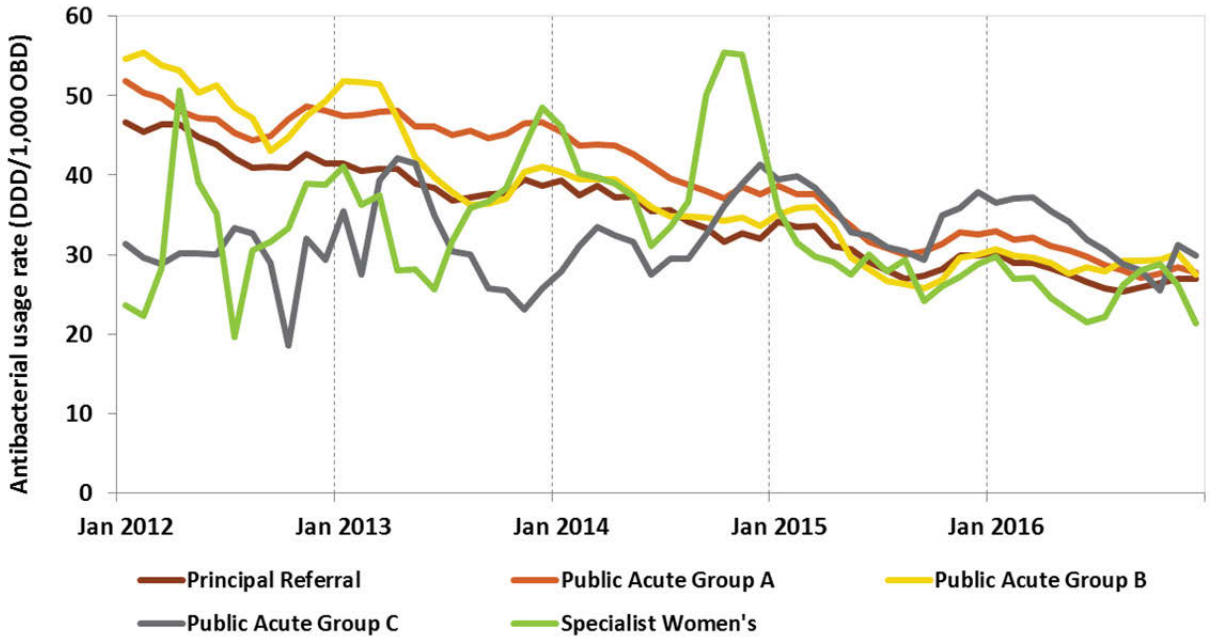
In the analyses below, private hospitals were included with public hospitals of similar size and patient mix. Data from Specialist Women's Hospitals were included in these analyses but the number of those hospitals is low (*n* = 4).

It is notable that for some antibacterial classes, usage is higher in Public Acute Group A, B and C Hospitals than in Principal Referral Hospitals. The reasons for this difference are not known; however, it may be that AMS programs are less well developed in smaller facilities.

Aminoglycosides – amikacin, gentamicin, tobramycin

Aminoglycoside usage rates show downward trends in Principal Referral, Public Acute Group A and Public Acute Group B Hospitals from 2012 to 2016 (Figure 28). In 2016, usage rates in all peer groups were similar.

Figure 28: Aminoglycoside usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2012–2016 (3-month moving average)

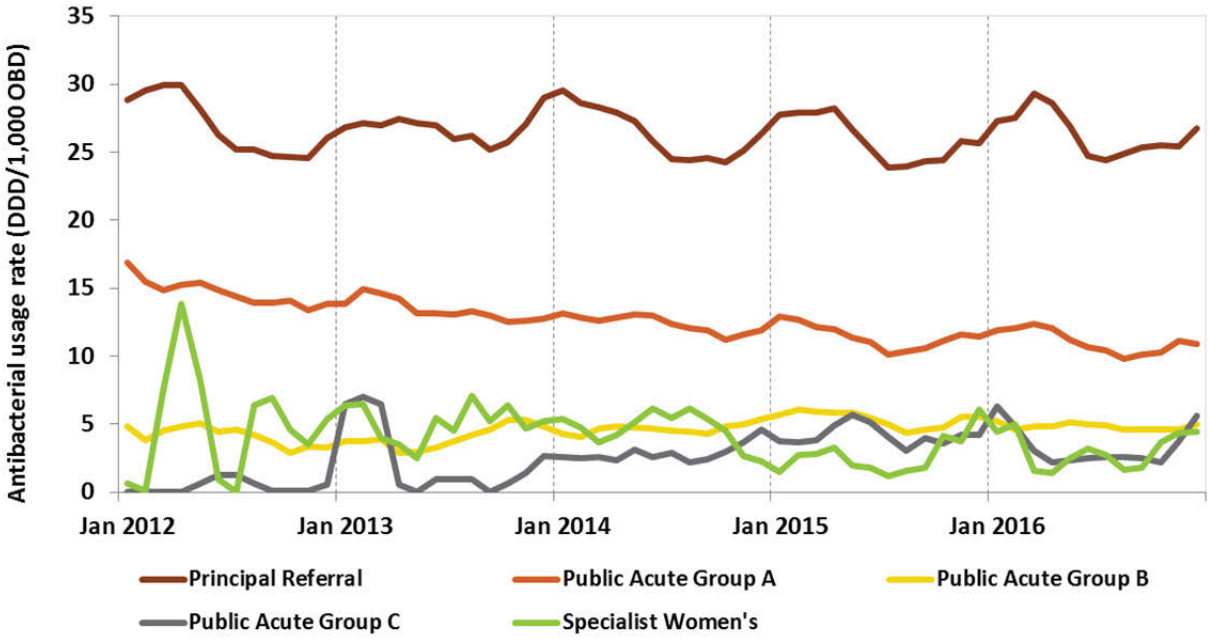


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

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 Hospitals (Figure 29). Use in smaller hospitals (Public Acute Group B and C) and in Specialist Women's Hospitals was minimal, but use in Public Acute Group C hospitals shows a possible trend upwards that requires ongoing monitoring.

Figure 29: Carbapenem usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2012–2016 (3-month moving average)

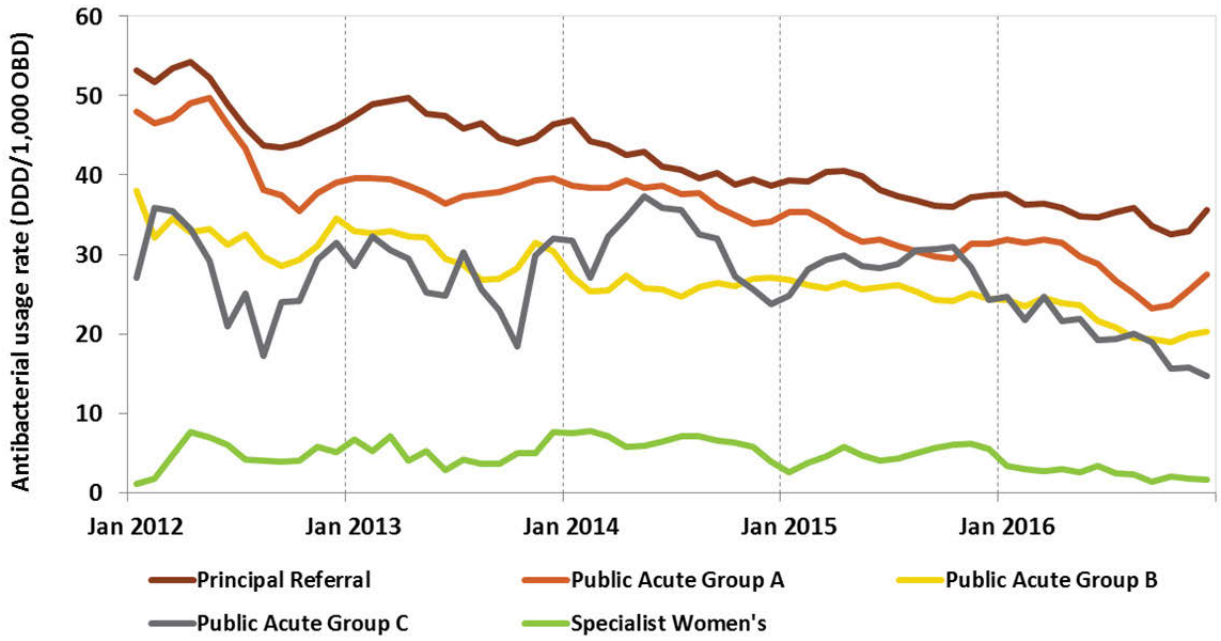


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Fluoroquinolones – ciprofloxacin, moxifloxacin, norfloxacin

Usage rates of fluoroquinolones in hospitals that contribute to NAUSP declined from 2012 to 2016 (Figure 30). However, usage rates appear to have increased in the larger hospitals with a more complex casemix since late 2016. Usage rates for Public Acute Group C Hospitals are lower than for other peer groups, and show a downward trend since late 2015. In 2016, usage rates of fluoroquinolones were similar in Public Acute Group B and C Hospitals, and minimal in Specialist Women's Hospitals.

Figure 30: Fluoroquinolone usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2012–2016 (3-month moving average)

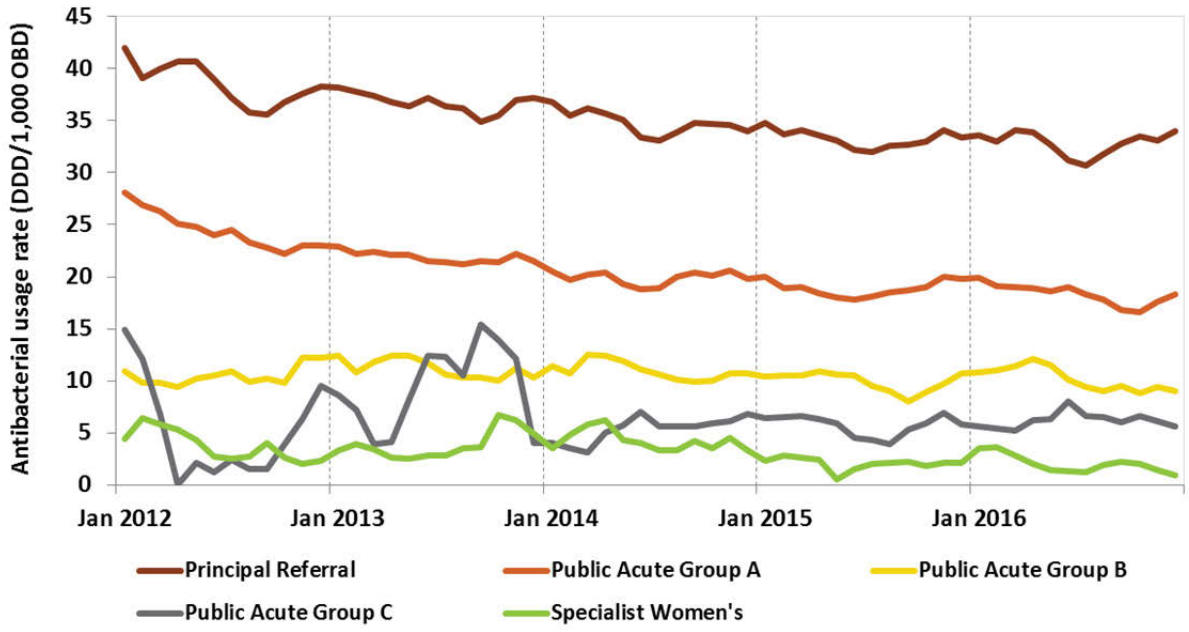


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Glycopeptides – teicoplanin, vancomycin

Usage rates of glycopeptides were highest in Principal Referral Hospitals and lowest in smaller hospitals that contributed to NAUSP in 2016, as expected for this antibacterial class with reserved indications (Figure 31).

Figure 31: Glycopeptide usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2012–2016 (3-month moving average)

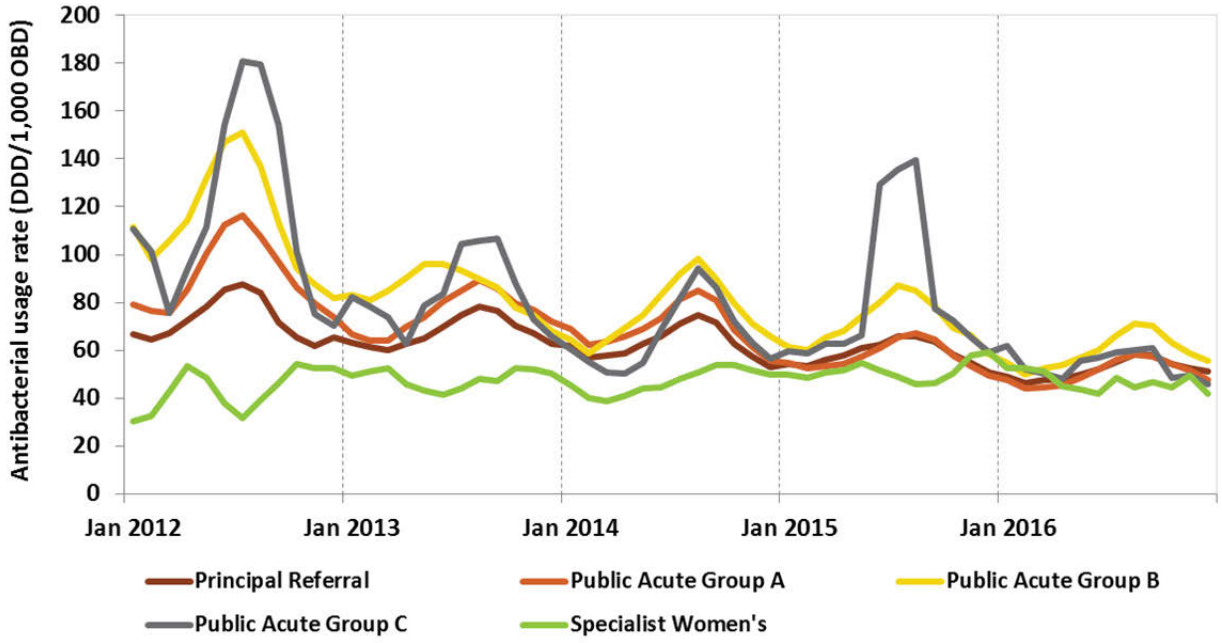


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Macrolides – azithromycin, clarithromycin, erythromycin, roxithromycin

Macrolide usage rates used to show wide seasonal variation, with highest use in the winter months (Figure 32). This is changing, possibly as a result of a switch to tetracyclines for lower respiratory tract infections as recommended in more recent versions of the national treatment guidelines. 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 32: Macrolide usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2012–2016 (3-month moving average)

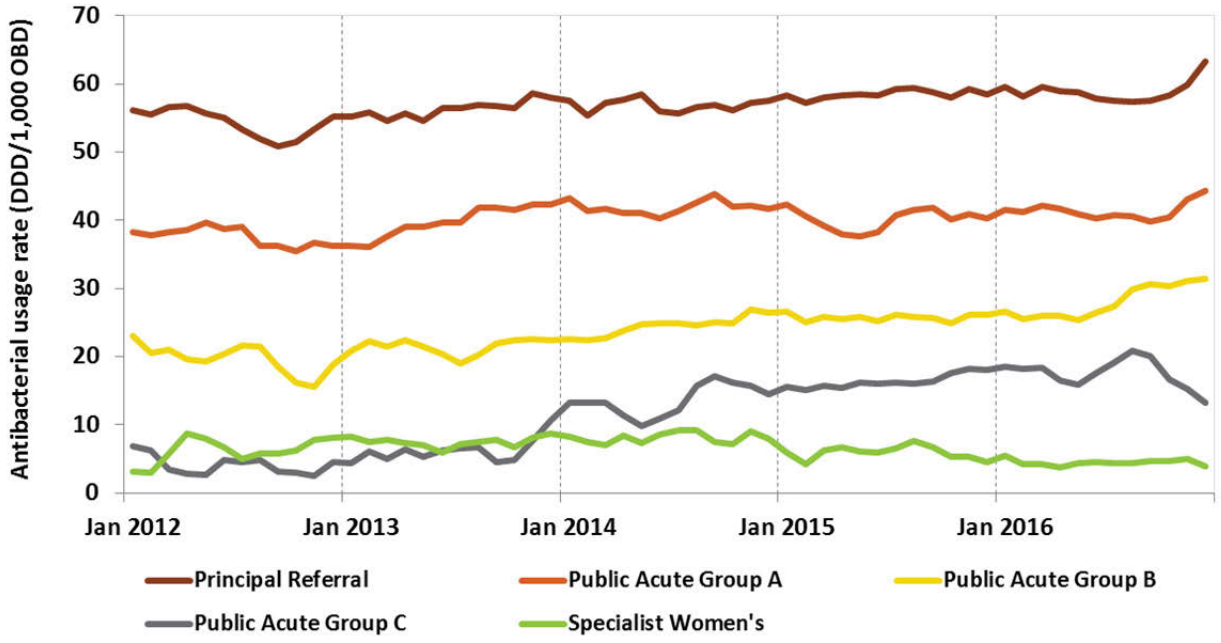


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

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 2016 (Figure 33). Because these antibacterials are generally restricted for use only in higher acuity patients, this pattern is to be expected. Use in smaller NAUSP contributor hospitals increased in 2015 and 2016. Usage rates of antipseudomonal penicillin–β-lactamase inhibitor combinations are low in Specialist Women's Hospitals.

Figure 33: Piperacillin–tazobactam and ticarcillin–clavulanate usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2012–2016 (3-month moving average)

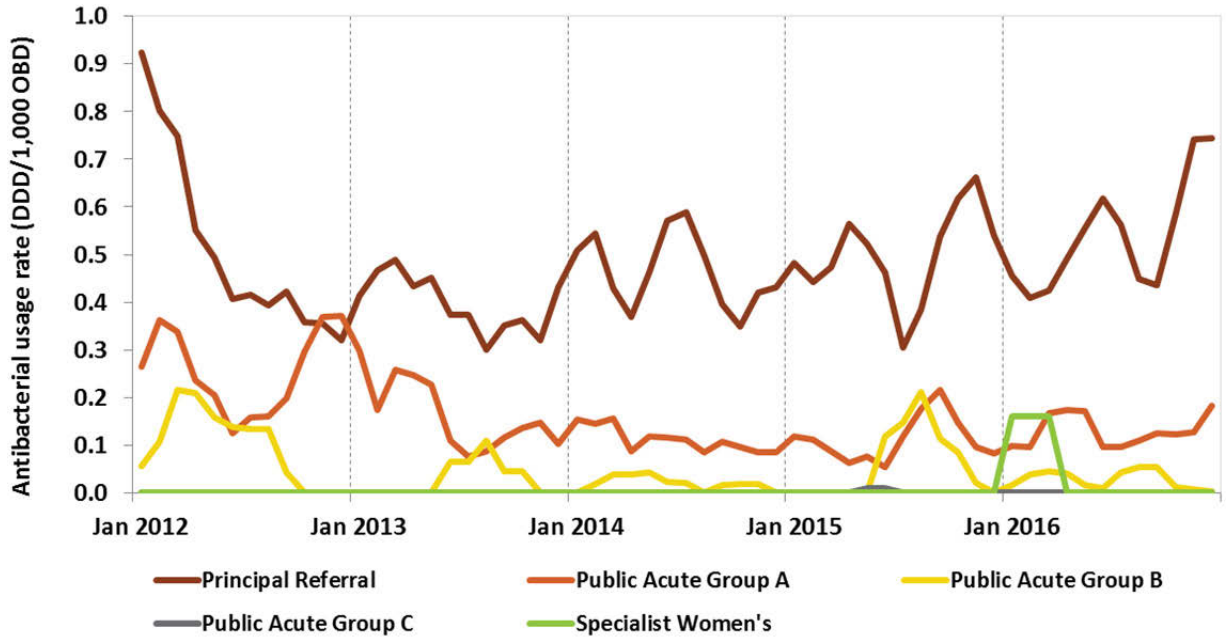


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Reserve-line antibacterials (broad spectrum) – ceftaroline, ceftazidime–avibactam, ceftolozane–tazobactam, tigecycline

These highly reserved broad-spectrum antibacterials are rarely used in Australian hospitals and usage was generally only in larger hospitals (Figure 34). In Principal Referral Hospitals, the trend in use appears to be increasing but rates remain less than 1 DDD per 1,000 OBDs.

Figure 34: Broad-spectrum reserve-line antibacterial* usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2012–2016 (3-month moving average)



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
* Ceftaroline, ceftazidime–avibactam, ceftolozane–tazobactam, tigecycline

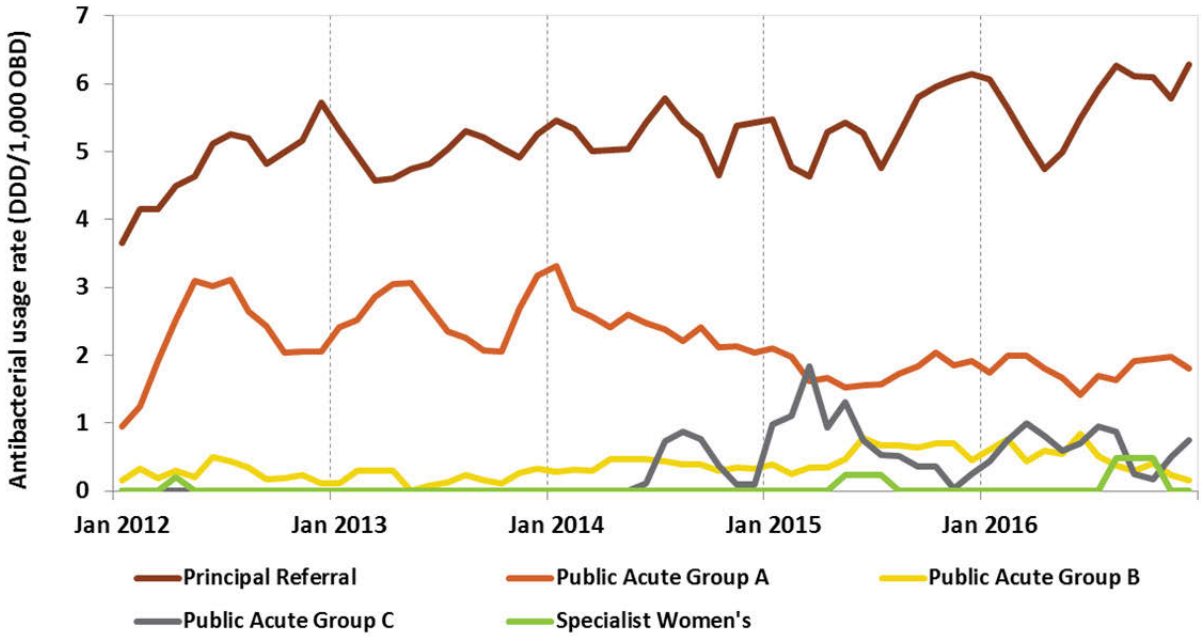
Reserve-line antibacterials (narrow spectrum) – colistin, daptomycin, linezolid, pristinamycin

Use of highly reserved narrow-spectrum antibacterials is mostly confined to Principal Referral and Public Acute Group A Hospitals that contributed to NAUSP from 2012 to 2016 (Figure 35). 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 usage rates. The average usage rate of colistin in this peer group for 2016 was 1.15 DDDs per 1,000 OBDs. The median was 0.2 DDDs per 1,000 OBDs (range 0–11.43 DDDs per 1,000 OBDs). Similarly, for daptomycin and linezolid, although average usage rates were low (2.17 and 1.52 DDDs per 1,000 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 2016.

Figure 35: Colistin, daptomycin, linezolid and pristinamycin (combined) usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2012–2016 (3-month moving average)

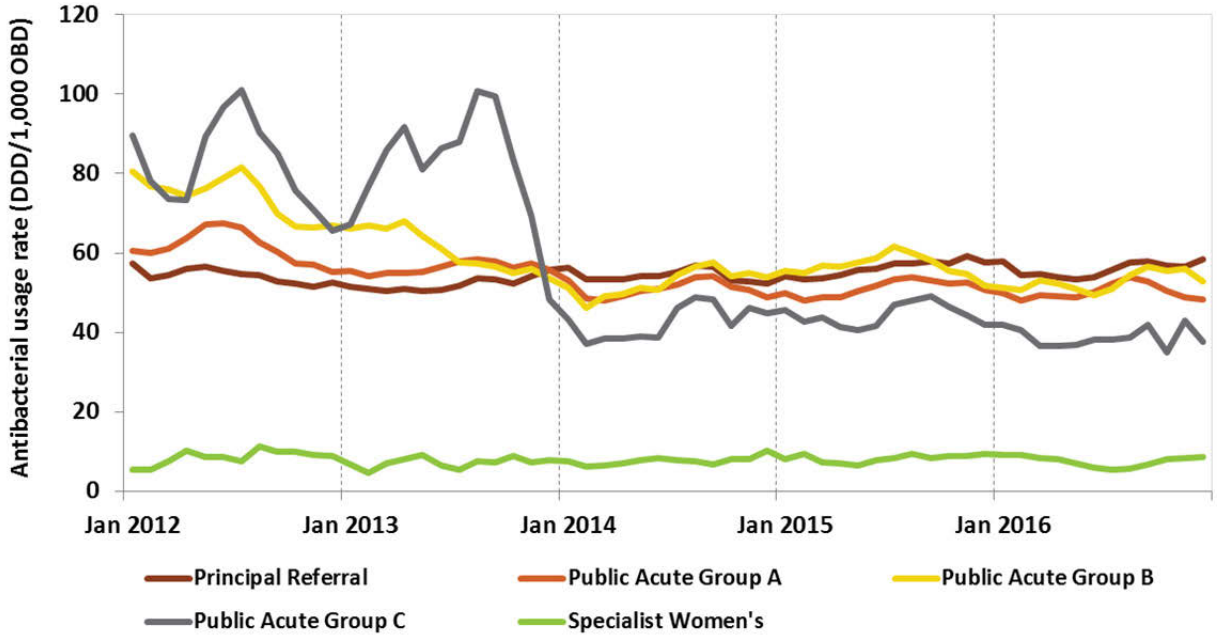


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

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

Usage rates of third- and fourth-generation cephalosporins were similar in all peer groups from 2015 to 2016 with the exception of Specialist Women's Hospitals (Figure 36). Although NAUSP data do not include any assessment of appropriateness of prescribing, in general, greater usage of broad-spectrum cephalosporins might be expected in larger hospitals with a more complex casemix. Broad-spectrum cephalosporins are generally reserved for specific indications, and in many states and territories there are formulary restrictions on prescribing. Review of hospital-level data could show whether use in facilities other than Principal Referral Hospitals was appropriate. The 2015 NAPS reported that approximately 30% of ceftriaxone prescriptions were inappropriate. The reasons most often given for inappropriateness of prescribing for respiratory tract infections were 'spectrum too broad' and 'antimicrobial not indicated'.[9]

Figure 36: Third- and fourth-generation cephalosporin usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by selected peer groups, 2012–2016 (3-month moving average)



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

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. The number of NAUSP contributor hospitals in this peer group increased from three in 2012 to 16 in 2016, and rates became more representative of this cohort from 2014.

Antifungal usage

This report is the first from NAUSP to include data on systemic antifungal agents. By way of comparison, the consumption of systemic antifungal agents in hospitals was reported to have increased in German hospitals over the decade to 2015.[15] Increased use could result in development of resistant organisms and lead to increased treatment cost. NAUSP collects data on a number of systemic antifungals, although not all hospitals provide these data. NAUSP does not collect data relating to topical antifungal use.

Antifungal usage in Australian hospitals

Tables 7 and 8 show antifungal usage rates in NAUSP hospitals and intensive care settings, respectively, where antifungal data were available. ICU usage is quadruple that in other hospital settings, reflecting that systemic antifungal agents are widely used in seriously ill patients, such as haematology and oncology patients.

Fluconazole is the most commonly used antifungal agent in NAUSP contributor hospitals, and triazole antifungals (fluconazole, itraconazole, posaconazole, voriconazole) accounted for almost 90% of total usage for the five years 2012–2016.

Echinocandins (anidulafungin, caspofungin, micafungin) accounted for 5.6% of total antifungal usage in 2016. The percentage usage of these agents has increased since 2012 when they accounted for 3.8% of total antifungal use. Anidulafungin is the most commonly used echinocandin, but the total-hospital usage rate is less than 1.2 DDDs per 1,000 OBDs. A similar pattern occurred for ICU usage. Triazole antifungals accounted for more than 80% of total ICU usage each year between 2012 and 2016. While the percentage usage of triazoles decreased over the last five years, the use of echinocandins as a percentage of all ICU usage has increased from 11% in 2012 to 15% in 2016. Anidulafungin is the most commonly used echinocandin in ICUs, and usage rates are more than 10 times those of total-hospital usage rates.

Table 7: Annual antifungal usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, 2012–2016

Antifungal	2012 (*n* = 79)	2013 (*n* = 94)	2014 (*n* = 111)	2015 (*n* = 122)	2016 (*n* = 133)
Amphotericin B (desoxycholate)	0.25	0.13	0.18	0.27	0.27
Amphotericin, lipid complex	0.02	0.06	0.02	0.00	0.00
Amphotericin, liposomal	1.05	0.92	0.97	0.80	0.60
Anidulafungin	0.28	0.46	0.83	1.11	1.16
Caspofungin	1.11	0.97	0.83	0.57	0.60
Fluconazole	23.34	24.00	22.66	20.82	19.80
Flucytosine	0.10	0.13	0.13	0.09	0.13
Griseofulvin	0.00	0.00	0.00	0.00	0.00
Itraconazole	2.31	2.02	2.40	2.13	2.44
Ketoconazole	0.50	0.35	0.15	0.12	0.04
Micafungin	0.00	0.00	0.00	0.05	0.17
Posaconazole	2.96	2.86	3.16	4.00	5.04
Terbinafine	0.66	0.53	0.59	0.67	0.75
Voriconazole	4.23	4.25	3.90	3.91	3.38
Total	**36.80**	**36.69**	**35.82**	**34.54**	**34.40**

DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Note: At the time of publication of this report, not all NAUSP contributors were able to supply antifungal data. Total number of contributors in 2012, 2013, 2014, 2015 and 2016 were 90, 118, 143, 157 and 169, respectively.

Table 8: Annual intensive care unit antifungal usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, 2012–2016

Antifungal	2012 (*n* = 43)	2013 (*n* = 50)	2014 (*n* = 52)	2015 (*n* = 58)	2016 (*n* = 62)
Amphotericin B (desoxycholate)	0.43	1.31	1.30	3.82	2.86
Amphotericin, lipid complex	0.05	0.44	0.06	0.02	0.00
Amphotericin, liposomal	5.67	4.24	3.73	4.92	2.52
Anidulafungin	4.33	5.19	10.46	12.15	12.15
Caspofungin	11.43	10.41	6.93	6.53	7.91
Fluconazole	97.01	100.72	93.37	92.90	81.79
Flucytosine	0.56	0.31	0.23	0.64	0.21
Griseofulvin	0.00	0.00	0.00	0.00	0.00
Itraconazole	5.57	3.47	6.54	7.12	8.15
Ketoconazole	0.37	0.09	0.12	0.06	0.00
Micafungin	0.00	0.00	0.00	0.48	1.39
Posaconazole	5.67	3.29	2.95	6.09	9.73
Terbinafine	0.77	0.57	0.54	0.41	1.39
Voriconazole	13.57	19.77	16.18	16.45	16.06
Total	**145.43**	**149.81**	**142.39**	**151.59**	**144.15**

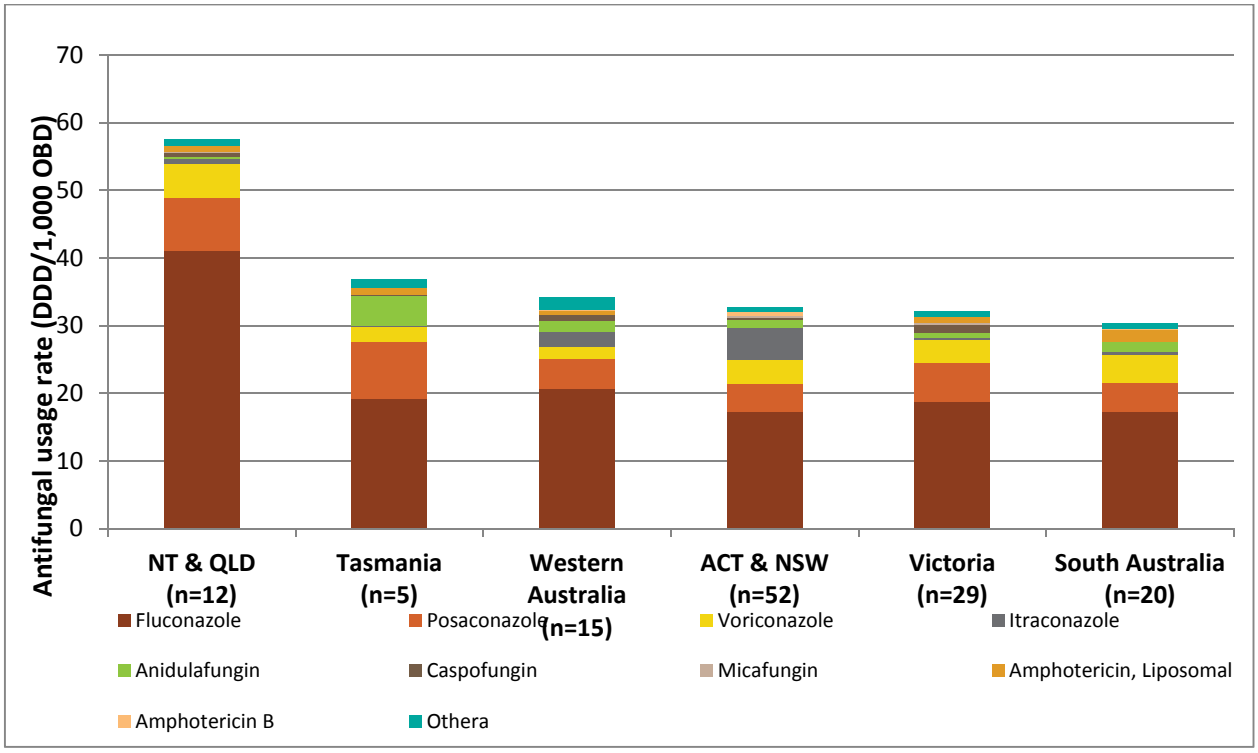
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Note: At the time of publication of this report, not all NAUSP contributors with ICUs were able to supply antifungal data. Total number of contributors in 2012, 2013, 2014, 2015 and 2016 were 55, 63, 67, 73 and 79, respectively.

Antifungal usage in Australian hospitals by state and territory

There are variations in rates of usage and agents used in states and territories (Figure 37)

Figure 37: Antifungal usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2016



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

* 'Other' comprises flucytosine, griseofulvin, ketoconazole and terbinafine. There was no reported usage of amphotericin lipid complex.

Note: Qld and NT data are made up predominantly of private hospitals' usage (eight of 12 are private hospitals). Antifungal data from 29 Queensland public hospitals were not available within the time frame for inclusion in analyses of 2016 data for this report due to technical reasons.

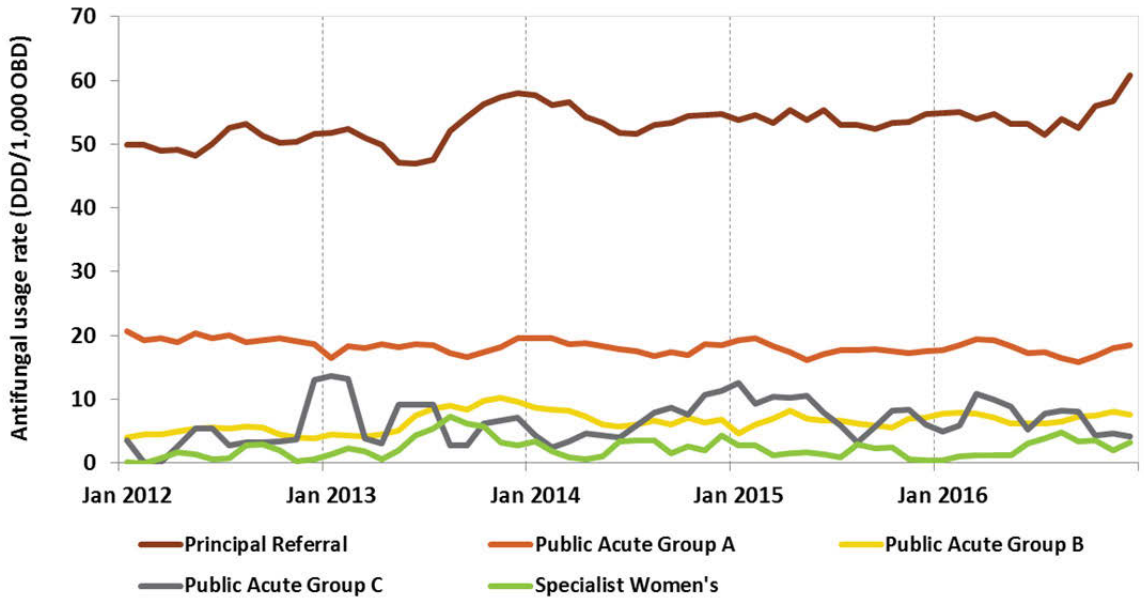
Antifungal usage in Australian hospitals by peer group

As would be expected, usage of systemic antifungals is higher in larger hospitals with a more complex casemix.

Figure 38 shows aggregated usage rates for all antifungals over the five-year period from 2012 to 2016 by AIHW peer group. As with other NAUSP analyses, private hospital data are included in the appropriate public hospital peer group due to low numbers. Triazole antifungals account for the most antifungal usage in NAUSP contributor hospitals, as illustrated by the similarities in Figures 38 and 39. Echinocandin usage is minimal in comparison; however, there is an upward trend in usage in Principal Referral Hospitals (Figure 40)

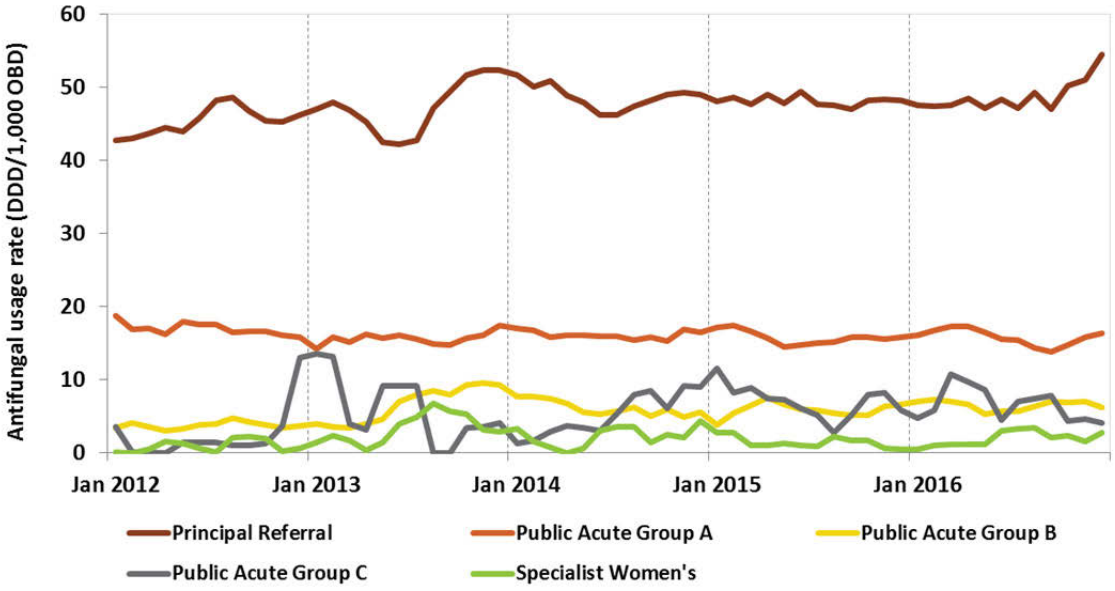
Usage of other antifungal agents is minimal – combined usage rates are less than 5 DDDs per 1,000 OBDs.

Figure 38: Systemic antifungal usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by peer group, 2012–2016 (3-month moving average)



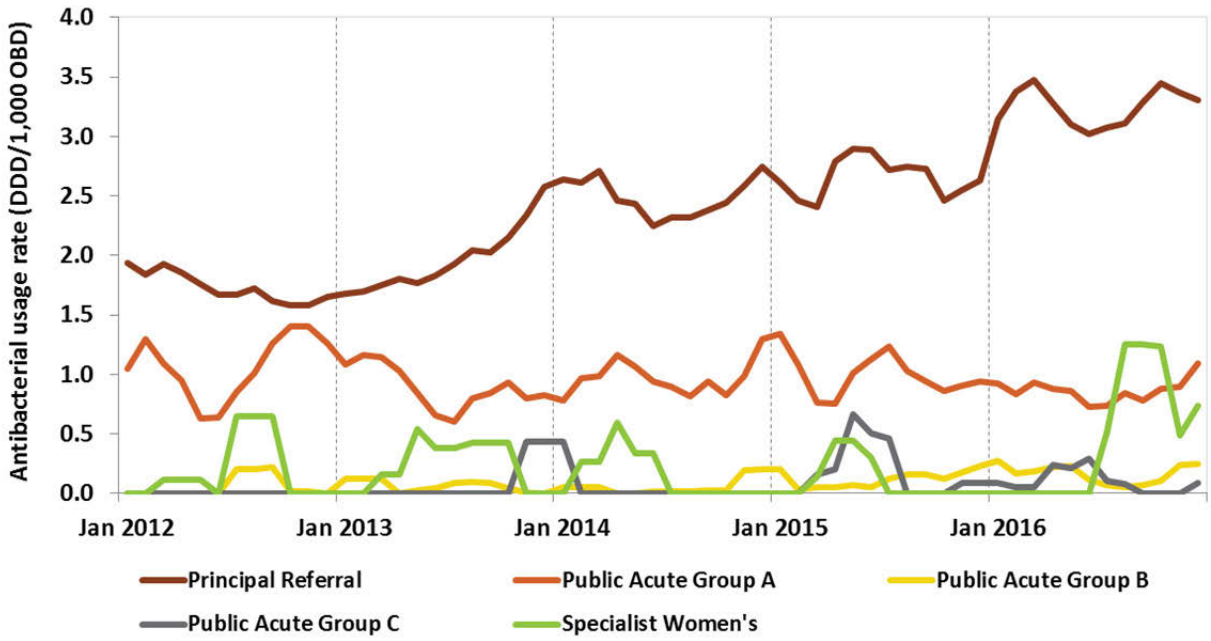
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Figure 39: Triazole systemic antifungal usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by peer group, 2012–2016 (3-month moving average)



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

Figure 40: Echinocandin antifungal usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, by peer group, 2012–2016 (3-month moving average)



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

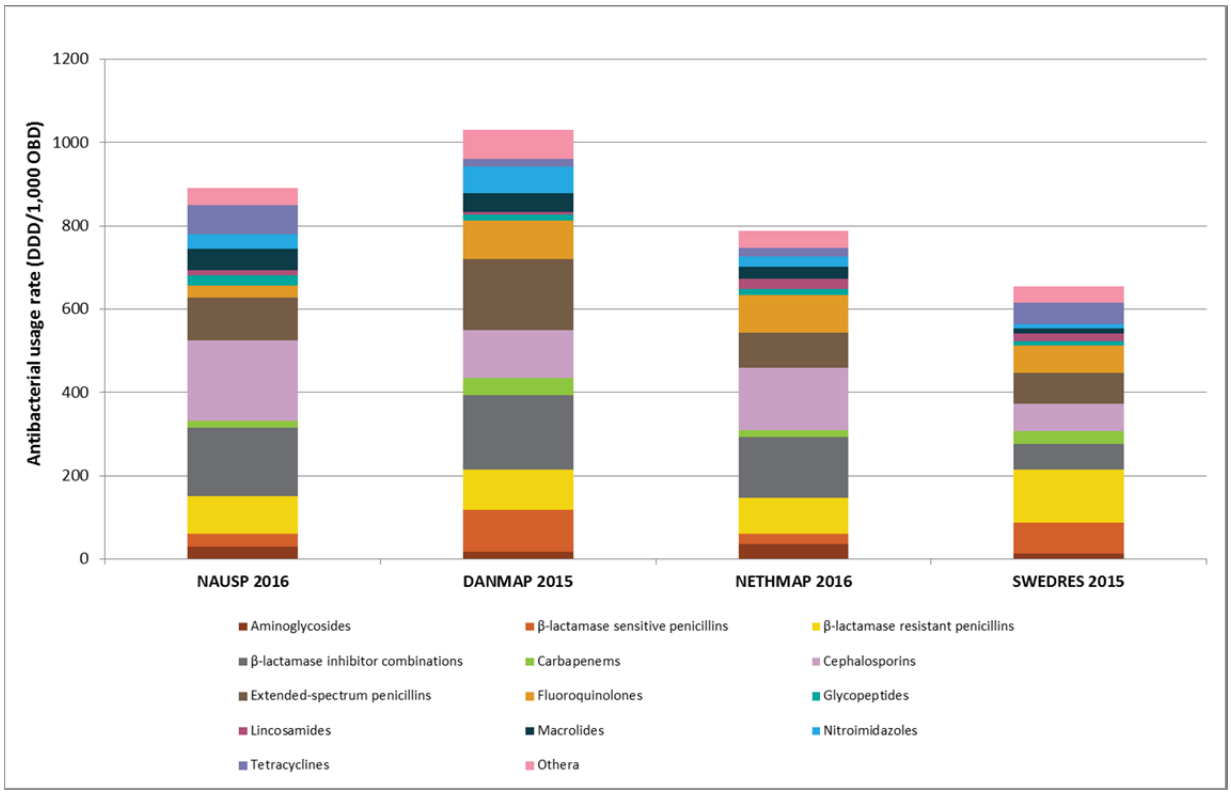
International surveillance programs and benchmarking

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 2).

Antibacterial data

Like Australia (for NAUSP), surveillance programs in Denmark (DANMAP), Sweden (SWEDRES) and the Netherlands (NethMap) use OBDs as a denominator for calculating rates of antibacterial use. Figure 41 shows antibacterial usage rates in Australian hospitals that contributed to NAUSP during 2016, compared with the most recent rates published in surveillance reports for Denmark (2015)[6], the Netherlands (2016)[8] and Sweden (2015).[7]

Figure 41: Antibacterial usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, and hospitals in Denmark, the Netherlands and Sweden (most recent available data)



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

* 'Other' comprises lipopeptides, monobactams, methenamine, nitrofurans, oxazolidinones, polymyxins, rifamycins, short-acting sulfonamides, streptogramins, steroids, trimethoprim–sulfamethoxazole and trimethoprim.

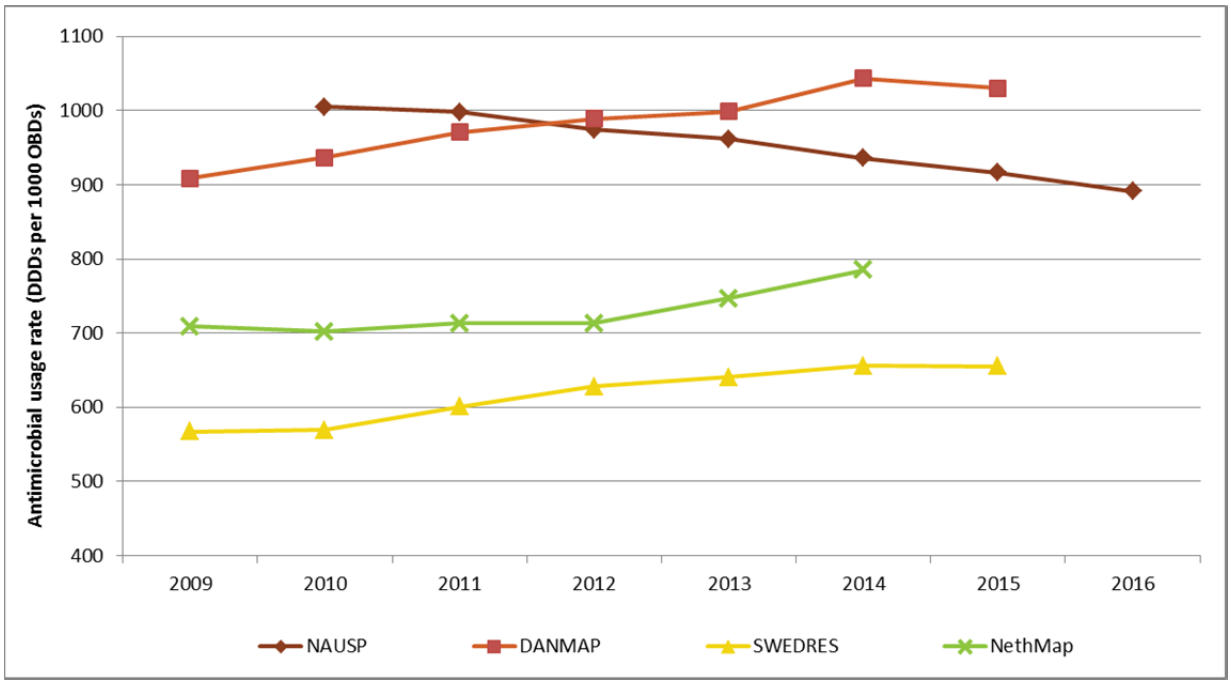
Notes: Includes Australian data from NAUSP for January to December 2016 (169 hospitals), NethMap 2016 rates (denominator data from 2014), and SWEDRES 2015 rates (denominator data from 2014).

Figure 42 shows annual usage rates of antibacterial agents in NAUSP hospitals compared with data from northern European countries. Although rates in the Netherlands are lower than in NAUSP hospitals, the current trend is upwards. Data from DANMAP show that for Denmark comparable usage rates have been greater than in Australia since 2013.

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). 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 1,000 inhabitants per day (a population measure) rather than DDDs per 1,000 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.

Figure 42: Annual hospital antimicrobial usage rates (DDD/1,000 OBD) in Australian hospitals compared to reported usage in Northern European countries, 2009–2016



DDD = defined daily dose; OBD = occupied bed day
Data source: DANMAP[6], SWEDRES[7], NethMap[8]

Antifungal data

International comparative data for usage of antifungal agents are scarce. Surveillance data from the Netherlands published in 2016 provided usage rates for systemic antimycotic agents used in university hospitals up to 2014.[8] NAUSP data for 2013 and 2014 are compared with NethMap data in Table 9.

Table 9: Antifungal usage rates (DDD/1,000 OBD) in NAUSP contributor hospitals, and hospitals in the Netherlands (most recent comparative data available)

Therapeutic group	NAUSP 2013 (*n* = 94)	NAUSP 2014 (*n* = 111)	NethMap 2013	NethMap 2014
Amphotericin B and derivatives	1.11	1.17	30.1	34.6
Triazole derivatives	33.13	32.12	62.9	71.5
Echinocandins	1.44	1.66	7.1	6.1
Ketoconazole	0.35	0.15	0.6	2.4
Other systemic antifungals	0.66	0.72	n/a	n/a
Total	**36.69**	**35.82**	**100.7**	**114.6**

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

Reasons for the variation in usage rates are unknown. Differences in prescribing policies, usual dosage ranges and in the acuity of the hospitals included in the analyses, may lead to these variations.

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. AMS governance committees also make use of aggregated data to track responses to AMS initiatives occurring at local, state or territory level, and to monitor national trends.

The NAUSP cohort continues to expand, with increased participation by private hospitals and Public Acute Group C hospitals in 2016. It is anticipated that by 2018 enough private hospitals will be contributing to NAUSP to enable benchmarking using the AIHW private hospital peer groups. This will support more accurate comparisons for all contributors, and align NAUSP categorisations with those used in AIHW publications. 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 disease services or other AMS resources.

Nationally, the aggregate usage rate fell by 2.7% from 916.5 DDDs per 1,000 OBDs in 2015 to 891.5 DDDs per 1,000 OBDs in 2016. The lower rate cannot be attributed to just the increase in participation by Public Acute Group B and C hospitals where antimicrobial usage rates would be expected to be lower than higher acuity facilities. When data for five years of continuous contribution were analysed, the decrease was still 2.2%. Following the introduction of the NSQHS Standards in 2012 and the requirement for hospitals to have an AMS program in place, AMS activities have expanded in Australian hospitals and led to decreased antimicrobial usage rates in many instances.

Average usage rates varied between states and territories (see Figures 9–14). Changes in usage rates from 2015 were minor for all states and territories except Tasmania, where a notable decline was evident – the average usage rate fell from 1,220 DDDs per 1,000 OBDs in 2015 to 898 DDDs per 1,000 OBDs in 2016.

Analyses of state and territory usage rates for the six major antibacterial classes with the greatest potential to fuel multi-drug resistance show that these classes accounted for 22% of total-hospital antimicrobial use. There were only slight variations between states and territories in 2016, and there did not appear to be a change compared with 2015.[1] Care is required when interpreting data relating to these six antibacterial classes because of a possible anomaly relating to DDDs. The DDD for piperacillin–tazobactam published by the 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 underestimation of Australia's usage rate for piperacillin–tazobactam. The published DDDs are reviewed annually by WHO; local adjustments to DDDs to reflect local prescribing recommendations have not yet been incorporated in NAUSP. An alternative metric, used by some other surveillance programs, is DDDs per 1,000 admissions (separations). Further exploration is needed to determine whether this metric would be useful in Australian hospitals.

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

Fluoroquinolone use showed a downward trend across all peer groups over the last five years. A small upturn in rates in Principal Referral and Public Acute Group A Hospitals in late 2016 will be monitored. Usage rates of third- and fourth-generation cephalosporins are similar in Principal Referral, Public Acute Group A and Public Acute Group B Hospitals, and only slightly lower in Public Acute Group C Hospitals. Possible explanations may include more generalist prescribing, less mature AMS programs, and transfer of patients to finish therapy initiated in hospitals that provide a more complex and specialised range of services.

The bar charts for state- and territory-based total usage have been designed to provide a snapshot for 2016, showing the range of use within and between peer groups. Individual hospitals and states and territories are encouraged to review their rankings in the context of these graphs. Characteristics of the local patient mix should be considered and may explain high use of particular antibacterial classes; for example, the use of glycopeptides in areas with high rates of infection with methicillin-resistant *Staphylococcus aureus*.

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

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 both institutional and local levels. 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.

Limitations of NAUSP data result from the voluntary participation in the program, and the subsequent inability to generate population-based denominator data. The current methods used by NAUSP limit international comparisons and benchmarking to some extent, as many international surveillance programs use DDDs per 1,000 inhabitants or days of therapy (DoT) as their usage measure for rate generation. (Analysis using DoTs requires access to patient-level data which is outside the scope of NAUSP data collection).

Upgrades to the NAUSP database introduced in 2017 allow contributors to submit data at a specialty level. Future reports will include data on usage in specialty areas other than ICUs. Prospective data analyses will determine those specialty areas where use of key antibacterials is high. This may help hospitals to focus resources to areas where AMS interventions are most needed.

Another limitation is that some areas of antimicrobial usage are not captured in NAUSP data. Surveillance of antimicrobial usage in paediatric settings has not been performed by NAUSP due to the DDD metric being applicable only to adults. In 2017 and 2018, methods for surveillance of paediatric use will be investigated by NAUSP, with a view to developing paediatric surveillance capability. Other settings to be considered for expansion of data collection include non-acute admitted care settings such as rehabilitation and mental health.

The significant data holdings on volume (NAUSP) and appropriateness of use (NAPS) of antimicrobials, together with increased functionality of reporting, allow Australian hospitals to combine these datasets to identify, implement and monitor targeted AMS interventions. NAUSP will continue to expand the scope of surveillance to create a robust and complementary resource to strengthen improvements in antimicrobial utilisation in Australia.

Appendix 1 Contributor information

Table A1: Hospitals contributing to the National Antimicrobial Utilisation Surveillance Program, 2016

State or territory	Hospital
New South Wales	Armidale Hospital, Auburn Hospital, Bankstown Hospital, Batemans Bay District Hospital*, Bathurst Base Hospital, Bega District Hospital, Belmont Hospital, Blacktown Hospital, Bowral Hospital, Broken Hill Base Hospital, 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, Mona Vale Hospital, Mt Druitt Hospital, Mudgee District Hospital, Muswellbrook Hospital*, Nepean Hospital, Newcastle Mater, Orange Health Service, Port Macquarie Base Hospital, Prince of Wales Hospital, Royal North Shore Hospital, Royal Prince Alfred Hospital, Ryde Hospital, Scott Memorial Hospital*, Shellharbour Hospital, Shoalhaven Hospital, St George Hospital, St Vincent's Hospital Sydney, Sutherland Hospital, Sydney Adventist Hospital*, Tamworth Hospital, The Tweed Hospital, Wagga Wagga Base Hospital, Westmead Hospital, Wollongong Hospital, Wyong Hospital
Victoria	Albury Wodonga – Albury, Albury Wodonga – Wodonga, Alfred Hospital, Angliss Hospital, Austin Hospital, Ballarat Base Hospital, Bendigo Health, Box Hill Hospital, Cabrini Hospital Brighton, Cabrini Hospital Malvern, Casey Hospital, Dandenong Hospital, Frankston Hospital, Geelong Hospital, John Fawkner Private Hospital*, Maroondah Hospital, Mercy Women's Hospital, Monash Medical Centre Clayton, Monash Moorabbin Hospital, Royal Melbourne Hospital, Sandringham Hospital, St Vincent's Hospital Melbourne, St Vincent's Private East Melbourne, St Vincent's Private Fitzroy, The Northern Hospital, Warrnambool Base Hospital, Werribee Mercy Hospital, West Gippsland Hospital, Western Health Footscray, Western Health Sunshine
Queensland	Atherton Hospital, Bundaberg Hospital, Caboolture Hospital, Cairns Base Hospital, Caloundra Health Service, Gladstone Hospital, Gold Coast Private Hospital*, Gold Coast University Hospital, Gympie Health Service, Hervey Bay Hospital, Innisfail Hospital, Ipswich Hospital, Kingaroy Hospital, Logan Hospital, Mackay Base Hospital, Mareeba Hospital, Maryborough Hospital, Mater Gladstone, Mater Hospital Brisbane, Mater Mackay, Mater Mothers' Hospital, Mater Private Hospital Brisbane, Mater Redland Private, Mater Rockhampton, Nambour General Hospital, Princess Alexandra Hospital, Queen Elizabeth 2 Jubilee Hospital, Redcliffe Hospital, Redland Hospital, Robina Hospital, Rockhampton Hospital, Royal Brisbane and Women's Hospital, St Andrew's War Memorial Hospital*, Sunshine Coast Private Hospital*, The Prince Charles Hospital, Toowoomba Hospital, Townsville Hospital, Warwick Hospital, Wesley Hospital*
South Australia	Ashford Hospital, Berri Hospital, Calvary Central Districts Hospital, Calvary North Adelaide Hospital, Calvary Wakefield Private Hospital*, Flinders Medical Centre, Flinders Private Hospital, Gawler Health Service*, Lyell McEwin Hospital*, Memorial Hospital, Modbury Hospital*, Mt Gambier Hospital, Noarlunga Hospital, Port Augusta Hospital, Port Pirie Hospital, Queen Elizabeth Hospital, Repatriation General Hospital, Royal Adelaide Hospital, St Andrew's Hospital, Whyalla Hospital, Women's and Children's Hospital
Western Australia	Albany Hospital, Armadale Health Service, Bentley Health Service*, Bunbury Regional Hospital, Busselton Health, Fiona Stanley Hospital, Fremantle Hospital, Joondalup Health Campus, King Edward Memorial Hospital, Mount Hospital*, Osborne Park Hospital, Rockingham Hospital, Royal Perth Hospital, Sir Charles Gairdner Hospital, St John of God Midland*, St John of God Murdoch, St John of God Subiaco
Tasmania	Hobart Private Hospital, Launceston General Hospital, Mersey Community Hospital, North West Regional Hospital, Royal Hobart Hospital
Northern Territory	Alice Springs Hospital, Royal Darwin Hospital
Australian Capital Territory	Calvary Public Hospital Bruce, Canberra Hospital

* Site contributed between 6 and 12 months of data for the 2016 reporting period.

Appendix 2 WHO Anatomical Therapeutic Classification and defined daily doses for antimicrobial agents included in NAUSP analyses

Table A2: Antibacterial and antifungal agents

ATC classification	Generic name	DDD (g)	Route
	ANTIBACTERIAL AGENTS		
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	Amoxicillin	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
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

ATC classification	Generic name	DDD (g)	Route
J01DI	Other cephalosporins and penems		
J01DI02	Ceftaroline	1.2	P
J01DI54	Ceftolozane and tazobactam	3	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	1.9	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
J01FG02	Quinupristin/dalfopristin	1.5	P
J01GB	Aminoglycoside antibacterials		
J01GB01	Tobramycin	0.24	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

ATC classification	Generic name	DDD (g)	Route
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
A07AA	Intestinal anti-infectives		
A07AA11	Rifaximin	0.6	O
A07AA12	Fidaxomicin	0.4	O
ANTIFUNGAL AGENTS			
J02AB, J02AC	Triazole antifungals		
J02AC01	Fluconazole	0.2	O, P
J02AC02	Itraconazole	0.2	O, P
J02AC02	Itraconazole MR	0.1	O (MR)
J02AC03	Voriconazole	0.4	O, P
J02AC04	Posaconazole	0.8	O
J02AC04	Posaconazole	0.3	P
J02AA	Polyene antifungals		
J02AA01	Amphotericin B	0.035	P
J02AA01	Liposomal amphotericin	0.21*	P
J02AA01	Amphotericin lipid complex	0.35*	P
J02AX	Echinocandins		
J02AX04	Caspofungin	0.05	P
J02AX05	Micafungin	0.1	P
J02AX06	Anidulafungin	0.1	P
OTHER ANTIFUNGALS			
J02AX01	Flucytosine	10	O, P
D01BA01	Griseofulvin	0.5	O
D01BA02	Terbinafine	0.25	O
J02AB02	Ketoconazole	0.2	O

ATC = Anatomical Therapeutic Classification; DDD = defined daily dose; Inh = inhalation; MU = Million units; O = oral; P = parenteral; R = rectal MR = Modified Release
* DDD assigned by NAUSP
Source: WHO (2017)[11]

Glossary

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.
defined daily dose	The average maintenance dose per day for an average adult for the main indication of the medicine.
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 1,000 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: $\text{Usage density rate} = \frac{\text{Number of DDDs/time period}}{\text{OBDs/time period}} \times 1{,}000$

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Acknowledgements

This report was prepared by the Infection Control Service, Public Health and Clinical Systems, SA Health, in collaboration with the Australian Commission on Safety and Quality in Health Care.

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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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