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AURA
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Antimicrobial use in Australian Hospitals

Supplement: Biennial report of the National Antimicrobial Utilisation Surveillance Program: 2017-2018

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Contents

Introduction

This Supplement to the National Antimicrobial Utilisation Surveillance Program (NAUSP) 2017–2018 Biennial Report[1] (the NAUSP Biennial Report) includes updated antibacterial usage data and five-year trends for the period 2014 to 2018. The Supplement was prepared following re-submission of usage data for 2014 and 2015 by Queensland public hospitals. Data from these hospitals were excluded from the trend analyses presented in the NAUSP Biennial Report due to anomalies in the data validation process.

Antimicrobial usage rates presented in this Supplement were calculated using the new defined daily dose (DDD) values introduced by the World Health Organization on 1 January 2019. This means the data presented are not directly comparable with data reported in previous NAUSP reports. The re-analysis of usage rates using the new DDD values has resulted in substantial changes in the total reported usage rates for some antibacterial classes, including carbapenems, extended-spectrum penicillins, fourth-generation cephalosporins and polymyxins. However, longitudinal trends are comparable, as are usage rates for antimicrobials with unchanged DDD values.

Compared to other states and territories, between 2014 and 2018 in Queensland and the Northern Territory:

- Meropenem use was generally higher
- Ciprofloxacin use was generally lower
- Doxycycline use increased; however, there were seasonal variations, with higher use in winter.

Patient safety issues relating to the findings presented in this Supplement were identified in the NAUSP Biennial Report and include:

- Variation in antimicrobial usage between states and territories, across multiple antimicrobial classes, including classes for which access is usually restricted in hospitals – this will require review at a local level to identify opportunities for improvement
- Sustained increases in the use of broad-spectrum third- and fourth-generation cephalosporins since the resumption of normal piperacillin–tazobactam supply, along with increased fluoroquinolone use in smaller hospitals in 2017 and 2018, have the potential to contribute to increased antimicrobial resistance in gram-negative organisms
- Increases in total antimicrobial use were more pronounced in smaller hospitals (Public Acute Group B and C) compared to larger hospitals (Public Acute Group A and Principal Referral) contributing to NAUSP
- A clear upward trend in the use of last-line antimicrobials during 2017 and 2018.

The NAUSP is a long-term program partner of the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System. The Australian Commission on Safety and Quality in Health Care (the Commission) coordinates AURA with funding provided by the Australian Government Department of Health and states and territories. 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, consistent with the National Antimicrobial Resistance Strategy.[2]

Methods

A brief overview of the methods used for this Supplement is provided below. Additional details on data definitions and analytic methodology are provided in the NAUSP Biennial Report.[1]

Data contributions

Australian public and private hospitals contribute data voluntarily to NAUSP. Hospitals must have submitted at least six months of data, validated to be compliant with NAUSP definitions, for their data to be included in the analyses.

The Australian Institute of Health and Welfare (AIHW) peer groups are used to categorise public and private hospitals for comparative analyses of data submitted to NAUSP.[3] Hospital peer groupings include similar hospitals based on complexity of service delivery characteristics, allowing benchmarking within peer groups, or comparisons between different peer groups.[4]

The AIHW peer group criteria were amended in November 2015 to include private hospital peer groups. Historically, private hospitals have been assigned by NAUSP to an appropriate AIHW public hospital peer group for analyses. This convention will continue until private hospital representation increases sufficiently to allow reporting by the AIHW private hospital peer groups. De-identified private hospital data have been included in intrastate usage rate analyses and in aggregated statewide and peer group analyses.

Data elements

Pharmacy departments of NAUSP contributor hospitals supply aggregated monthly antimicrobial utilisation data, based on dispensing and distribution reports to clinical departments or wards for inpatient use. Denominator data are collected on a monthly basis in the form of occupied bed days (OBDs) for acute adult inpatient wards.

Each contributing hospital is assigned a unique code by NAUSP. Contributor codes allow de-identified comparative usage rates to be reported and enable hospitals to benchmark their usage against other hospitals in similar peer groups. All hospitals currently contributing data to NAUSP were issued with a new contributor code on 1 January 2020.

Data quality

Each contributing site is responsible for the accuracy of antimicrobial usage data submitted to NAUSP, including compliance with NAUSP data definitions.[5] Alerts are generated automatically during the data submission process if quantities fall outside expected ranges. This enables validation of numerator data at an early stage of the data submission process.

NAUSP also performs periodic quality assurance processes to validate the accuracy and integrity of data uploaded to the portal.[6] The NAUSP team notifies contributors if data anomalies are identified or if resubmission of data is required.

Measurement of usage rates

Antimicrobial surveillance data are reported by NAUSP as a standardised usage density rate on a monthly basis. Usage rates are only calculated for inpatient use, using occupied bed days (OBDs) as the denominator. Consumption data submitted to NAUSP is aggregated into the total number of grams used each month for each individual antimicrobial.

Antimicrobial usage is then converted from total grams used into the Defined Daily Dose (DDD) metric assigned for each antimicrobial by the WHO. DDD values are based on "the assumed average maintenance dose per day for the main indication in adults".[7] One limitation of the DDD as a consumption metric is that for some antimicrobials, the DDD does not reflect the usual daily doses used in Australian clinical practice.

DDDs are reviewed by the WHO annually, as dosing recommendations change over time and may no longer correlate with DDD values. On 1 January 2019, new increased DDD values were assigned to nine antimicrobials (Table 1).

Table 1: World Health Organization changes to defined daily dose values from 1 January 2019

Antibacterial	Anatomical Therapeutic Chemical Classification	Route of administration	DDD* prior to January 2019	DDD* from January 2019
Amoxicillin	J01CA04	Oral	1g	1.5g
Amoxicillin	J01CA05	Parenteral	1g	3g
Amoxicillin with clavulanic acid	J01CR02	Oral	1g	1.5g
Ampicillin	J01CA01	Parenteral	2g	6g
Ampicillin with sulbactam	J01CR01	Parenteral	2g	6g
Cefepime	J01DE01	Parenteral	2g	4g
Ciprofloxacin	J01MA02	Parenteral	0.5g	0.8g
Colistin	J01XB01	Parenteral	0.1g (3MU)	0.3g (9MU)
Meropenem	J01DH02	Parenteral	2g	3g

* DDD = defined daily dose
Note: The antimicrobial utilisation rates included in the NAUSP Biennial Report were calculated using 2018 DDD values. Utilisation rates in this Supplement have been calculated using the DDD values as at January 2019.8

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 per 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 data for most states and territories).
- Median: The middle value of individual hospitals' usage rates.

Limitations and considerations for interpretation of data

Due to the WHO changes to DDDs, some figures in this Supplement are not directly comparable with figures in the NAUSP Biennial Report or with previous NAUSP and AURA publications. See Box 2 for examples of the impact of these changes between the two reports related to this revision.

In addition to the changes to DDD values (Table 1), care is required when interpreting NAUSP data because of possible anomalies relating to DDD definitions for other antimicrobials. For example, the DDD for parenteral flucloxacillin published by the WHO is 2 grams. This DDD does not reflect the Australian setting, where doses of 8 grams per day are routinely used (2 grams, four times per day).[9] This may contribute to an overestimation of comparative daily usage rates for β–lactamase-resistant penicillins in Australia compared to other antimicrobials. Other examples of discrepancies between WHO DDDs and commonly used Australian daily doses are:

- Cefazolin – doses of 2 grams three times per day are recommended for a range of indications, however the WHO DDD is 3 grams
- Vancomycin – doses in clinical practice often exceed the WHO DDD of 2 grams.[8]

The data presented in this Supplement are correct at the time of writing, and reflect usage rates based on data on antibacterial and antifungal quantities and OBDs supplied by individual contributors to NAUSP.

There may be minor discrepancies compared with previous NAUSP reports, because of retrospective data submission by contributor hospitals or inclusion of data from hospitals that were excluded from previous reports due to data validity issues; this includes data for Queensland public hospitals for 2017 and 2018.

Further details on data limitations, inclusions and exclusions, and interpretation of NAUSP data are included the NAUSP Biennial Report.[1]

Box 2: Impact of WHO DDD definition revisions on reported usage

Because of changes to the WHO DDDs from 1 January 2019 (see Table 1), reported total-hospital antibacterial usage rates varied by 10.4% and 10.7% compared to the NAUSP Biennial Report for 2017 and 2018, respectively.

Changes to the DDDs for extended-spectrum penicillins and β-lactamase inhibitor combinations have driven the majority of the changes in calculated rates due to their large contribution to overall use in Australian hospitals. Reported DDD values for three extended-spectrum penicillins (oral amoxicillin, parenteral amoxicillin, and ampicillin), decreased by 50.7% using the new DDD values; this reduced the reported total aggregate usage rates by 52.8 DDDs per 1,000 OBDs (104.1 DDDs per 1,000 OBDs to 51.3 DDDs per 1,000 OBDs [Table 4]).

Reductions in reported usage for other antimicrobials such as carbapenems and fourth-generation cephalosporins, although large in comparison to previously reported usage, have relatively smaller impacts on changes in reported overall aggregate total hospital usage. This is because they are used less frequently than other antimicrobials. The new DDD value for cefepime (now 4 grams compared to 2 grams) reduced usage rates for fourth-generation cephalosporins by 49.5%, and reduced aggregate usage by 5.5 DDDs per 1,000 OBDs (5.6 DDDs per 1,000 OBDs from 11.1 DDDs per 1,000 OBDs).

Other reductions in usage rates for antibacterial classes included a decrease of:

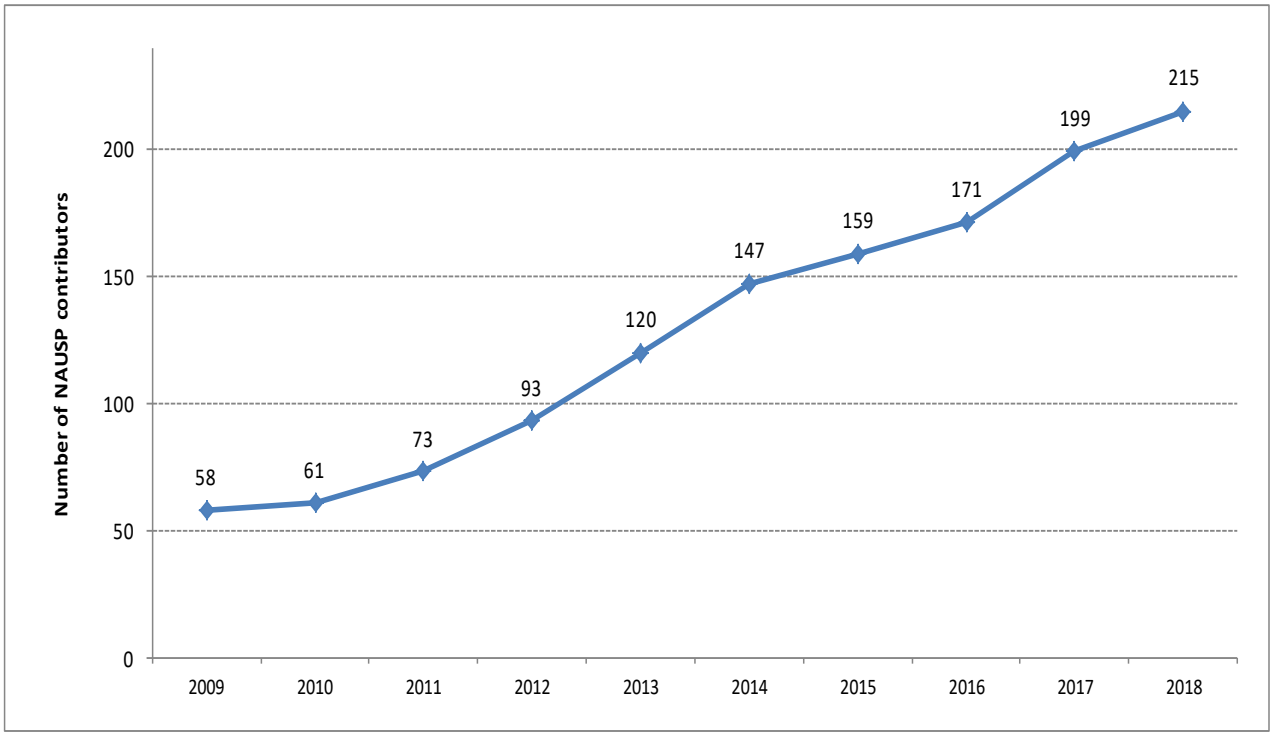
- 22.9% for β-lactamase inhibitor combinations
- 19.9% for fluoroquinolones
- 25% for polymixin (from 0.4 DDDs per 1,000 OBDs to 0.3 DDDs per 1,000 OBDs).

Findings

Contributing hospitals

All Australian states and territories have been represented in NAUSP since 2012. Figure 1 shows the growth in the number of hospitals participating in NAUSP from 2009 to 2018.

Figure 1: Number of public and private hospitals that have participated in NAUSP, 2009–2018



Note: The numbers shown on this chart reflect the number of hospitals registered to participate in NAUSP. As not all contributor hospitals could provide validated data for this Supplement, some contributors' data were excluded from some or all of the analyses.

Tables 2 and 3 provide information on the cohort of hospitals included in the analyses for 2017 and 2018, respectively. See Appendix 1 for a list of all contributors included in the analyses.

Data from 167 public and 38 private Australian hospitals are included in the analyses in this Supplement. Of the 32 Queensland and Northern Territory hospitals that contributed to NAUSP in 2014 and 2015, data from nine Queensland hospitals are not included in the state and territory comparative longitudinal trend analyses, as they did not resubmit validated data by 31 December 2019. These include two Principal Referral hospitals, four Public Acute Group A hospitals, one Public Acute Group B hospital and two Public Acute Group C hospitals.

Table 2. Number and percentage representation of hospitals included in the NAUSP cohort for analyses, by peer group* and state and territory, 2017

State	Principal Referral		Public Acute						Private Acute								Specialist Women's		Other§	Total
			Group A		Group B		Group C		Group A		Group B		Group C		Group D					
	No.	%†	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	No.
NSW/ACT	12	100	23	100	15	88	12	29	1	50	5	33	1	6	0	0	0	0	0	**69**
Vic	6	100	13	81	7	78	0	0	1	17	1	11	2	15	0	0	1	50	0	**31**
Qld/NT	7	100	13	100	7	88	7	26	4	44	1	20	4	33	1	8	1	100	1	**46**
SA	2	100	3	75	4	100	4	18	2	100	4	100	0	0	1	8	1	100	0	**21**
WA	3	100	5	100	3	60	2	13	1	50	2	67	1	33	0	0	1	100	1	**19**
Tas	1	100	2	100	1	100	0	0	1	100	0	0	1	33	0	0	0	0	0	**6**
Total	31	100	59	94	37	84	25	18	10	45	13	36	9	18	2	3	4	67	2	**192**

* Based on AIHW criteria

† Percentages represent proportion of hospitals in each peer group contributing to NAUSP.

§ Other includes one public un-peered hospital and one private mixed sub- &non-acute hospital

Table 3. Number and percentage representation of hospitals included in the NAUSP cohort for analyses, by peer group* and state and territory, 2018

State	Principal Referral		Public Acute						Private Acute								Specialist Women's		Other§	Total
			Group A		Group B		Group C		Group A		Group B		Group C		Group D					
	No.	%†	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	No.
NSW/ACT	12	100	23	100	15	88	14	34	1	50	5	33	1	6	0	0	0	0	0	**71**
Vic	6	100	13	81	7	78	0	0	1	17	2	22	2	15	0	0	1	50	2	**34**
Qld/NT	7	100	13	100	7	88	7	26	4	44	1	20	4	33	1	8	1	100	1	**46**
SA	2	100	3	75	4	100	4	18	2	100	4	100	0	0	1	8	1	100	0	**21**
WA	3	100	5	100	4	80	9	56	1	50	2	67	1	33	0	0	1	100	1	**27**
Tas	1	100	2	100	1	100	0	0	1	100	0	0	1	33	0	0	0	0	0	**6**
Total	31	100	59	94	38	86	34	24	10	45	14	39	9	18	2	3	4	67	4	**205**

* Based on AIHW criteria

† Percentages represent proportion of hospitals in each peer group contributing to NAUSP.

§ Other includes one public un-peered hospital, one private mixed sub- & non-acute hospital and two private other acute specialised hospitals.

Annual usage rates for all antibacterial classes

Table 4 provides the annual total-hospital antibacterial usage rates in NAUSP contributor hospitals for the years 2014 to 2018. The changes to the WHO DDD values for a number of antimicrobials (Table 1 and Box 2) resulted in an overall reduction in the annual total-hospital antibacterial usage rates compared with those previously reported.

The aggregate total-hospital antibacterial usage rate for all NAUSP contributor hospitals was 857.4 DDDs per 1,000 OBDs in 2018 and 861.2 DDDs per 1,000 OBDs in 2017. Despite the changes in overall calculated usage due to the new DDD values, the usage trends from 2016 to 2018 are similar to those reported previously. The proportional contribution of antibacterials to aggregate use was similar across years (Figure 2). Revised annual aggregate total-hospital antibacterial usage decreased by 1.8% between 2014 and 2016, and increased to 2014 levels in 2018 (Figure 3a).

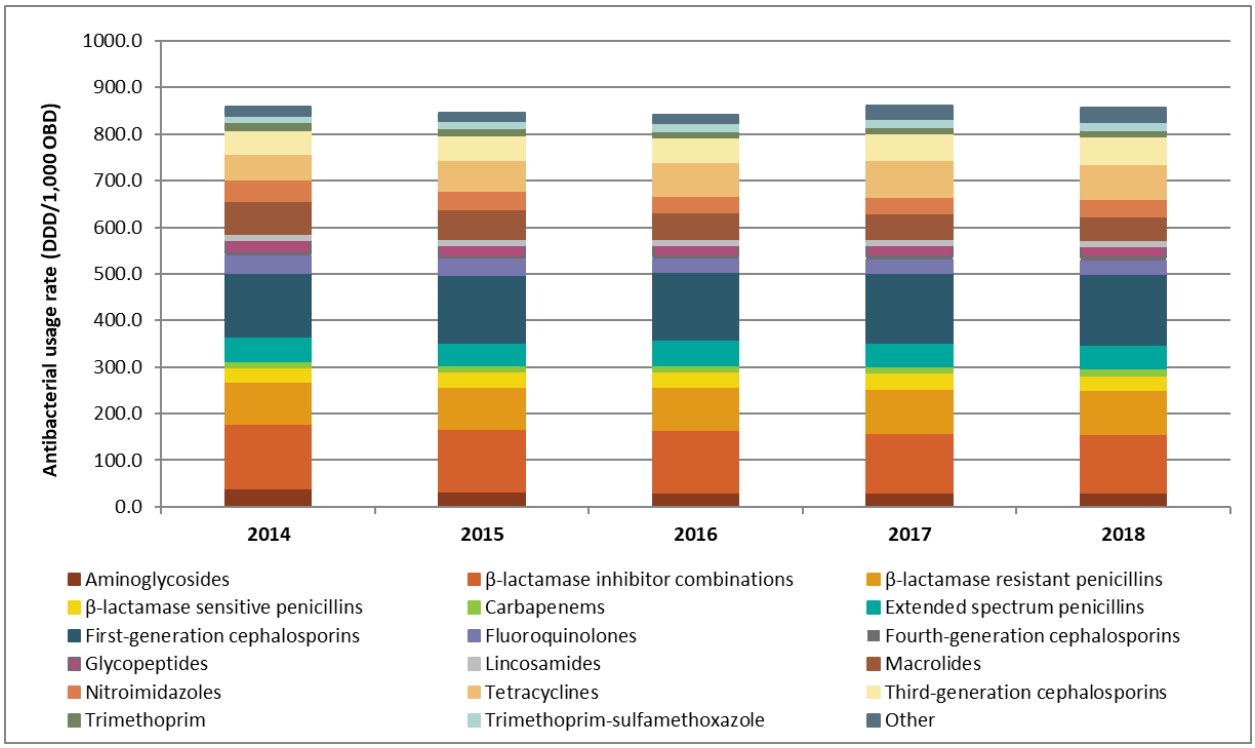
Trends varied for specific antibacterial agents (Figure 3b-f). From 2016 to 2018, there were decreases in usage rates for β-lactamase inhibitor combinations, fluoroquinolones, macrolides and trimethoprim (6.7%, 3.8%, 9.0% and 12.7% respectively - see Table 4.) Over the same period, there were large increases in the usage of many broad-spectrum antibacterials, including fourth-generation cephalosporins (85.6%), other antibacterials (72.1%), other cephalosporins and penems (both 59.8%), streptogramins (20.8%), and carbapenems (8.5%). Some of these changes are likely attributable to β-lactamase inhibitor combination shortages over this time period. Increases were also observed for other more commonly used antimicrobials, including trimethoprim–sulfamethoxazole (8.6%), third-generation cephalosporins (15.8%) and second-generation cephalosporins (25.2%). The proportional contribution of antibacterials to aggregate use was fairly constant (Figure 3).

Table 4: Annual total-hospital antibacterial usage rates (DDDs/1,000 OBDs) in NAUSP contributor hospitals, by antibacterial class, 2014–2018

Antibacterial (WHO) classification	2014 (n = 132)	2015 (n = 145)	2016 (n = 173)	2017 (n = 192)	2018 (n = 205)	% change 2014 – 18	% change 2016 – 18
Alimentary antibiotics*				8.1	8.7	n/a	n/a
Aminoglycosides	38.7	32.4	31.0	29.8	30.9	-20.2	-0.3
Amphenicols	0.0	0.0	0.0	0.0	0.0	0.0	0.0
β-lactamase inhibitor combinations	138.8	135.4	133.3	128.6	124.4	-10.4	-6.7
β-lactamase resistant penicillins	91.8	89.2	93.0	94.0	95.0	3.5	2.2
β-lactamase sensitive penicillins	30.1	34.4	34.1	35.1	32.4	7.6	-5.0
Carbapenems	13.0	12.6	13.0	13.3	14.1	8.3	8.5
Extended spectrum penicillins	52.1	48.7	53.6	52.0	51.3	-1.5	-4.3
First-generation cephalosporins	137.9	145.4	145.5	148.4	152.1	10.3	4.5
Fluoroquinolones	37.9	33.7	29.9	30.1	28.8	-24.0	-3.7
Fourth-generation cephalosporins	3.0	3.1	3.0	5.7	5.6	86.7	86.7
Glycopeptides	28.3	26.4	26.1	25.5	25.6	-9.5	-1.9
Lincosamides	14.4	13.1	13.0	13.3	13.2	-8.3	1.5
Macrolides	70.8	63.2	55.8	53.9	50.8	-28.2	-9.0
Monobactams	0.3	0.2	0.4	0.3	0.4	33.3	0.0
Nitrofurans	0.9	1.0	1.2	1.4	1.4	55.6	16.7
Nitroimidazoles (metronidazole and tinidazole)	44.4	41.3	36.9	35.2	36.3	-18.2	-1.6
Other antibacterials (linezolid and daptomycin)	2.8	2.7	2.8	3.5	4.8	71.4	71.4
Other cephalosporins and penems (ceftaroline, ceftolozane–tazobactam)	0.1	0.1	0.1	0.1	0.2	100	100
Polymyxins	0.4	0.5	0.4	0.4	0.3	-25.0	-25.0
Rifamycins	6.4	6.0	5.5	5.3	5.0	-21.9	-9.1
Second-generation cephalosporins	5.6	6.5	7.0	8.4	8.7	55.4	24.3
Steroids (fusidic acid)	1.5	1.2	1.1	1.0	0.8	-46.7	-27.3
Streptogramins	0.5	0.3	0.4	0.4	0.4	-20.0	0.0
Streptomycins	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sulfonamide & trimethoprim combinations	14.6	15.6	16.5	17.6	17.9	22.6	8.5
Tetracyclines	55.1	65.8	72.5	79.8	75.9	37.7	4.7
Third-generation cephalosporins	51.5	52.1	51.5	56.2	59.6	15.7	15.7
Trimethoprim	16.9	15.8	14.7	13.7	12.8	-24.3	-12.9
Grand Total	**857.9**	**846.7**	**842.3**	**861.1**	**857.4**	**-0.0**	**1.8**

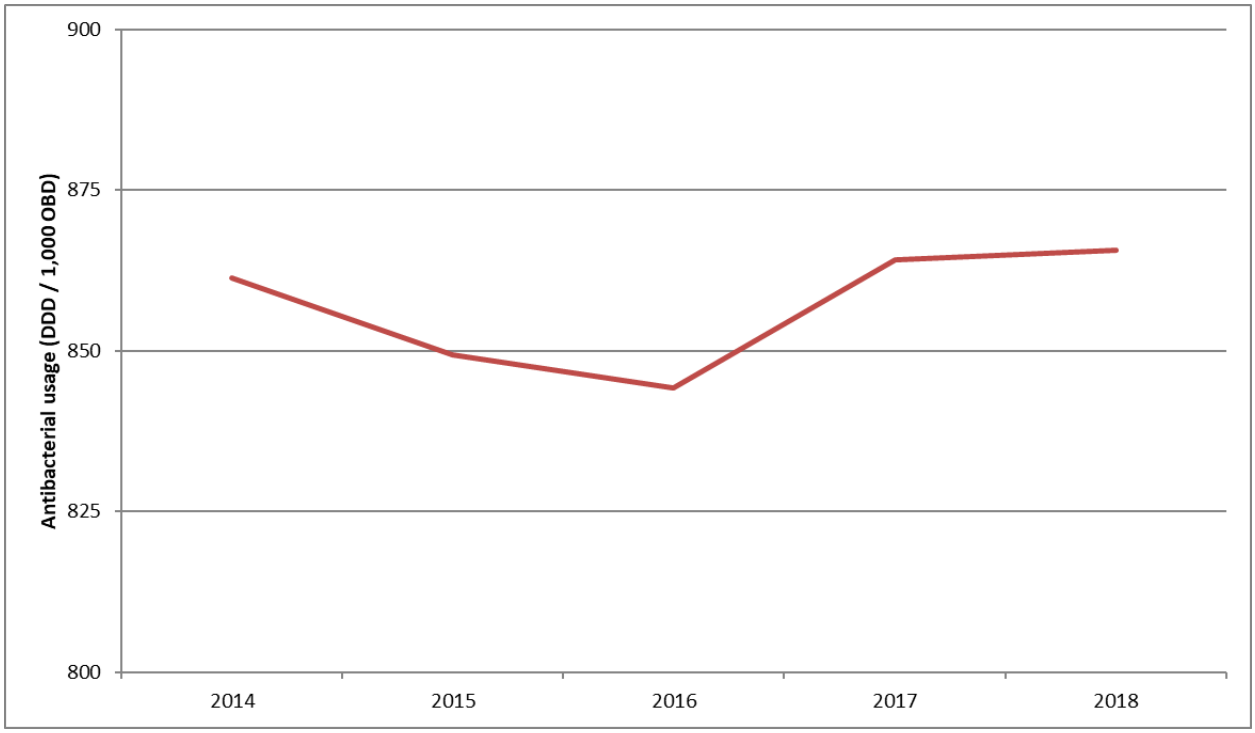
Notes: Rates (DDD/1,000 OBD) may vary slightly from previous reports as a result of retrospective usage data adjustments, the number of hospitals contributing to aggregate data and changes to DDD values assigned by the WHO.
* Alimentary antibiotics were not collected by NAUSP prior to 2017

Figure 2: Annual total-hospital antibacterial usage rates (DDDs/1,000 OBDs) in NAUSP contributor hospitals, by antibacterial class, 2014–2018



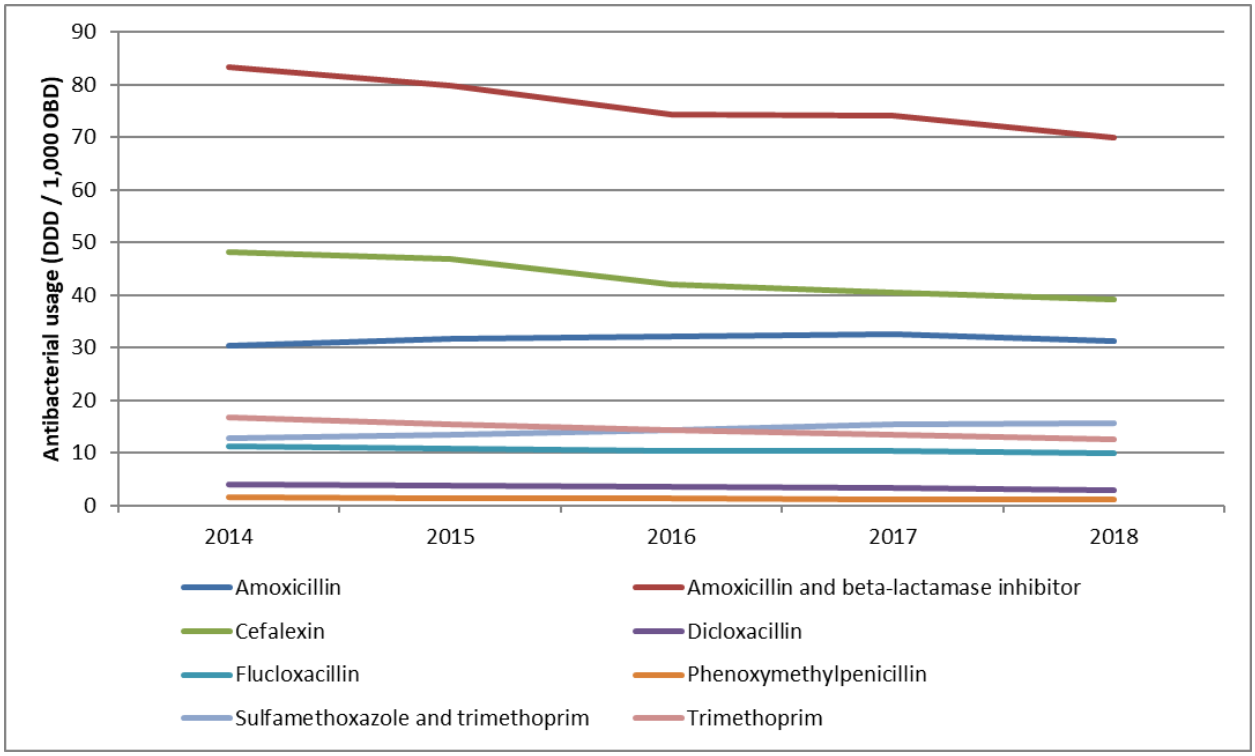
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Figure 3a: Annual aggregate total-hospital antibacterial usage rates in NAUSP contributor hospitals, 2014–2018



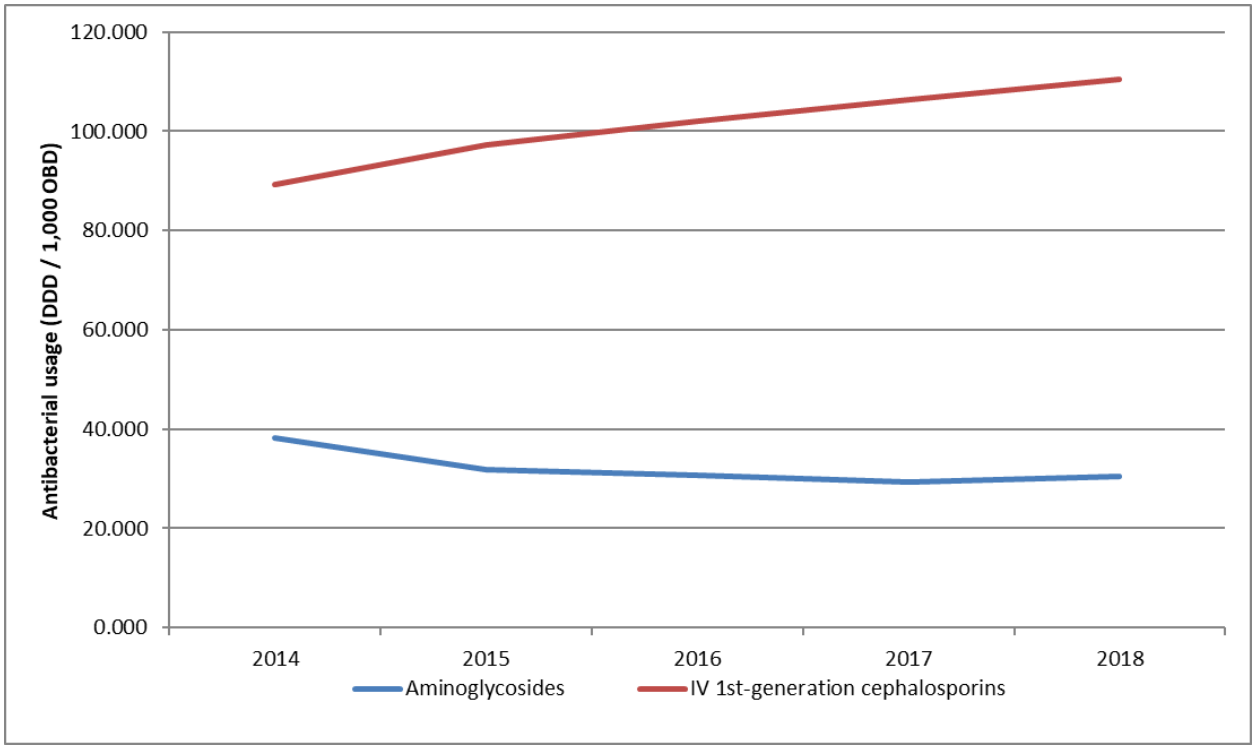
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Note: y-axis truncated to aid visibility of trend

Figure 3b: Annual aggregate total-hospital usage rates for selected commonly used oral antibacterials in NAUSP contributor hospitals, 2014–2018



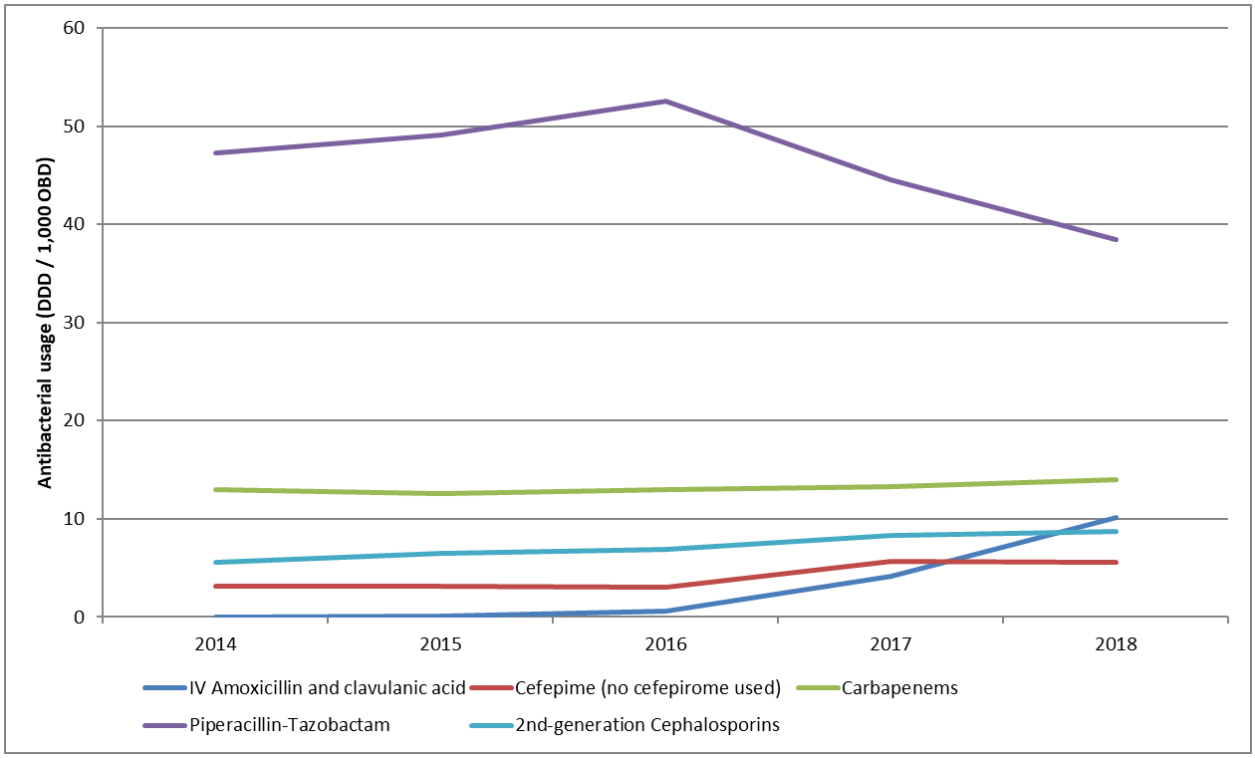
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Figure 3c: Annual aggregate total-hospital usage rates for selected other antibacterial classes in NAUSP contributor hospitals, 2014–2018



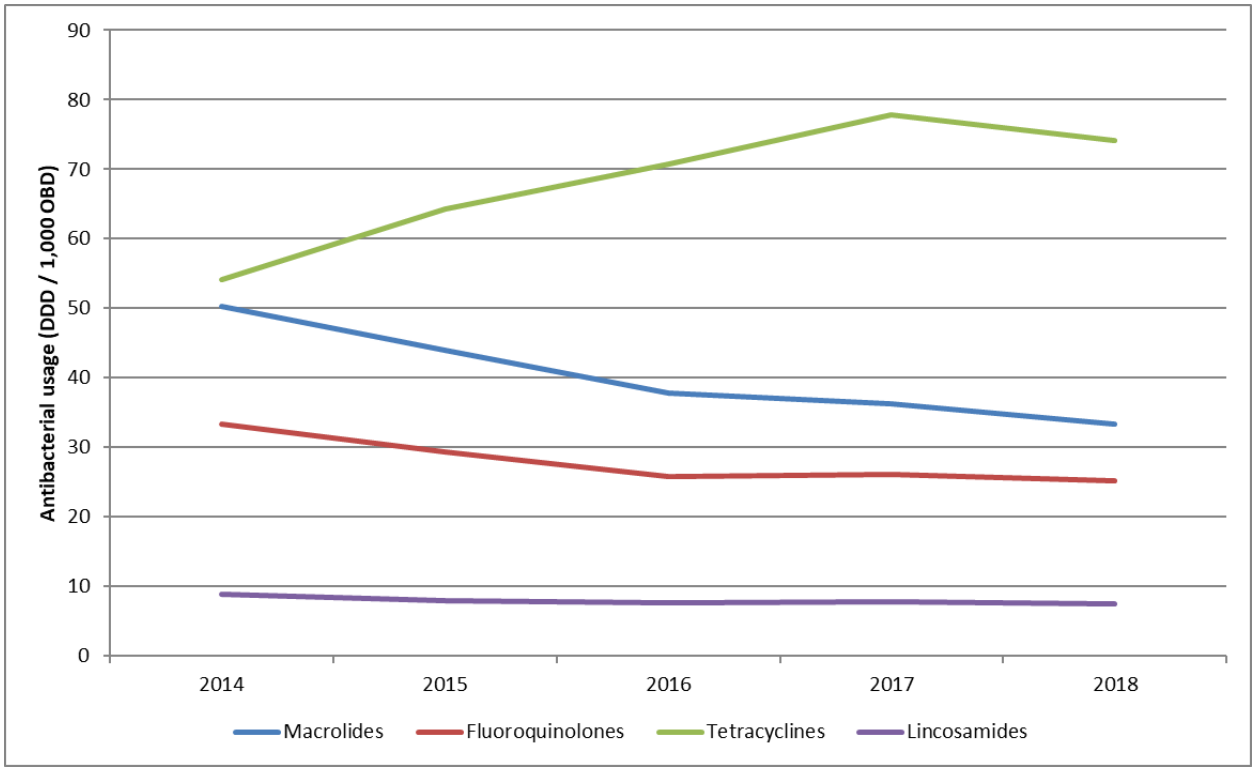
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Figure 3d: Annual aggregate total-hospital usage rates for commonly used broad-spectrum antibacterial classes in NAUSP contributor hospitals, 2014–2018



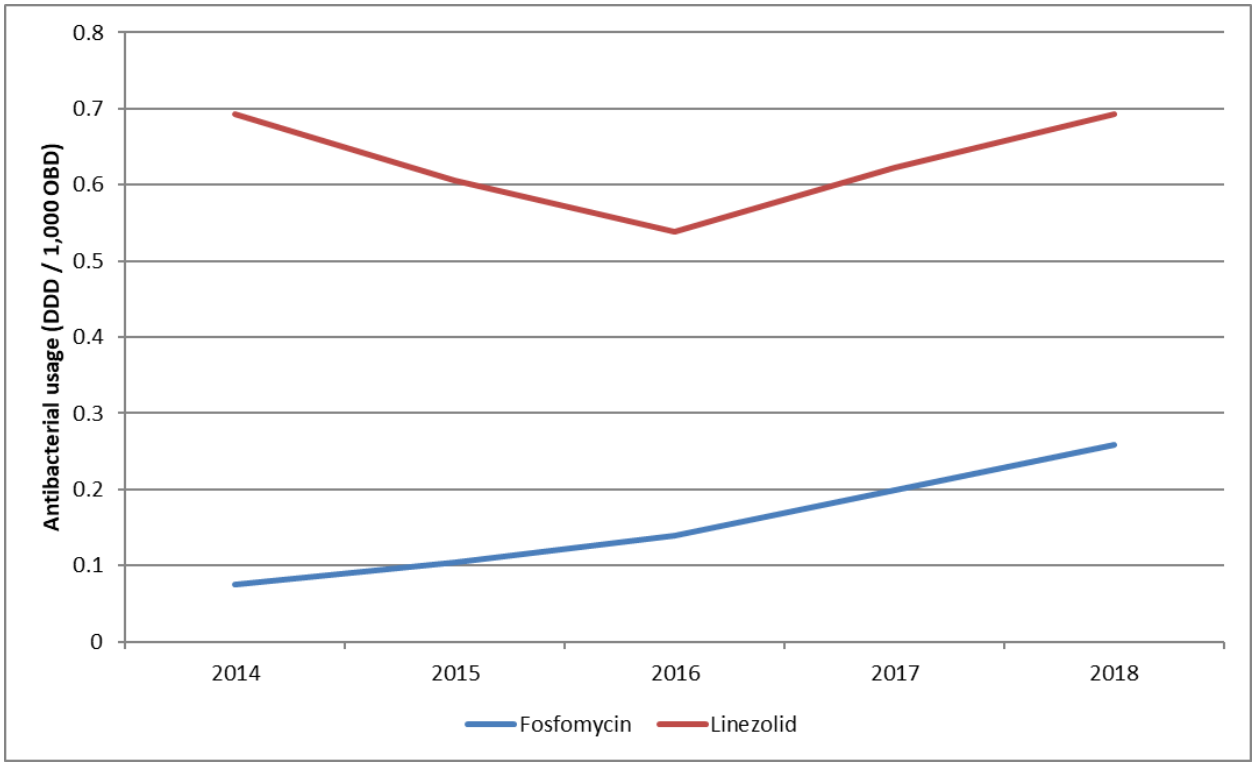
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Figure 3e: Annual aggregate total-hospital usage rates for commonly used oral broad-spectrum antibacterial classes in NAUSP contributor hospitals, 2014–2018



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

Figure 3f: Annual aggregate total-hospital usage rates for restricted oral broad-spectrum antibacterial classes in NAUSP contributor hospitals, 2014–2018



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

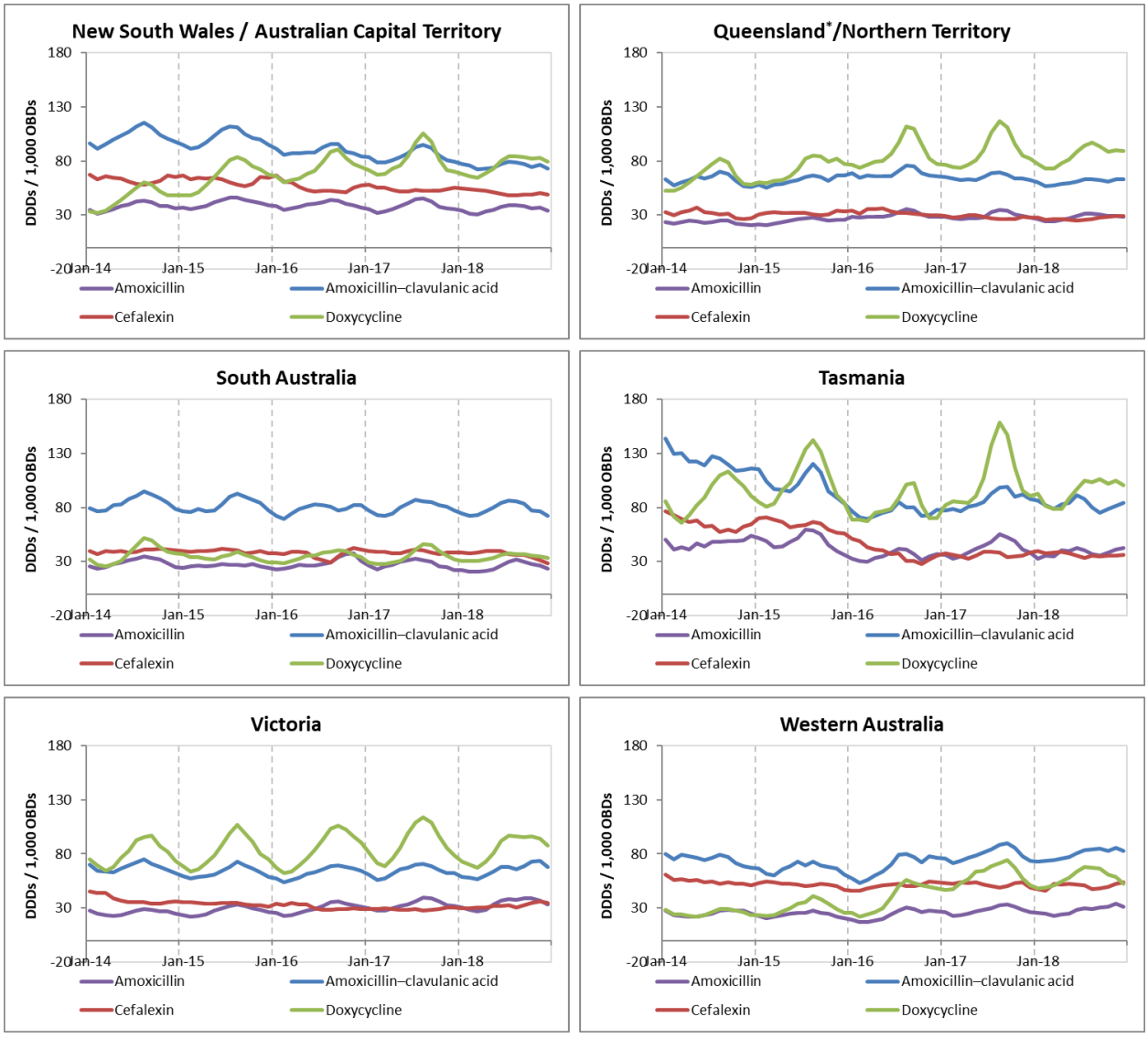
Usage rates for individual antibacterials, 2014–2018

This section summarises usage rates for individual antibacterials and trends from 2014 to 2018 in all states and territories.

High volume oral antibacterials

Amoxicillin–clavulanic acid, doxycycline and cefalexin were among the most commonly prescribed oral antibacterials in NAUSP contributor hospitals (Figure 4). Although usage rates varied between states and territories, a downward trend in amoxicillin–clavulanic acid use was observed in New South Wales/Australian Capital Territory and in Tasmania over the five-year period. Seasonal variation in the use of doxycycline was evident. Overall, use of this antibacterial increased across all states and territories between 2014 and 2018, most notably in New South Wales/Australian Capital Territory, Queensland/Northern Territory and in Western Australia.

Figure 4: Oral amoxicillin–clavulanic acid and cefalexin usage rates (DDDs/1,000 OBDs) in NAUSP contributor hospitals, by state and territory, 2014–2018 (3-month moving average)



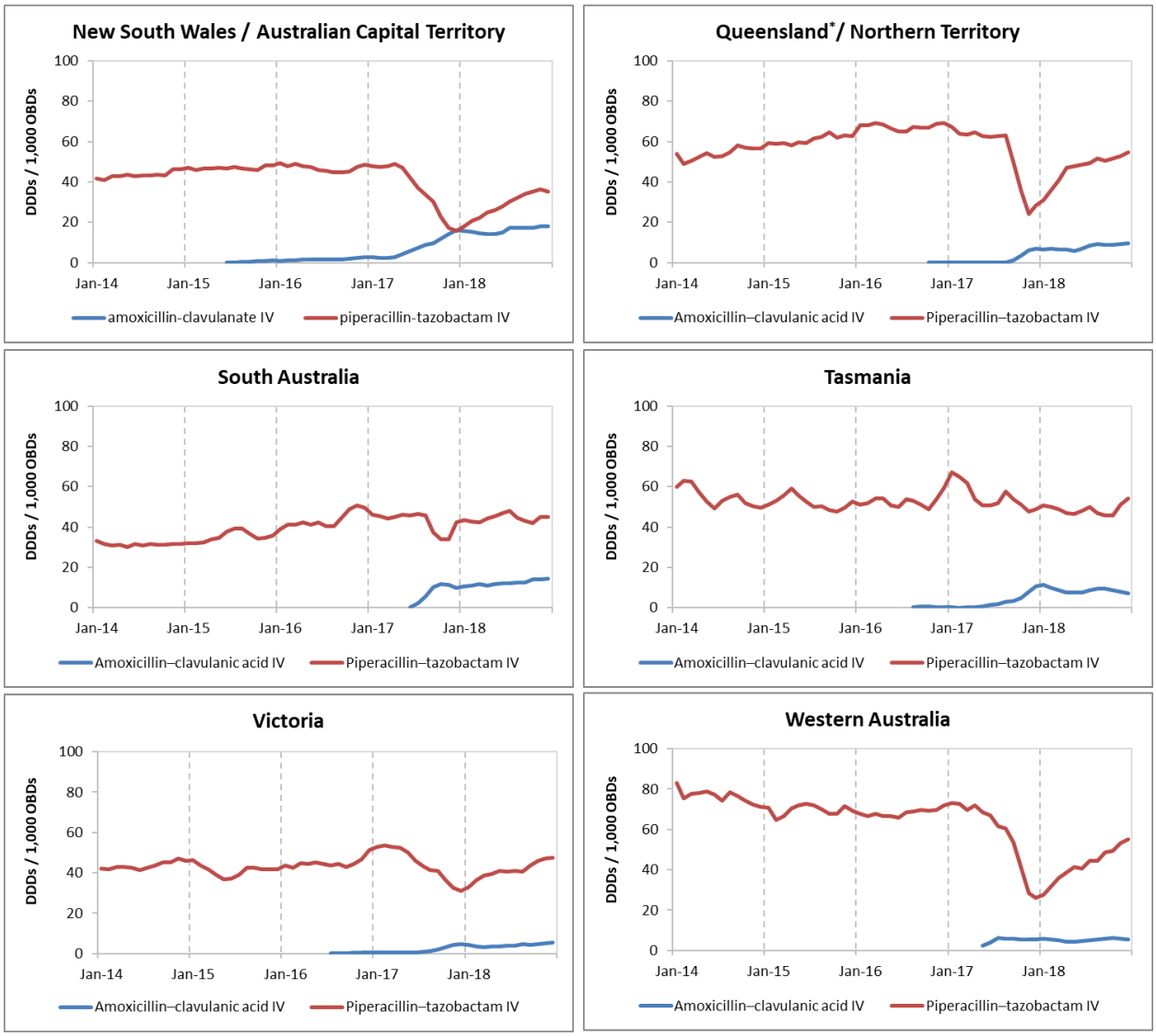
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
*Note: Queensland/Northern Territory rates for 2014 and 2015 are calculated using data from 71.8% of hospitals from these states enrolled in NAUSP. Data was unavailable for two principal referral hospitals, four Acute Group A hospitals, one Acute Group B and two Acute Group C hospitals for 2014 and 2015.

Intravenous penicillin–β-lactamase inhibitor combinations: amoxicillin–clavulanic acid and piperacillin–tazobactam

Two intravenous penicillin–β-lactamase inhibitor combinations (amoxicillin–clavulanic acid and piperacillin–tazobactam) are registered with the Therapeutic Goods Administration for use in Australia. Piperacillin–tazobactam is currently the primary penicillin–β-lactamase inhibitor combination used in Australian hospitals (Figure 5). Before 2017, amoxicillin–clavulanic acid was only readily available in oral formulations in Australia. Intravenous amoxicillin–clavulanic acid accounted for less than 0.5% of total antibacterial use in NAUSP contributor hospitals in 2017, and increased to 1.1% in 2018.

The effect of a piperacillin–tazobactam shortage in 2017 is evident in Figure 5. In some states and territories, use returned to previous levels after normal supply resumed in 2018. In Western Australia, usage was higher between 2014 and 2017 compared to other states and territories, and increased in 2018 after normal supply resumed. However, usage was lower than previous years.[10]

Figure 5: Penicillin–β-lactamase inhibitor combination usage rates in NAUSP contributor hospitals, by state and territory, 2014–2018 (3-month moving average)



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

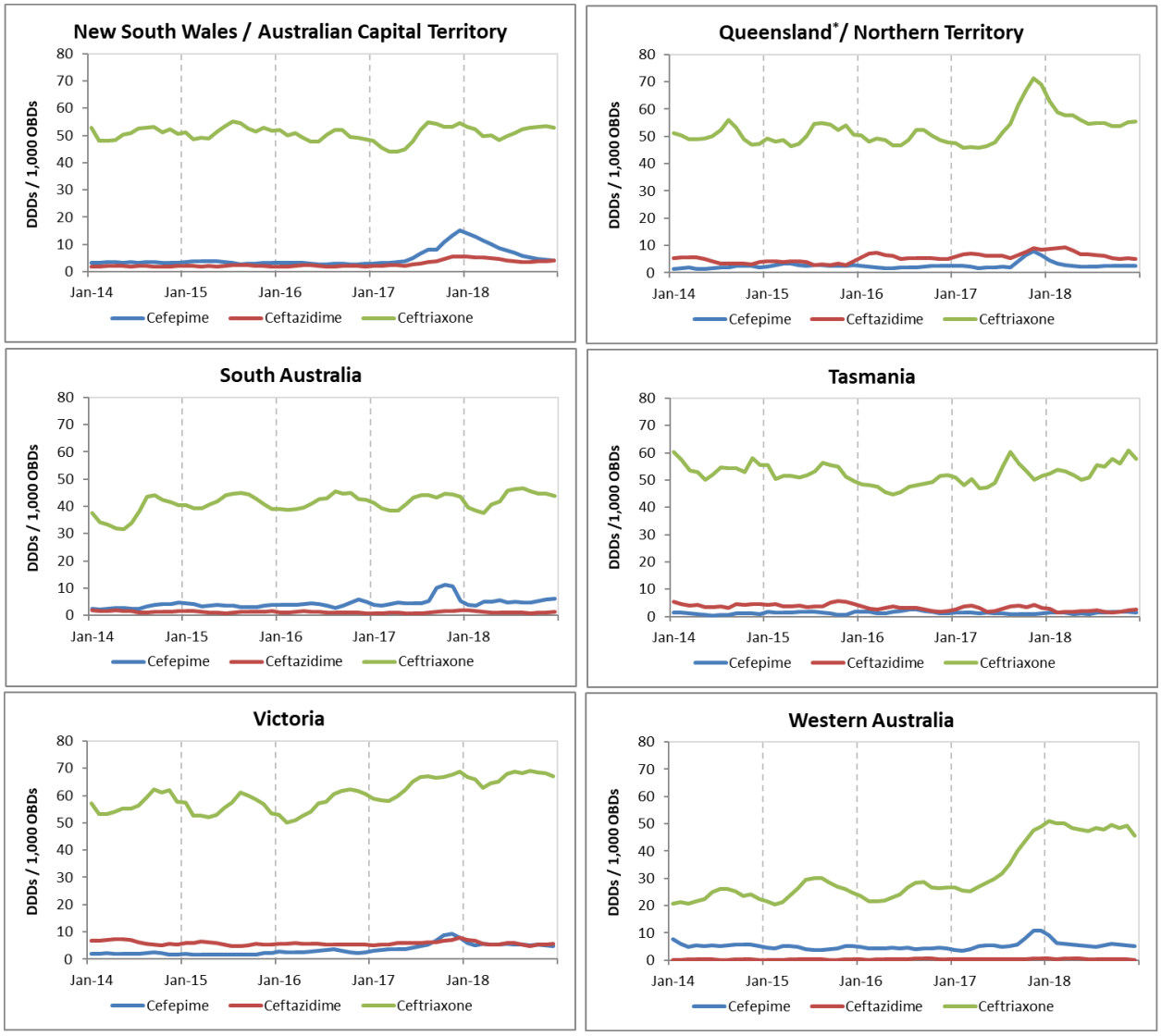
*Note: Queensland/Northern Territory rates for 2014 and 2015 are calculated using data from 71.8% of hospitals from these states enrolled in NAUSP. Data was unavailable for two principal referral hospitals, four Acute Group A hospitals, one Acute Group B and two Acute Group C hospitals for 2014 and 2015.

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

Figure 6 shows the usage rates for third- and fourth-generation cephalosporins (cefepime, ceftazidime, and ceftriaxone) from 2014 to 2018. As there was minimal use of cefotaxime over this time period, it was not included in the figures below. The shortage of piperacillin–tazobactam in 2017 resulted in a corresponding increase in the use of third- and fourth-generation cephalosporins in all states and territories; the extent of this increase varied between jurisdictions.

There was increased usage of cefepime in all states and territories except Tasmania during the piperacillin–tazobactam shortage. In Queensland/Northern Territory, ceftriaxone usage peaked in November 2017; monthly usage was approximately 50% higher than usage reported for November 2016. There was also a large spike in ceftriaxone usage in Western Australia; higher usage persisted after the shortage was resolved. On average, usage in Victoria was higher than other states and territories.

Figure 6: Cephalosporin usage rates in NAUSP contributor hospitals, by state and territory, 2014–2018 (3-month moving average)



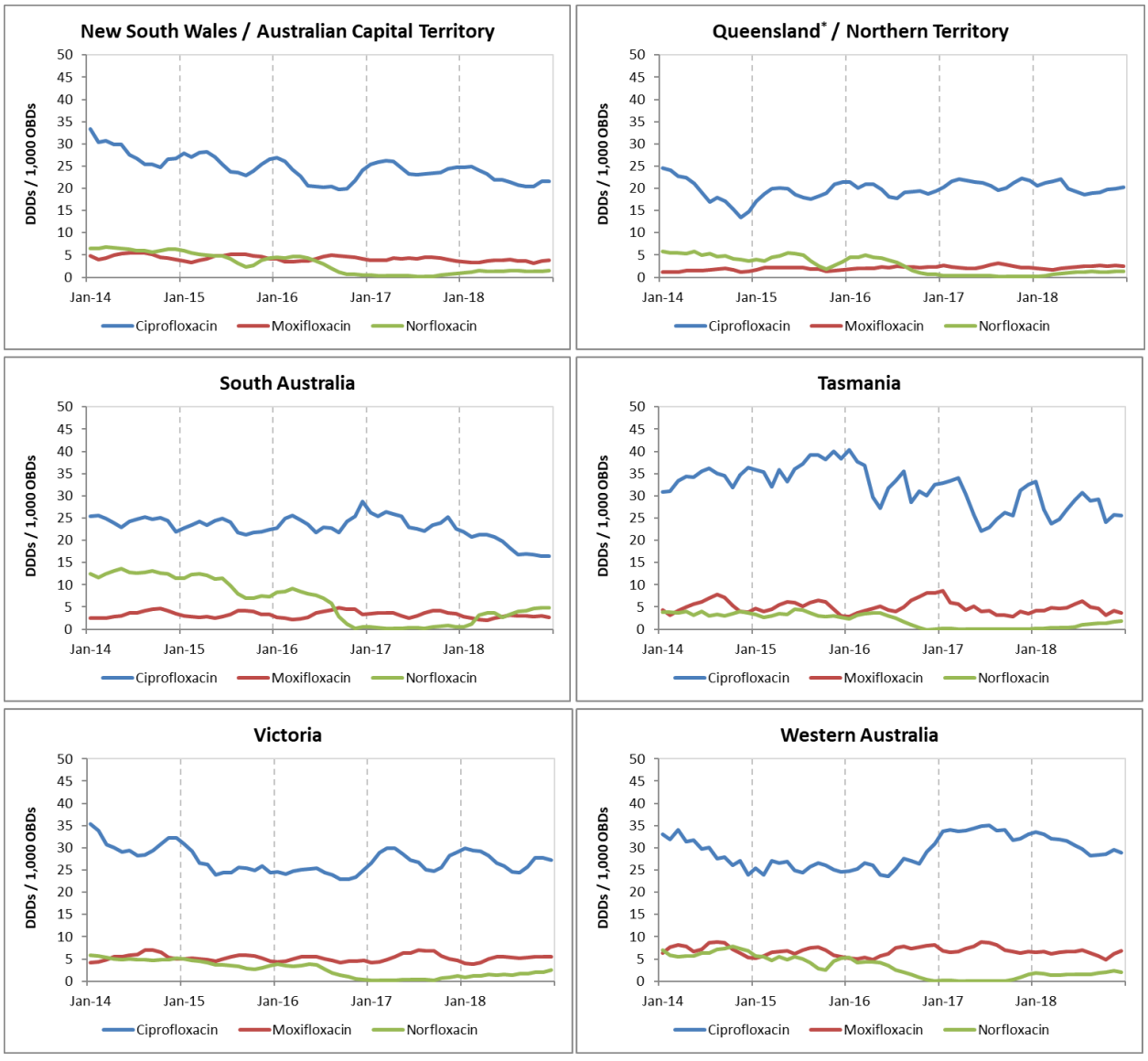
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
*Note: Queensland/Northern Territory rates for 2014 and 2015 are calculated using data from 71.8% of hospitals from these states enrolled in NAUSP. Data was unavailable for two principal referral hospitals, four Acute Group A hospitals, one Acute Group B and two Acute Group C hospitals for 2014 and 2015.

Fluoroquinolones – ciprofloxacin, moxifloxacin and norfloxacin

Fluoroquinolone usage rates decreased over the last five years in most states and territories (Figure 7). Most Australian hospitals and statewide formularies (where they exist) have restrictions on the use of fluoroquinolones, and there are few indications where a fluoroquinolone is the first-line recommendation. Ciprofloxacin is the most frequently used fluoroquinolone in NAUSP contributor hospitals. The new DDD value for parenteral ciprofloxacin (0.8 grams, compared to 0.5 grams) has had minimal effect on the reported usage rates. Parenteral use of ciprofloxacin is very low in Australia; average monthly use in Principal Referral hospitals in 2018 was 2.6 DDDs per 1,000 OBDs.

Usage rates for moxifloxacin are low and have remained relatively constant, however the total annual aggregate usage rate varies substantially between the states and territories. On average, between 2014 and 2018, usage rates for moxifloxacin were highest in Western Australia, whereas Queensland/Northern Territory had the lowest usage rate. A nationwide shortage of norfloxacin from late 2016 resulted in negligible usage from then until early 2018.[11]

Figure 7: Fluoroquinolone usage rates in NAUSP contributor hospitals, by state and territory, 2014–2018 (3-month moving average)

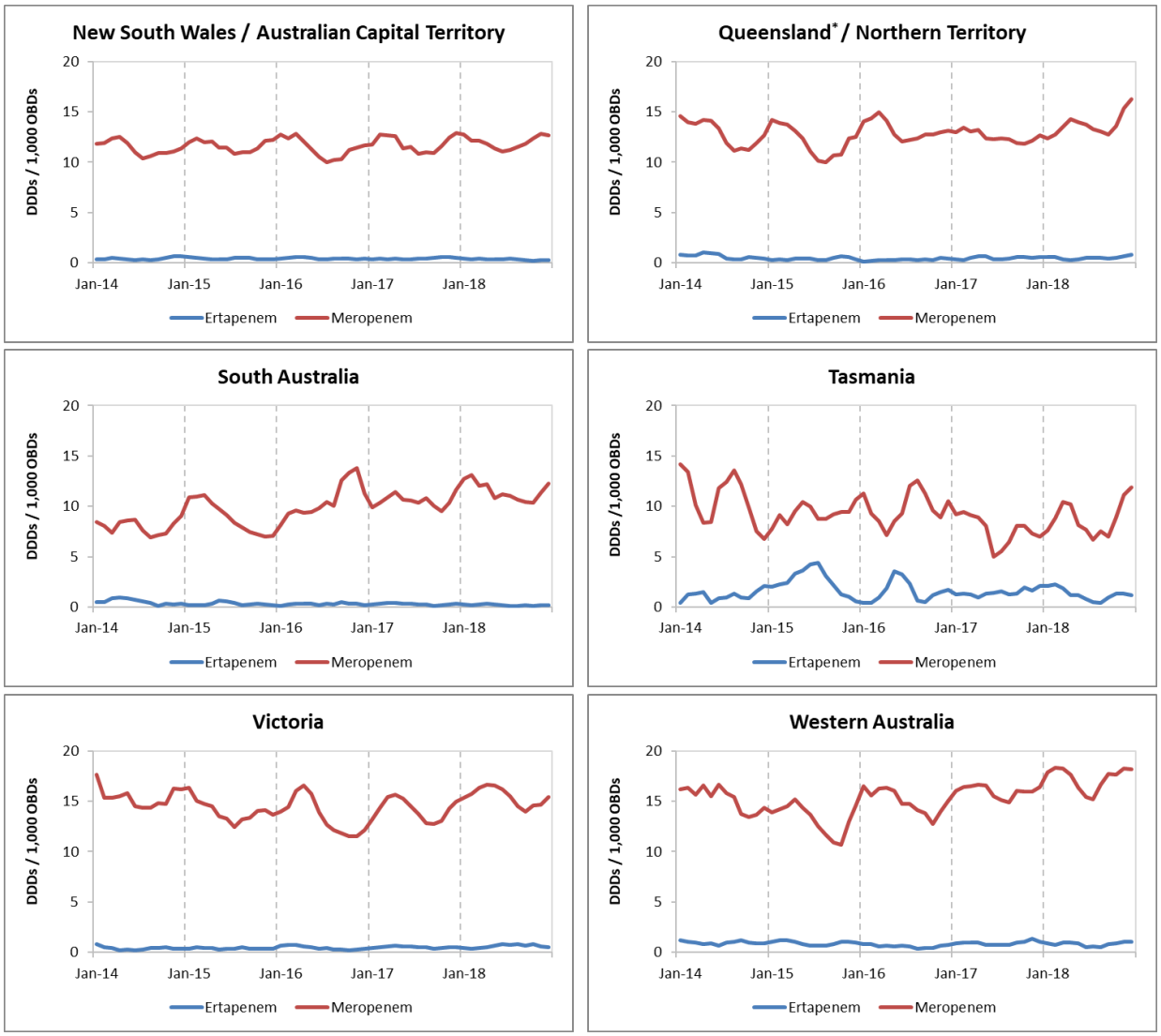


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
*Note: Queensland/Northern Territory rates for 2014 and 2015 are calculated using data from 71.8% of hospitals from these states enrolled in NAUSP. Data was unavailable for two Principal Referral hospitals, four Acute Group A hospitals, one Acute Group B and two Acute Group C hospitals for 2014 and 2015.

Carbapenems – ertapenem and meropenem

Meropenem is the predominant carbapenem used in NAUSP contributor hospitals, and is a key reserve-line antibacterial due to its role in treating infections with resistance to multiple other antibacterial classes. It is also used for the treatment of melioidosis, which is more common in northern Australia. Despite monthly fluctuations, average usage of meropenem remained relatively constant across all states and territories from 2014 to 2018, except for a notable increase in usage rates in South Australia and an upward trend in Queensland/Northern Territory and Western Australia (Figure 8). On average, usage in Western Australia, Queensland/Northern Territory and Victoria was higher than other states and territories. Doripenem and imipenem–cilastatin use was minimal, so these agents have not been included in the figures below.

Figure 8: Carbapenem usage rates in NAUSP contributor hospitals, by state and territory, 2014–2018 (3-month moving average)

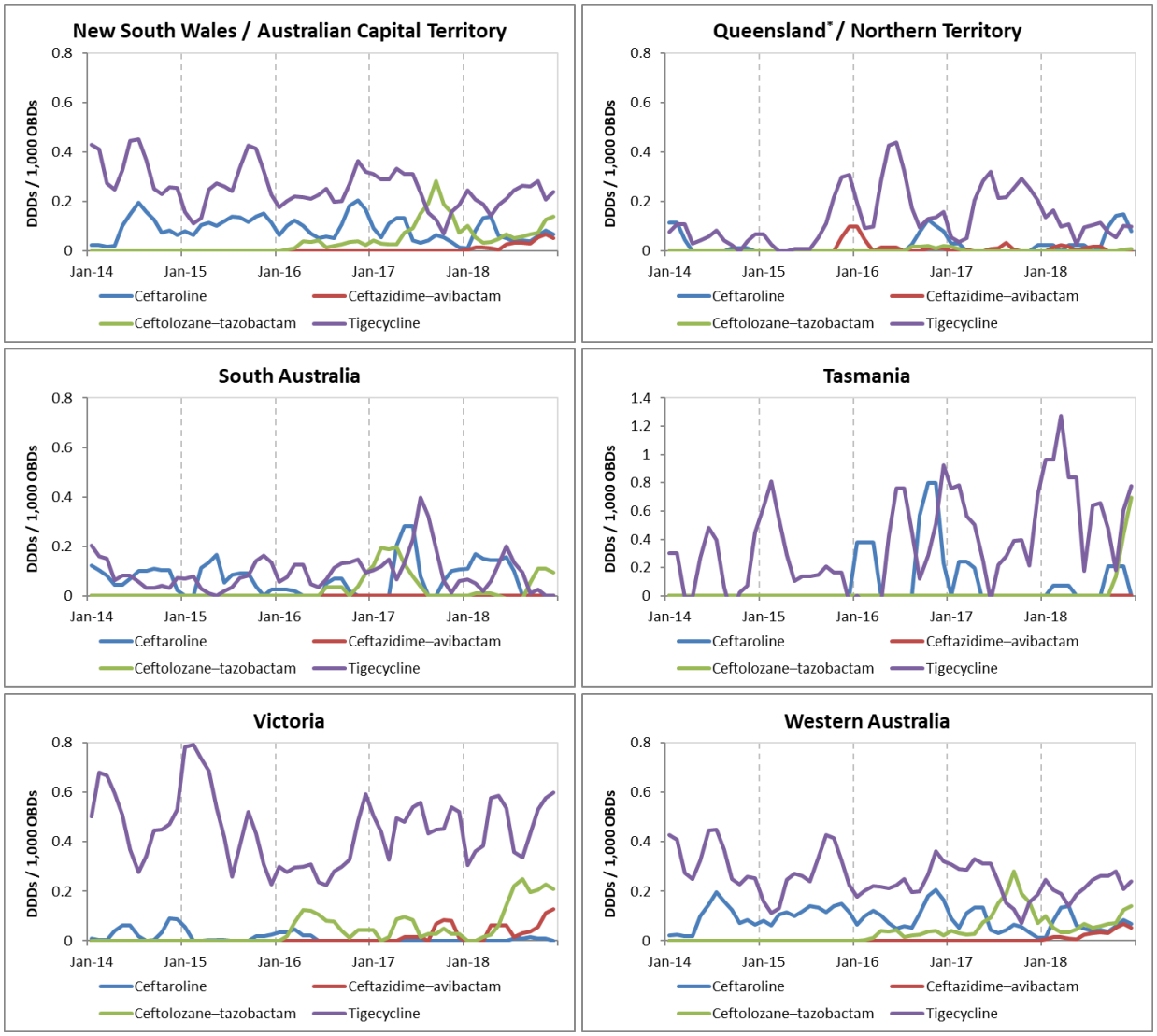


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
*Note: Queensland/Northern Territory rates for 2014 and 2015 are calculated using data from 71.8% of hospitals from these states enrolled in NAUSP. Data was unavailable for two Principal Referral hospitals, four Acute Group A hospitals, one Acute Group B and two Acute Group C hospitals for 2014 and 2015.

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

Usage of the newer antibacterial agents, ceftaroline, ceftazidime–avibactam and ceftolozane–tazobactam was low and variable between states and territories (Figure 9). These reserve-line agents, used to treat multidrug-resistant infections, were registered for use in Australia in 2019 and their usage has been increasing since 2016. Use of tigecycline, an older reserve-line broad spectrum antibacterial, remains very low in Australian hospitals, but has increased since 2016. Tigecycline usage is consistently higher in Victoria compared to other states and territories.

Figure 9: Broad-spectrum reserve-line antibacterial usage rates in NAUSP contributor hospitals, by state and territory, 2014–2018 (3-month moving average)



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Note: y-axis varies for Tasmania
*Note: Queensland/Northern Territory rates for 2014 and 2015 are calculated using data from 71.8% of hospitals from these states enrolled in NAUSP. Data was unavailable for two Principal Referral hospitals, four Acute Group A hospitals, one Acute Group B and two Acute Group C hospitals for 2014 and 2015.

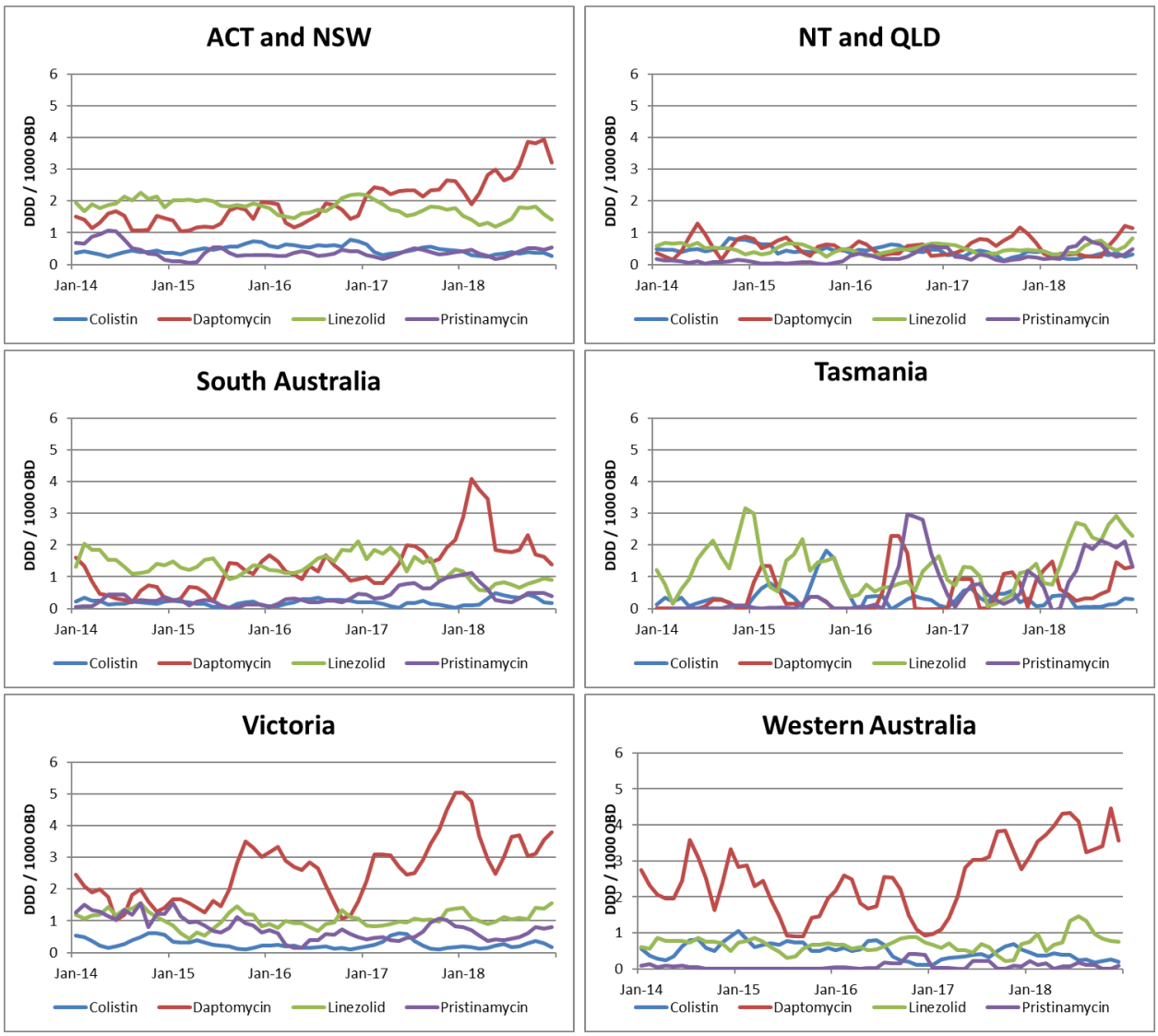
Reserve-line narrow spectrum antibacterials – colistin, daptomycin, linezolid and pristinamycin

The polymyxin antibacterial, colistin (administered parenterally as the prodrug, colistin methanesulphonate) is a last-line option for the treatment of multidrug-resistant infections, including those caused by carbapenemase-producing gram-negative organisms. The DDD value for colistin was increased in January 2019[12], resulting in reduction in the reported usage rates compared to the rates reported previously. Usage of colistin in Australian hospitals remains low.

Although daptomycin usage is low nationally, this increased substantially in most states and territories except Queensland/Northern Territory (Figure 10).

There is marked variation in linezolid usage rates between hospitals, and states and territories; overall usage is highest in Victoria and Western Australia.

Figure 10: Narrow-spectrum reserve-line antibacterial usage rates (DDDs/1,000 OBDs) in NAUSP contributor hospitals, by state and territory, 2014–2018 (3-month moving average)



DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Note: Colistin usage rates include both nebulised and parenteral formulations, as some NAUSP contributors are not able to provide separate data for each.
*Note: Queensland/Northern Territory rates for 2014 and 2015 are calculated using data from 71.8% of hospitals from these states enrolled in NAUSP. Data was unavailable for two principal referral hospitals, four Acute Group A hospitals, one Acute Group B and two Acute Group C hospitals for 2014 and 2015.

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 where more specialised or complex care is provided. For several antibacterial classes however, usage is higher in Public Acute Group A, B and C hospitals than in Principal Referral hospitals. The reasons for these findings are unclear; it may be that AMS programs are less well developed in smaller facilities.

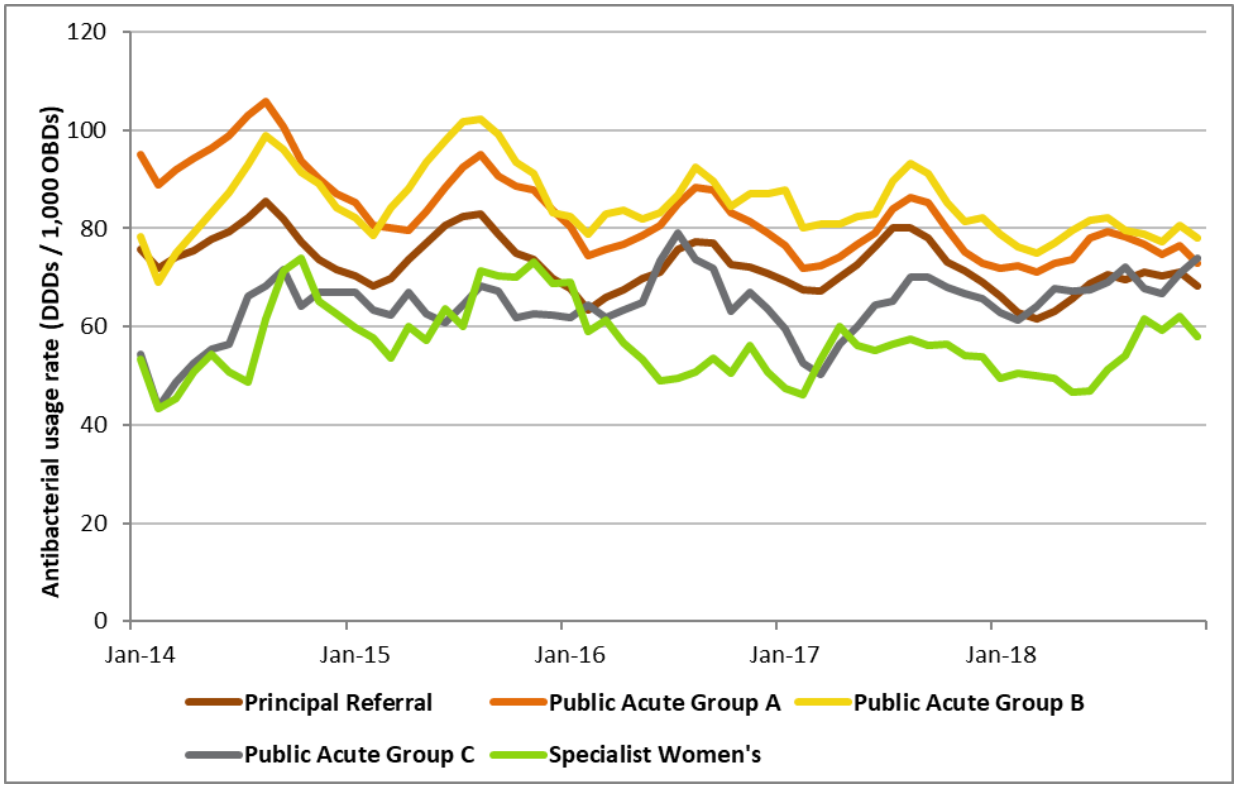
High volume oral antibacterials

Comparative usage between peer groups has been included for the following high volume oral antibacterials: amoxicillin–clavulanic acid, cefalexin, and dicloxacillin/flucloxacillin.

Oral amoxicillin–clavulanic acid

Usage of oral amoxicillin–clavulanic acid declined across all peer groups from 2014 to 2018, except for Public Acute Group C hospitals, where usage increased (Figure 11). Seasonal variation is apparent, with higher use in winter months, which could potentially be due to its use in the treatment of pneumonia.

Figure 11: Oral amoxicillin–clavulanic acid usage rates in NAUSP contributor hospitals, by selected peer groups, 2014–2018 (3-month moving average)

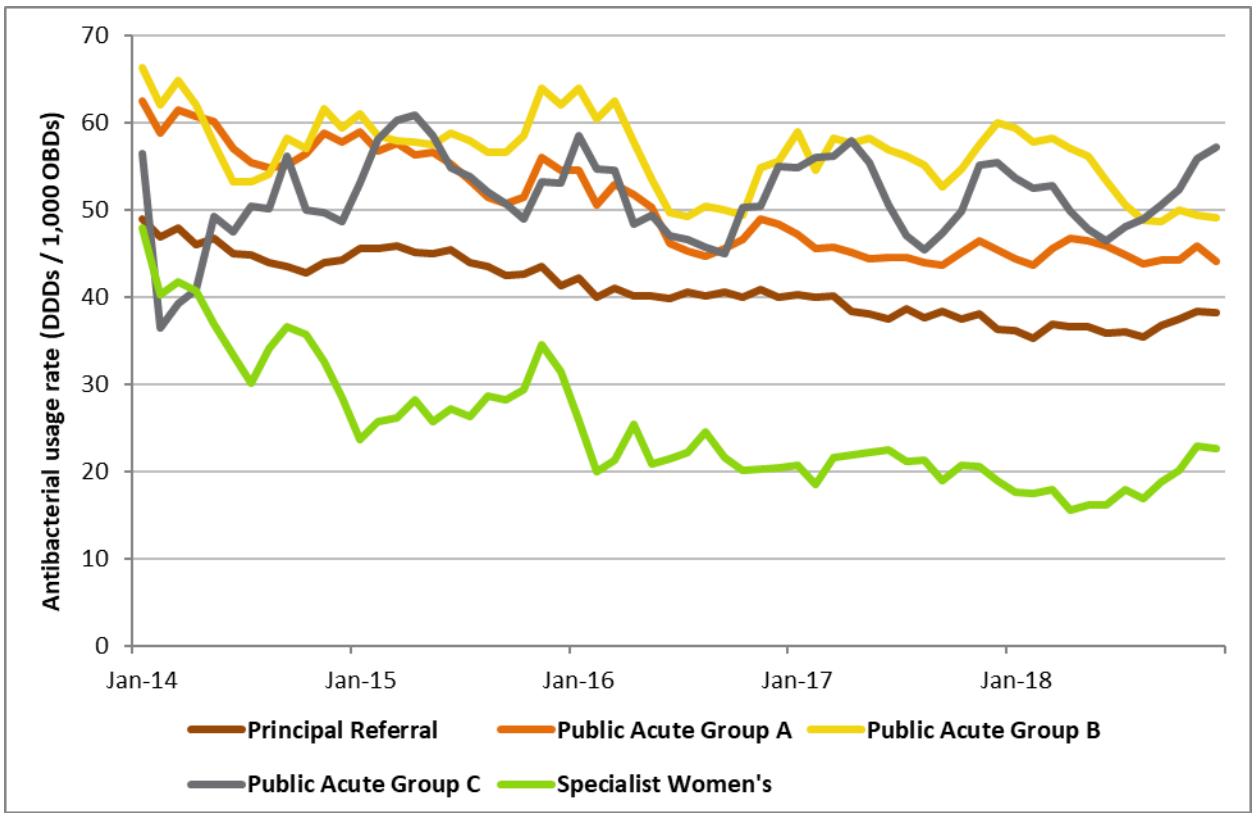


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Note: data from Private Acute Group D hospitals are aggregated with Public Acute Group C and Private Acute Group C hospital data due to the small number of sites.

Cefalexin

Cefalexin usage rates were higher in Public Acute Group A, B and C hospitals than in Principal Referral hospitals (Figure 12). This may be due to differences in casemix. Usage of cefalexin trended downwards between 2014 and 2018 in all peer groups except in Public Acute Group C hospitals.

Figure 12: Cefalexin usage rates (DDDs/1,000 OBDs) in NAUSP contributor hospitals, by selected peer groups, 2014–2018 (3-month moving average)

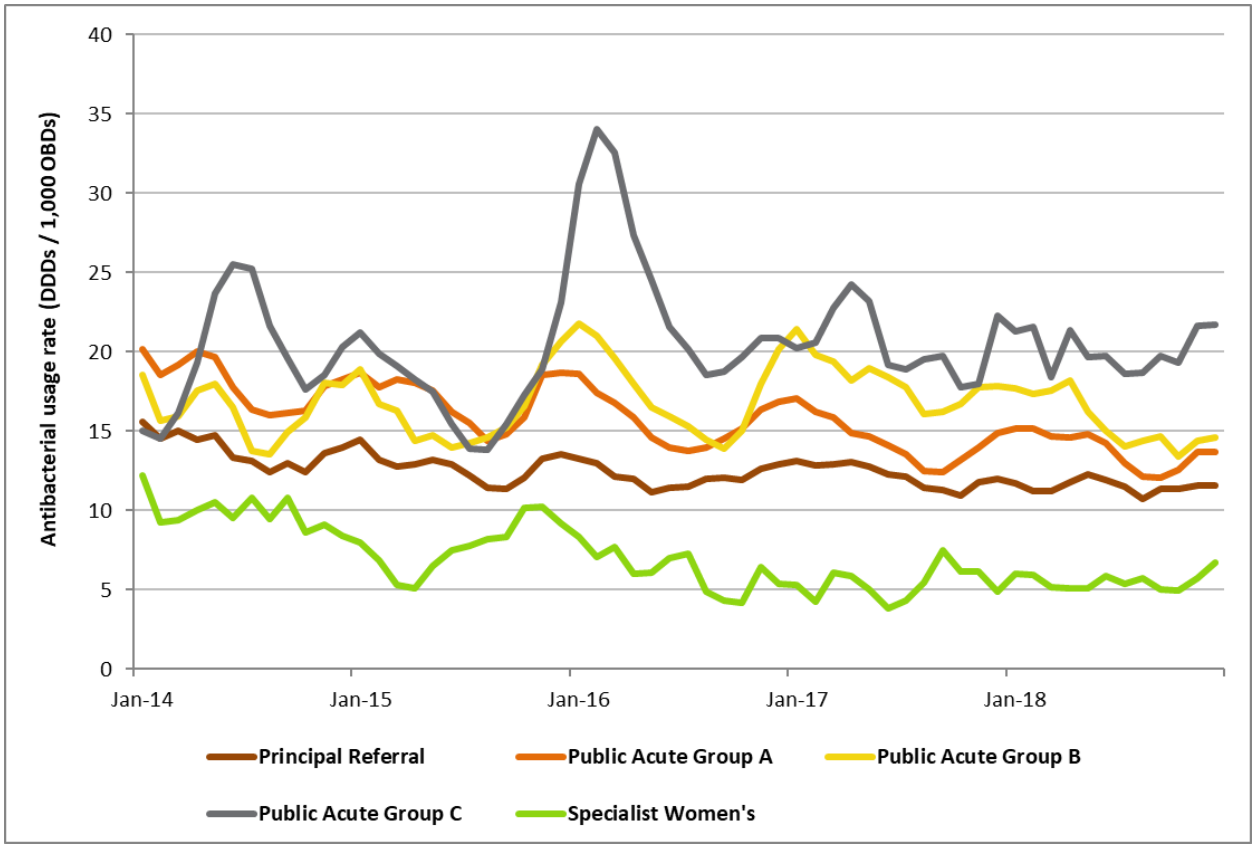


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Note: data from Private Acute Group D hospitals are aggregated with Public Acute Group C and Private Acute Group C hospital data due to the small number of sites.

Dicloxacillin and flucloxacillin

Seasonal variation in dicloxacillin and flucloxacillin usage is apparent, with highest use in the summer months (Figure 13). Usage rates for dicloxacillin and flucloxacillin were highest in Public Acute Group C and Public Acute Group B hospitals. Usage in Specialist Women's hospitals was lower than rates in the other hospital peer groups.

Figure 13: Dicloxacillin and flucloxacillin usage rates in NAUSP contributor hospitals, by selected peer groups, 2014–2018 (3-month moving average)



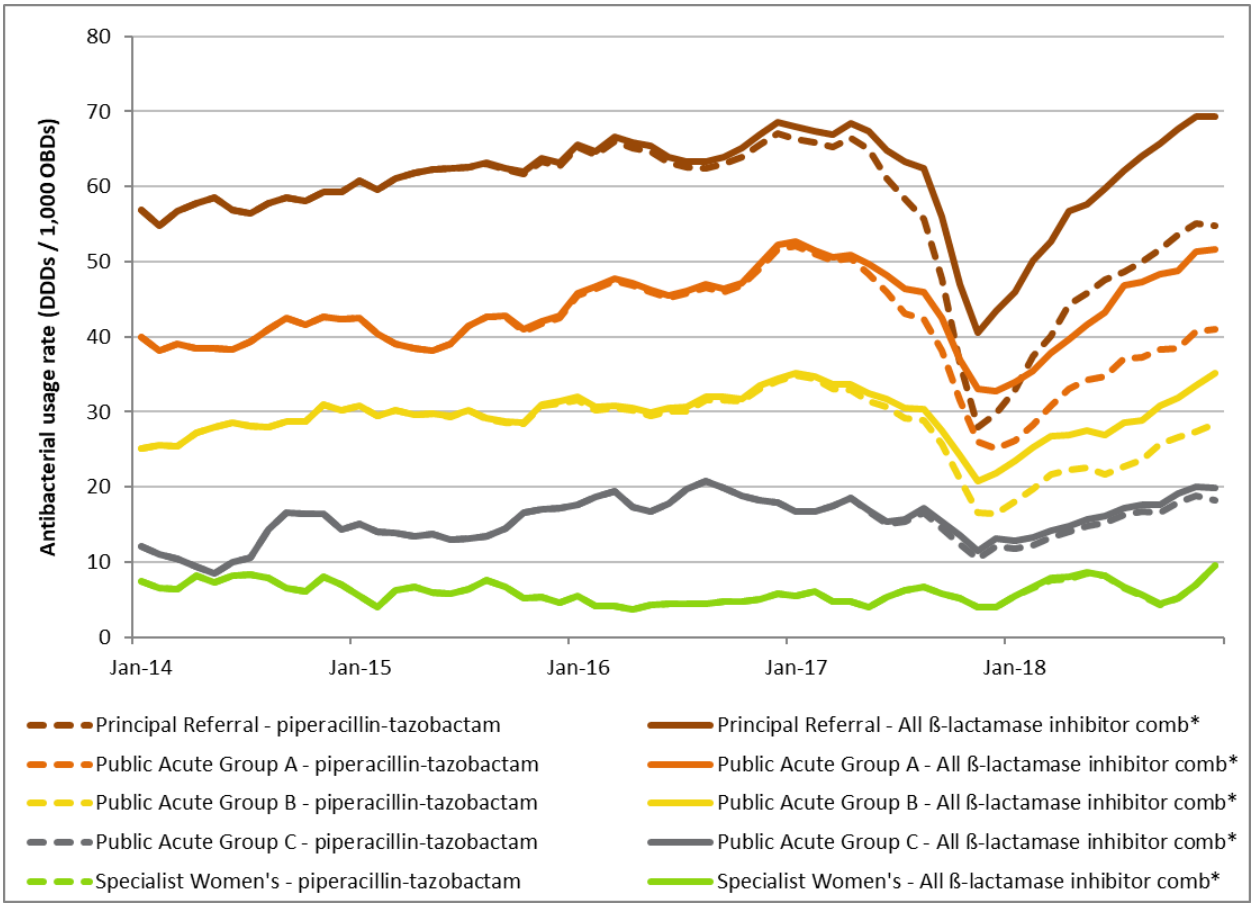
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Note: this figure shows combined rates for flucloxacillin and dicloxacillin
Note: data from Private Acute Group D hospitals are aggregated with Public Acute Group C and Private Acute Group C hospital data due to the small number of sites.

Penicillin–β-lactamase inhibitor combinations

There are two intravenous penicillin–ß-lactamase inhibitor combination products available in Australia, piperacillin–tazobactam and amoxicillin–clavulanic acid. Piperacillin–tazobactam has a broader spectrum of activity than amoxicillin–clavulanic acid, including anti-pseudomonal activity. Piperacillin–tazobactam is the most commonly used penicillin–ß-lactamase combination in Australian hospitals across all peer groups (Figure 14). Intravenous amoxicillin–clavulanic acid was registered for use in Australia in January 2017.

Usage rates of piperacillin–tazobactam were greatest in larger hospitals that contributed to NAUSP from 2014 to 2018. As these antibacterials are generally restricted for use in higher acuity patients, it is expected that usage would be higher in Principal Referral hospitals and Public Acute Group A hospitals. Usage rates of anti-pseudomonal penicillin–β-lactamase inhibitor combinations were low in Specialist Women's hospitals. The shortage of piperacillin–tazobactam in late 2017 was associated with a relative increase in intravenous amoxicillin–clavulanic acid usage. Usage of intravenous amoxicillin–clavulanic acid was negligible in Specialist Women's hospitals.

Figure 14: Intravenous penicillin–ß-lactamase inhibitor combinations (piperacillin–tazobactam and amoxicillin–clavulanic acid) usage rates in NAUSP contributor hospitals, by selected peer groups, 2014–2018 (3-month moving average)

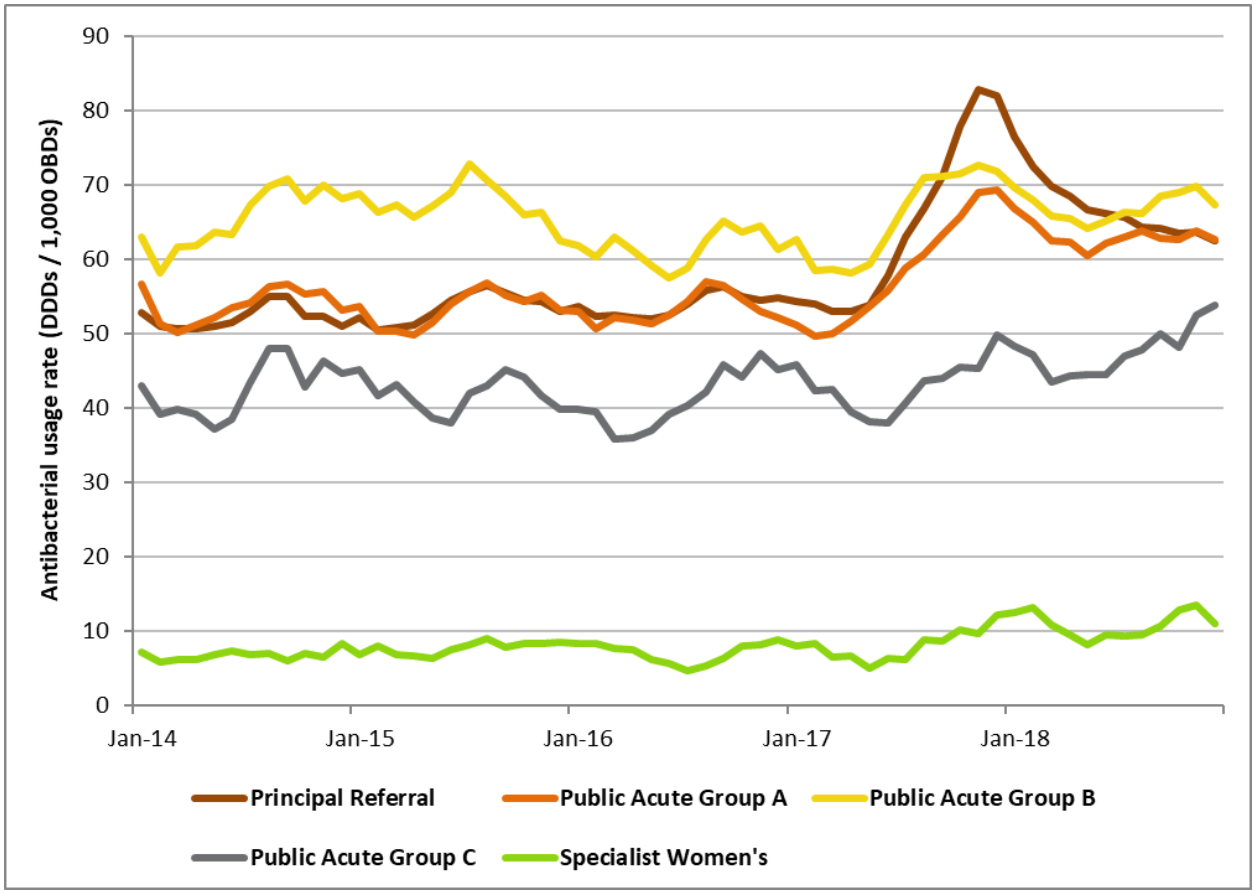


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
* piperacillin–tazobactam and amoxicillin–clavulanic acid usage combined
Note: data from Private Acute Group D hospitals are aggregated with Public Acute Group C and Private Acute Group C hospital data due to the small number of sites.

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

Usage rates of third- and fourth-generation cephalosporins were stable in the Principal Referral, Public Acute Group A and Public Acute Group B hospitals from 2014 to mid-2017 (Figure 15). Use increased subsequently in all peer groups, likely due to the piperacillin–tazobactam shortage; the highest increases were observed in the larger hospitals. After the supply of piperacillin–tazobactam was restored, third- and fourth-generation cephalosporin usage rates decreased, although these remained higher than pre-2017 levels.

Figure 15: Third- and fourth-generation cephalosporin usage rates in NAUSP contributor hospitals, by selected peer groups, 2014–2018 (3-month moving average)

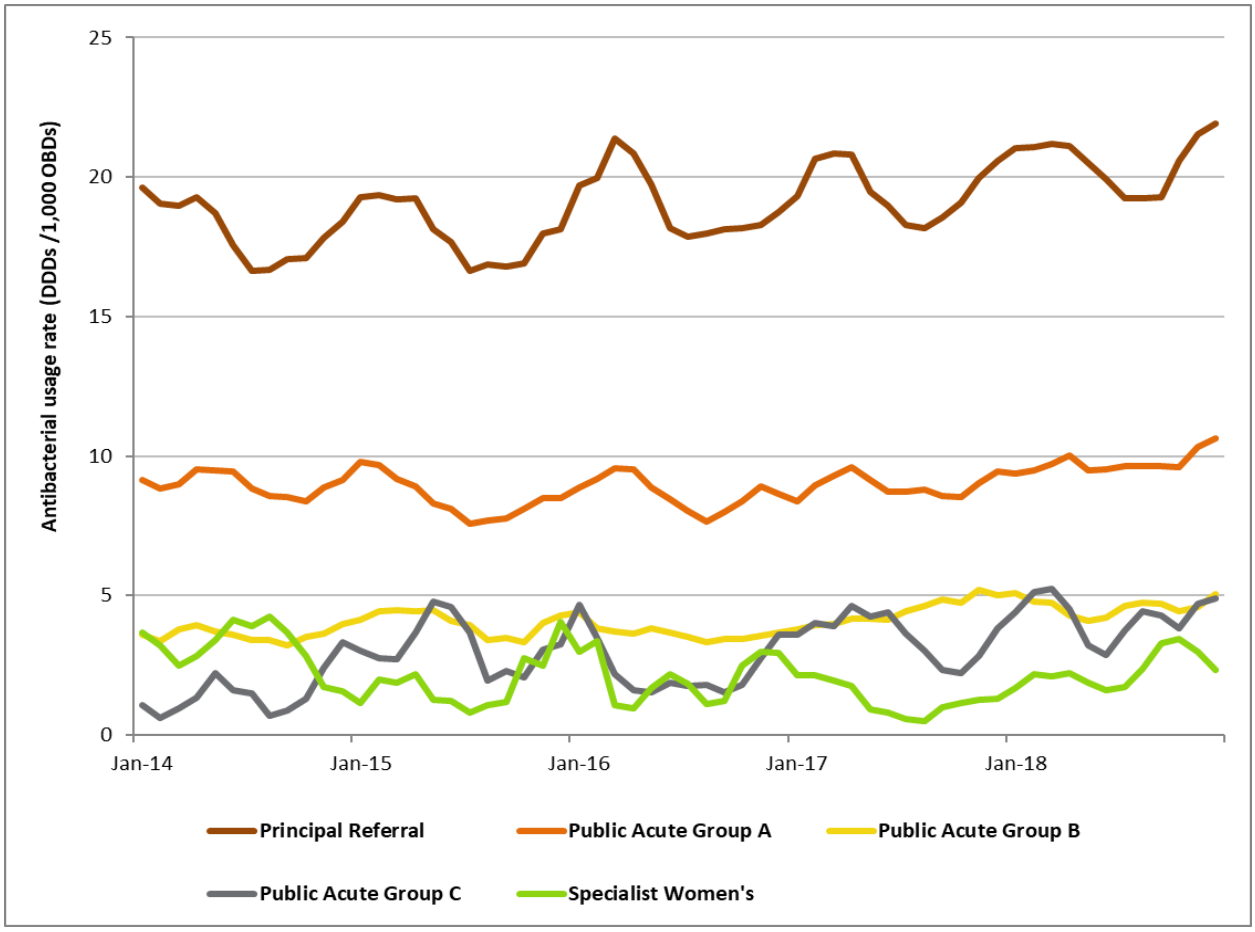


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Note: data from Private Acute Group D hospitals are aggregated with Public Acute Group C and Private Acute Group C hospital data due to the small number of sites.

Carbapenems – meropenem, ertapenem and imipenem-cilastatin

Carbapenems have a broad spectrum of activity and are reserved for the treatment of infections caused by multidrug-resistant organisms. Meropenem is the most commonly used carbapenem in Australian hospitals. Carbapenem usage rates across all peer groups were approximately one third lower than rates reported in the NAUSP Biennial report due to the revised DDD value for meropenem that changed from 2 grams to 3 grams (Figure 16). There was a slight upward trend in carbapenem usage in most peer groups between 2014 and 2018.

Figure 16: Carbapenem usage rates in NAUSP contributor hospitals, by selected peer groups, 2014–2018 (3-month moving average)

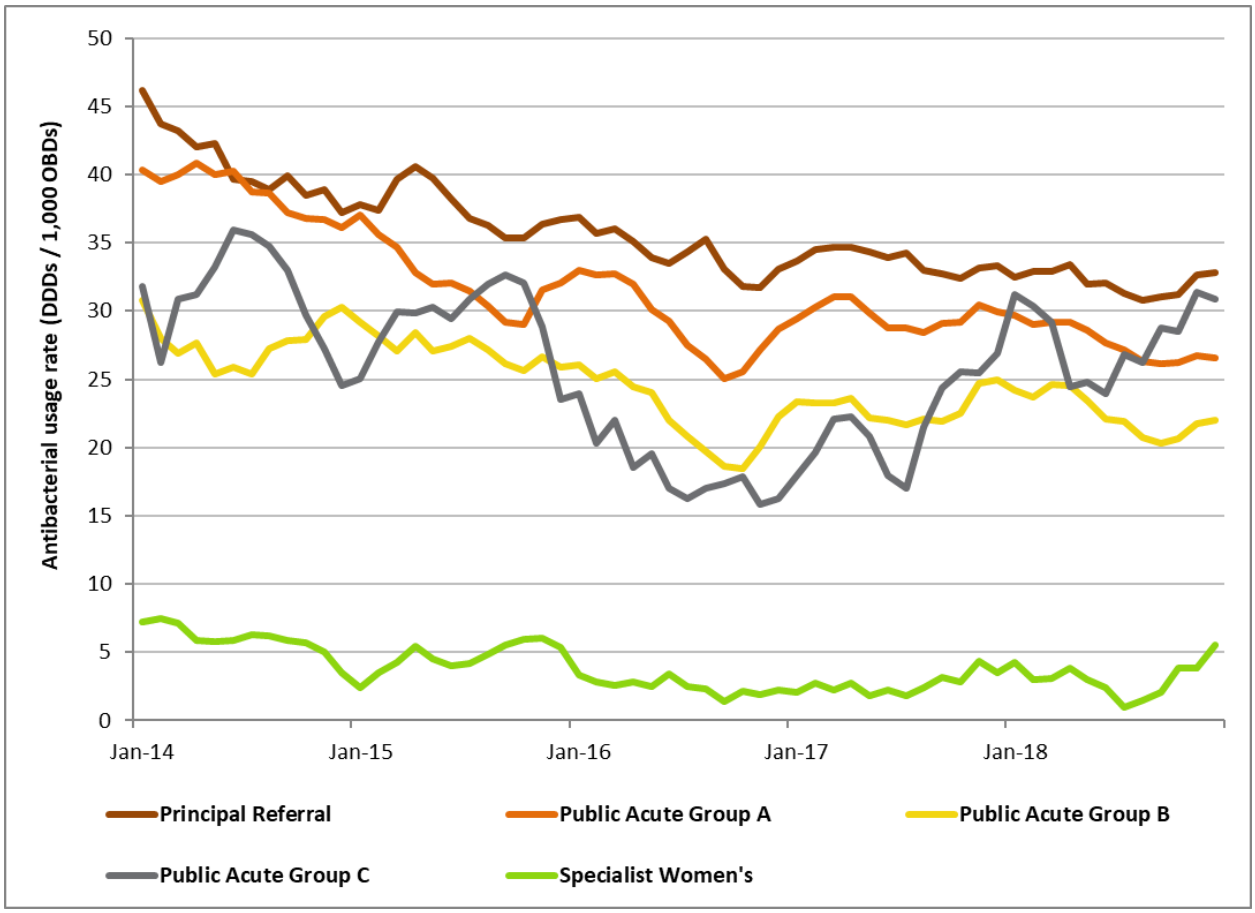


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Note: data from Private Acute Group D hospitals are aggregated with Public Acute Group C and Private Acute Group C hospital data due to the small number of sites.

Fluoroquinolones – ciprofloxacin, moxifloxacin and norfloxacin

Usage rates of fluoroquinolones trended downwards over from 2014 to 2018, with the most marked decreases observed in Principal Referral and Public Acute Group A NAUSP contributor hospitals (Figure 17). The exception was Public Acute Group C hospitals; whilst usage declined between 2014 and 2016, it increased from mid-2017 to 2018. Fluoroquinolone usage was minimal in Specialist Women's hospitals. The DDD value for intravenous ciprofloxacin increased to 0.8 grams from 0.5 grams in January 2019, which resulted in slightly lower reported rates compared to the NAUSP Biennial report.

Figure 17: Fluoroquinolone usage rates in NAUSP contributor hospitals, by selected peer groups, 2014–2018 (3-month moving average)

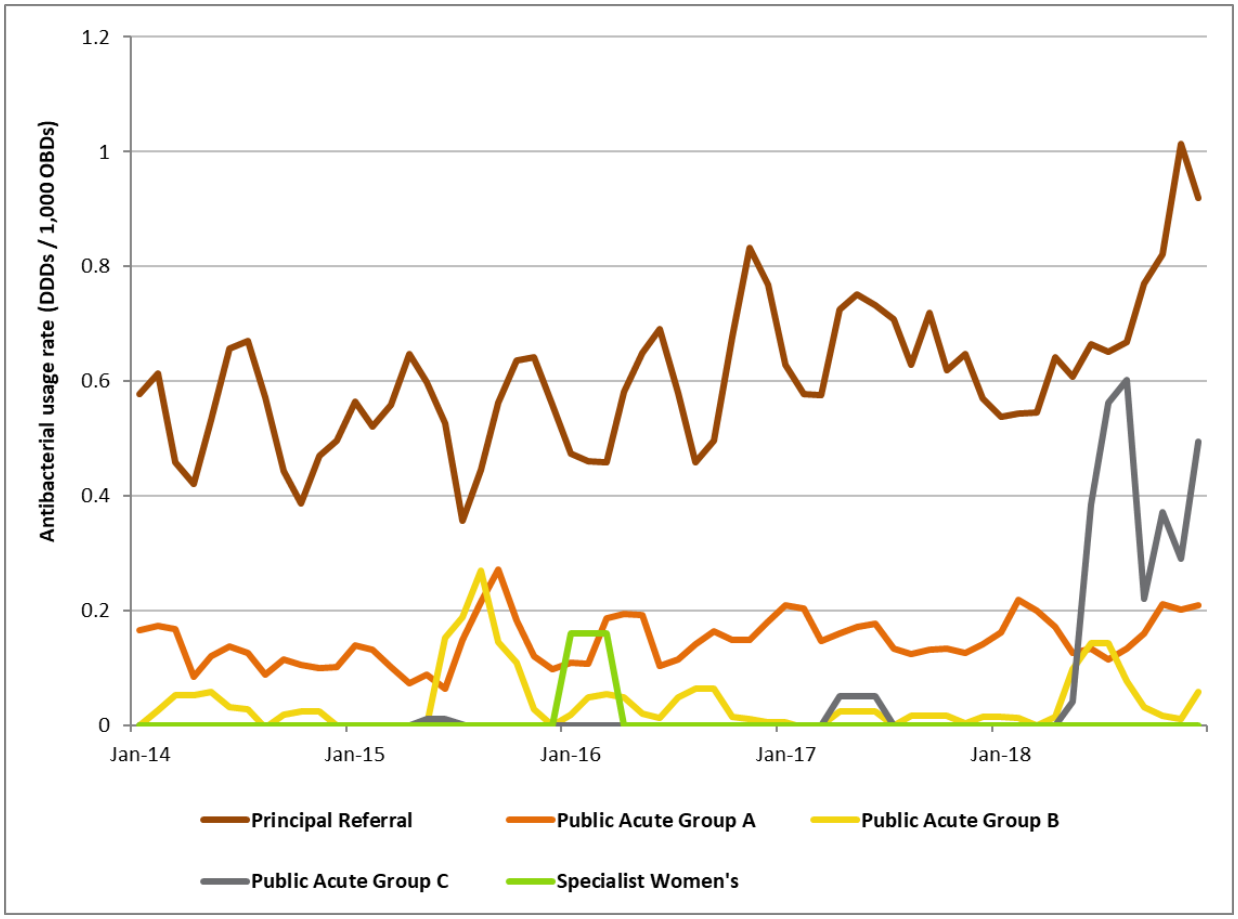


DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Note: data from Private Acute Group D hospitals are aggregated with Public Acute Group C and Private Acute Group C hospital data due to the small number of sites.

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

Usage rates for these highly reserved broad-spectrum antibacterials are low in Australian hospitals; usage was primarily reported by larger hospitals (Figure 18). In Principal Referral hospitals, the use of these antibacterials has increased, likely due to increases in multidrug-resistant infections. However, usage rates were less than 1 DDD per 1,000 OBDs. In mid-2018 there was a notable increase in usage in Public Acute Group C hospitals. This increase was driven by a rise in the use of tigecycline and ceftolozane–tazobactam between June and September 2018. The reasons for this are unclear.

Figure 18: Broad-spectrum reserve-line antibacterial* usage rates in NAUSP contributor hospitals, by selected peer groups, 2014–2018 (3-month moving average)



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

* Ceftaroline, ceftazidime–avibactam, ceftolozane–tazobactam, tigecycline rates combined

#Minimal usage in Specialist Women's hospitals – not shown in this chart

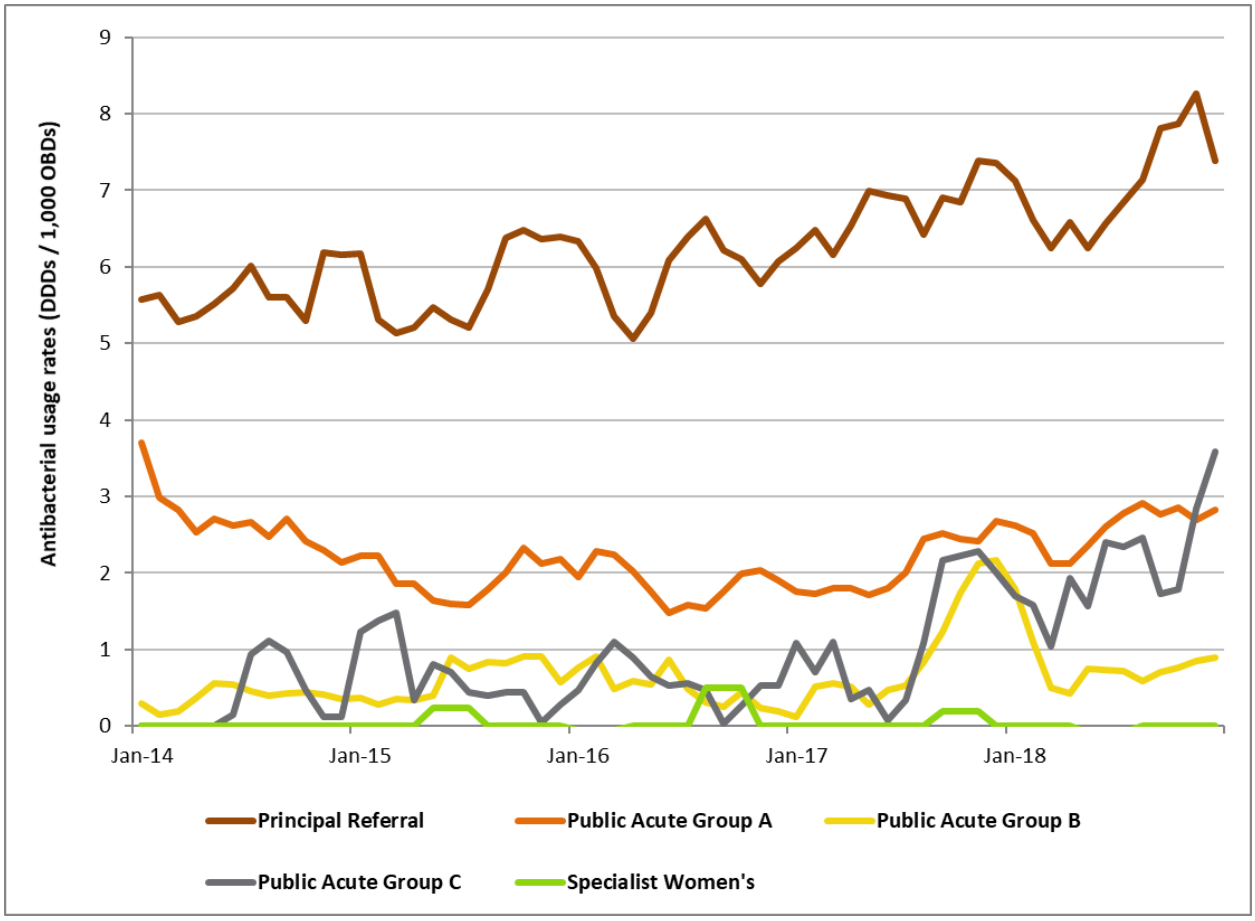
Note: data from Private Acute Group D hospitals are aggregated with Public Acute Group C and Private Acute Group C hospital data due to the small number of sites.

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

Use of highly reserved narrow-spectrum antibacterials was mostly confined to Principal Referral and Public Acute Group A hospitals that contributed to NAUSP from 2014 to 2018 (Figure 19). Usage in Principal Referral hospitals trended upwards over the five-year period. There was a notable increase in usage rates in Public Acute Group C hospitals from mid-2017; and in 2018, the average monthly use was more than double the usage rates in Public Acute Group B hospitals and almost as high as usage rates in Public Acute Group A hospitals. The reasons for this are unclear, but possible explanations include:

- Transfer of rural patients who require admission to large metropolitan hospitals to their local hospital to complete their antibacterial treatment
- Smaller facilities may not have established AMS programs, including a method of managing restrictions on prescribing broad-spectrum antibacterials
- Changes in prescribing preferences towards daptomycin, compared to other agents
- Increases in multidrug-resistant infections where prescriptions of these antimicrobials are indicated such as vancomycin-resistant Enterococci (VRE) or methicillin-resistant *Staphylococcus aureus* (MRSA) infections.

Figure 19: Colistin, daptomycin, linezolid and pristinamycin (combined) usage rates in NAUSP contributor hospitals†, by selected peer groups, 2014–2018 (3-month moving average)



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

† Minimal usage in Specialist Women's hospitals – not shown in this chart

Note: data from Private Acute Group D hospitals are aggregated with Public Acute Group C and Private Acute Group C hospital data due to the small number of sites.

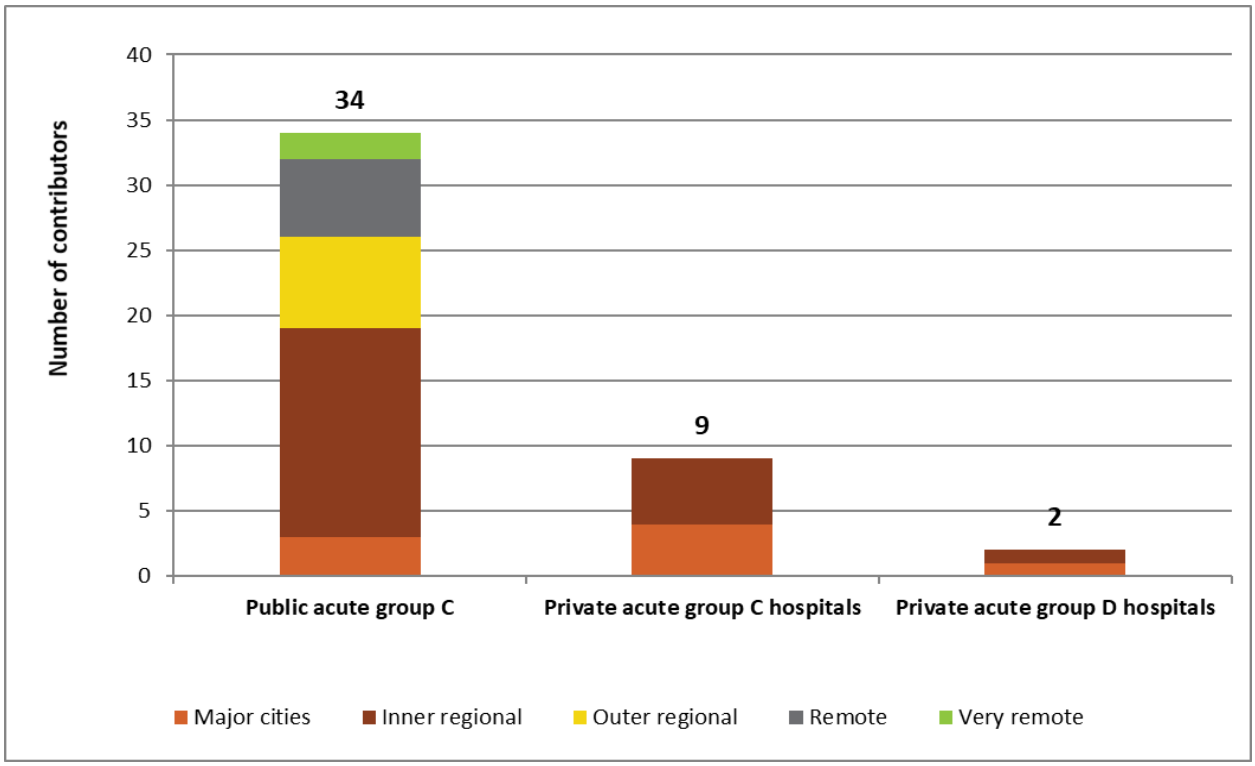
Vignette - Antimicrobial usage rates in smaller facilities

Increased participation in surveillance of antimicrobial usage in smaller hospitals, particularly in rural and remote areas, has been identified as a focus area for enhancement of the AURA Surveillance System.[10]

There is low participation in NAUSP by smaller hospitals; none of the 191 Public Acute Group D hospitals currently contribute data to NAUSP.[4] Most are located in regional and remote areas and serviced by larger hospitals or by community pharmacies. Consequently, there is limited capability for these sites to submit usage data to NAUSP. In addition, with very low patient numbers, it is challenging to produce meaningful reports to assist stewardship in these sites.

To minimise identification of individual hospitals, data submitted to NAUSP by Private Acute Group C and Private Acute Group D hospitals are aggregated with data from Public Acute Group C hospitals for comparative analyses. These contributor hospitals are mostly located in inner regional areas and major cities (Figure 20).

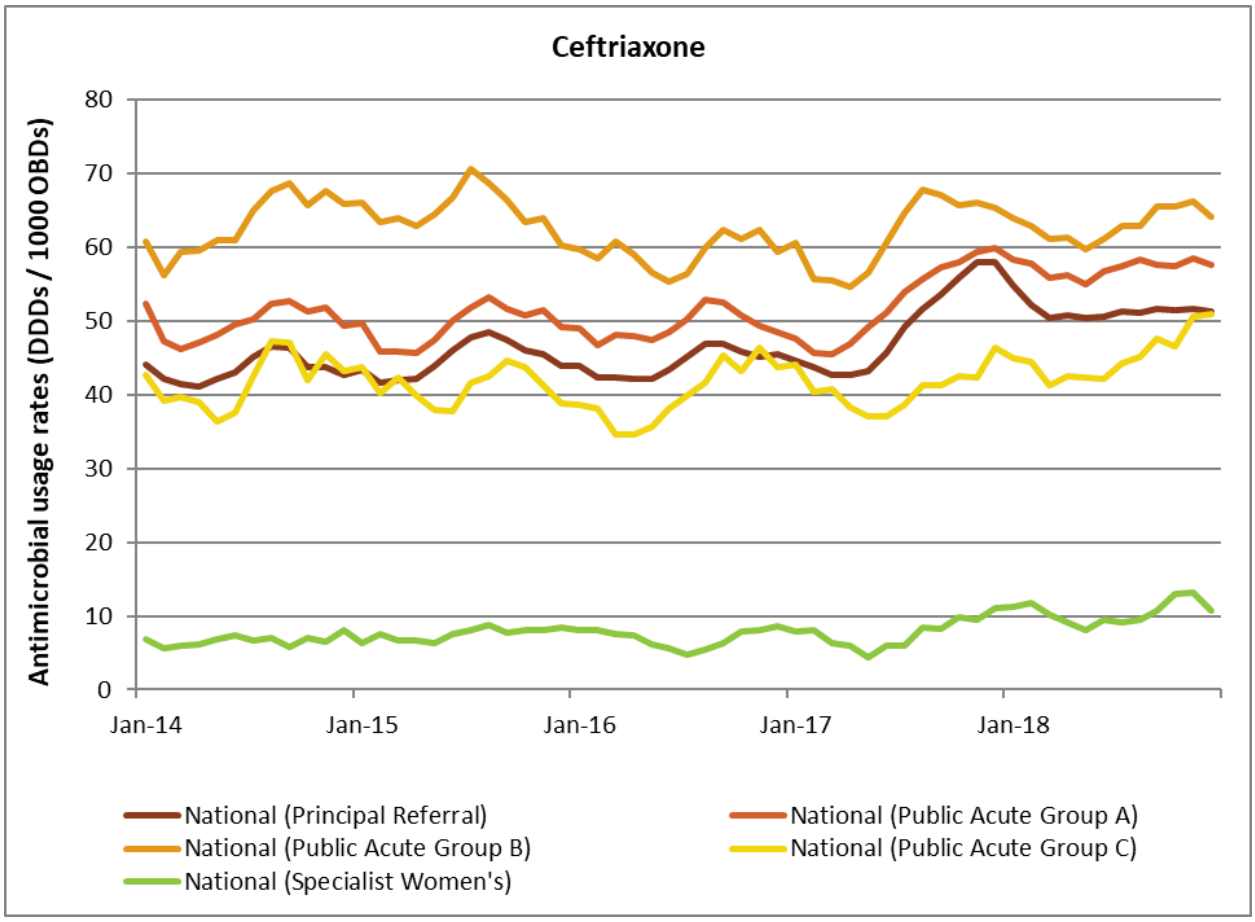
Figure 20: Public Acute Group C, Private Acute Group C and Private Acute Group D contributors to NAUSP according to remoteness area



NAUSP = National Antimicrobial Utilisation Surveillance Program

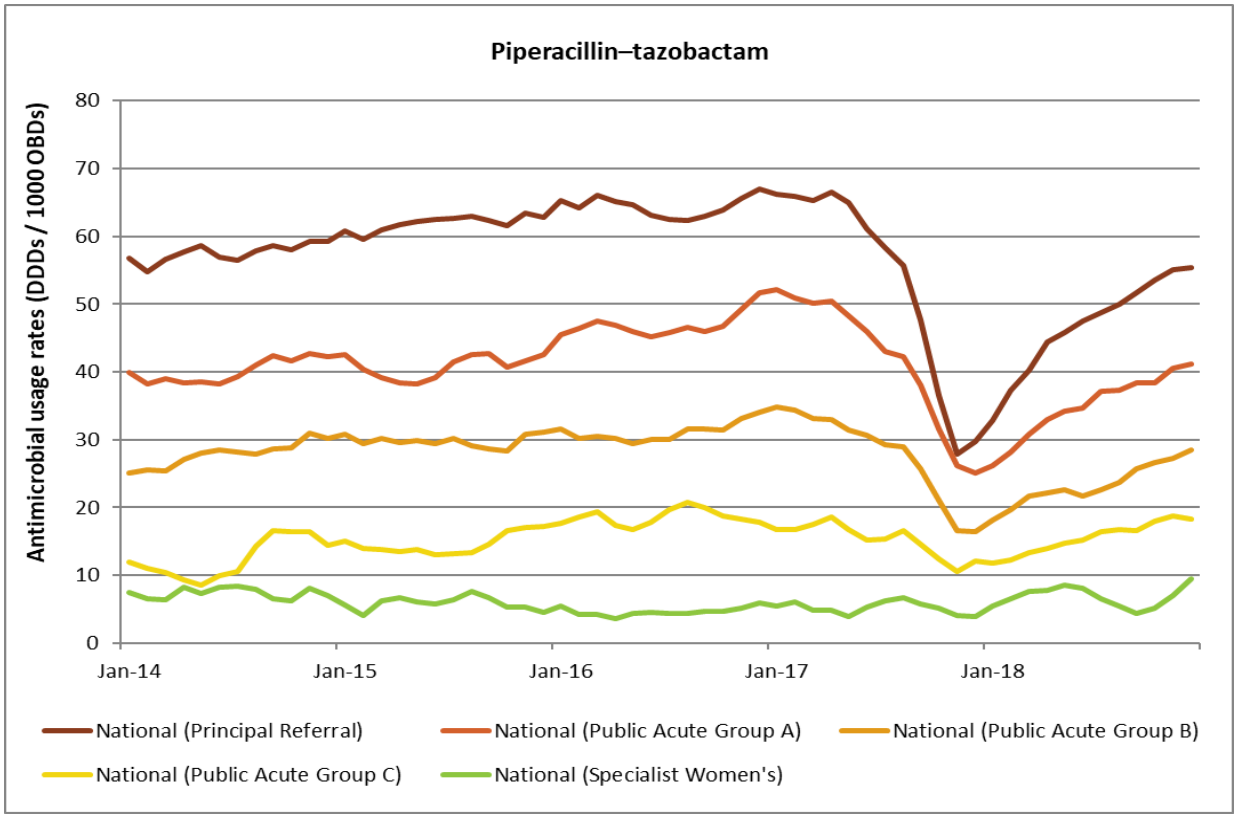
Usage of ceftriaxone in Public Acute Group C hospitals is lower than Principal Referral hospitals; however, usage increased from 2014 to 2018 (Figure 21). Ceftriaxone use was highest in Public Acute Group A and Public Acute Group C hospitals over this period. Piperacillin–tazobactam usage did not change substantially in Public Acute Group C hospitals between 2014 and 2018 (Figure 22). Although total ciprofloxacin usage trended downwards overall in Australia, there was an upward trend in usage in Public Acute Group C hospitals from 2016 to 2018 (Figure 23). Drug shortages may have contributed to this increased usage, highlighting the importance of AMS support in smaller facilities. There was an upward trend in vancomycin usage in Public Acute Group C hospitals between 2014 and 2018 (Figure 24).

Figure 21: Usage rates in NAUSP contributor hospitals for ceftriaxone by selected peer groups, 2014–2018 (3-month moving average)



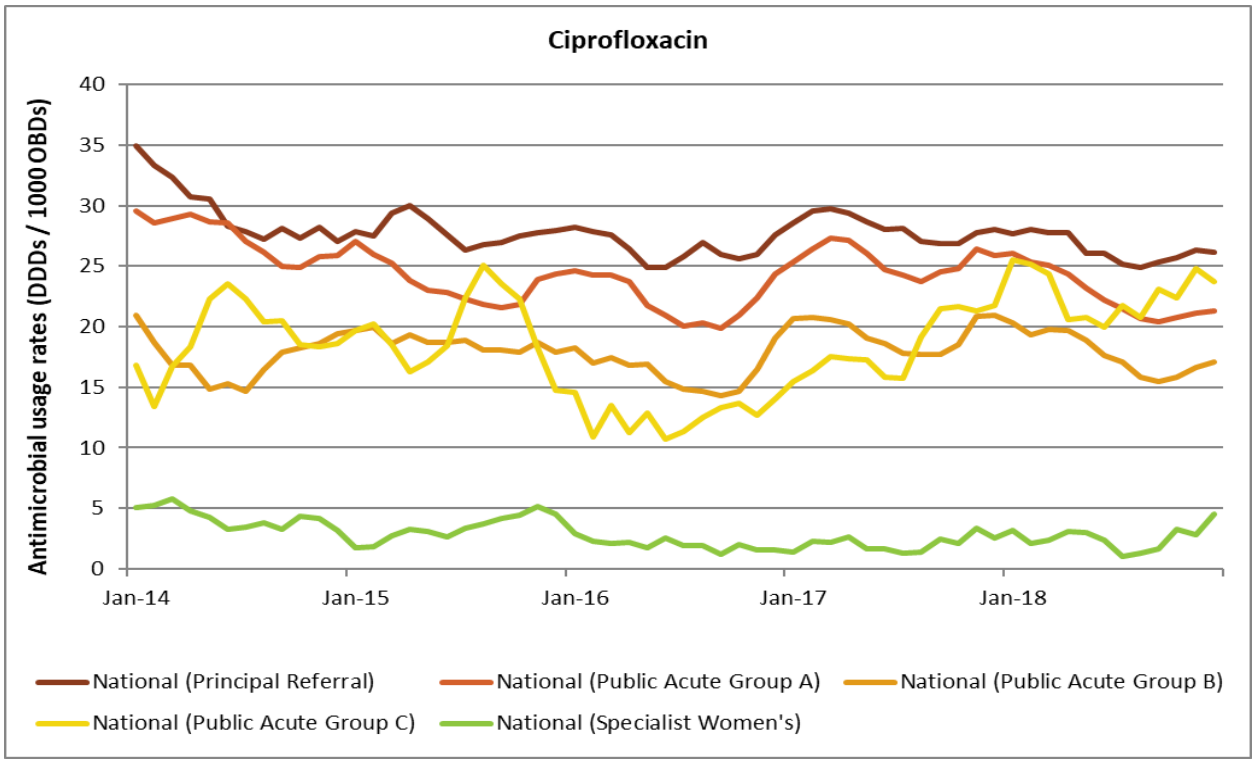
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day
Note: data from Private Acute Group D hospitals are aggregated with Public Acute Group C and Private Acute Group C hospital data due to the small number of sites.

Figure 22: Usage rates in NAUSP contributor hospitals for piperacillin–tazobactam by selected peer groups, 2014–2018 (3-month moving average)



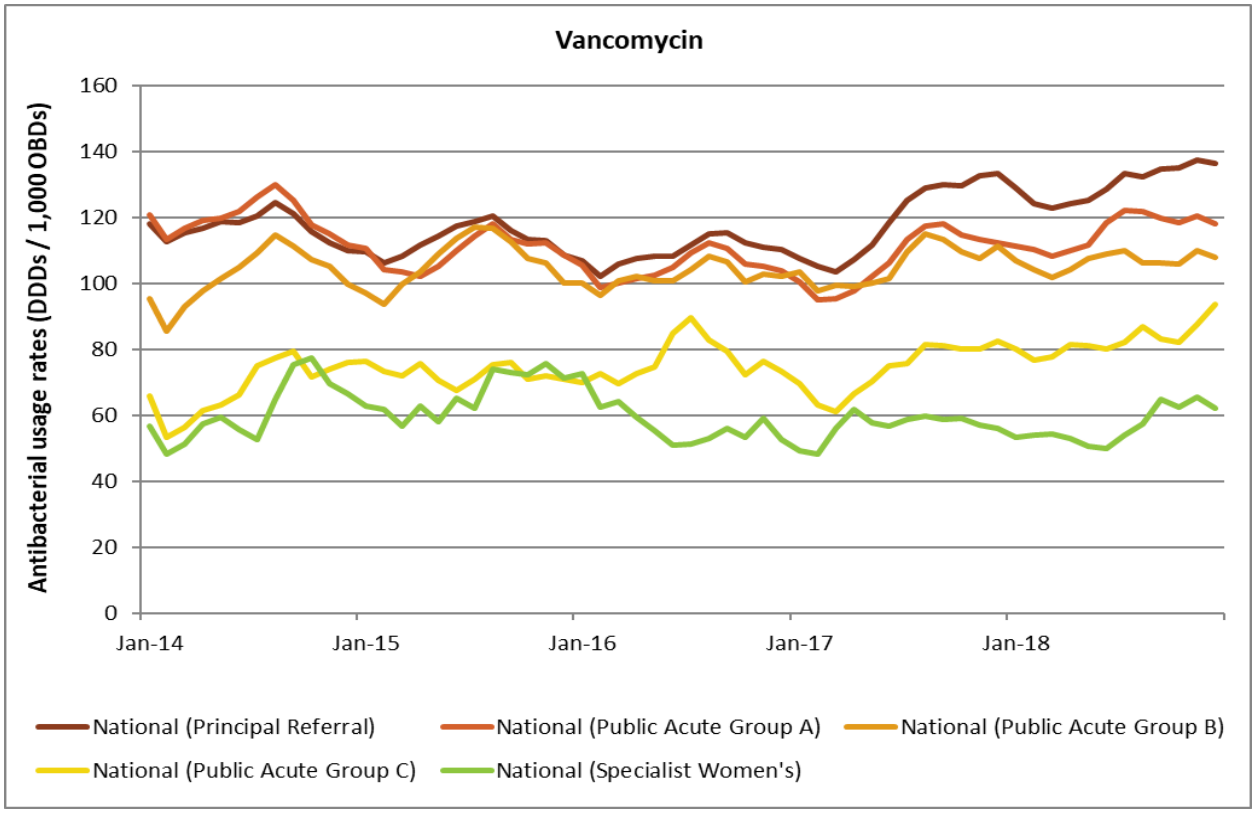
DDD = defined daily dose; NAUSP = National Antimicrobial Utilisation Surveillance Program; OBD = occupied bed day

Figure 23: Usage rates in NAUSP contributor hospitals for ciprofloxacin by selected peer groups, 2014–2018 (3-month moving average)



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

Figure 24: Usage rates in NAUSP contributor hospitals for vancomycin by selected peer groups, 2014–2018 (3-month moving average)



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

The 2018 Hospital National Antimicrobial Prescribing Survey (NAPS) identified that appropriateness of antimicrobial prescribing was lower in smaller hospitals compared to Principal Referral hospitals and specialised hospitals.[13] In addition, Hospital NAPS contributors located in major cities reported higher rates of compliance with either *Therapeutic Guidelines*[9] or locally endorsed guidelines than hospitals in other remoteness areas. Antimicrobial stewardship resources are often limited in smaller regional and remote hospitals making it more challenging to monitor prescribing restrictions on broad-spectrum antimicrobials.

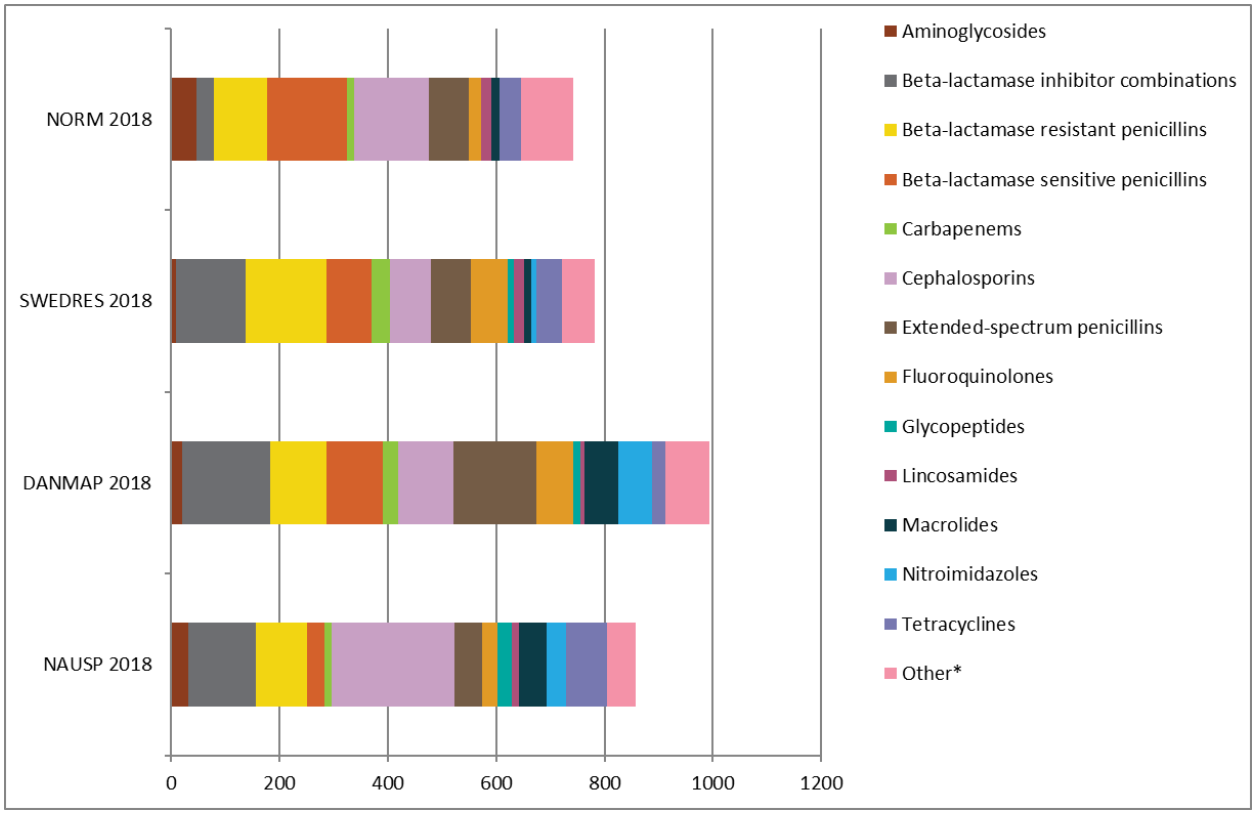
The 2018 Hospital NAPS also highlighted inappropriate prescribing of a number of broader spectrum agents in smaller hospitals. There may be a number of factors contributing to inappropriate prescribing in smaller hospitals, including the possible lack of antimicrobial stewardship support. The results in this report and the 2018 Hospital NAPS highlight the importance of identifying and developing strategies and resources to further support AMS programs for smaller hospitals.

International surveillance programs and benchmarking

2018 antibacterial data

European programs that use the same metrics (DDDs per 1,000 OBDs) as NAUSP include DANMAP (Denmark), SWEDRES (Sweden), NORM (Norway) and NethMap (the Netherlands). Since publication of the NAUSP Biennial Report, 2018 data has been published for Denmark, Norway and Sweden. Figure 25 illustrates the antibacterial usage rates for Australian hospitals that contributed to NAUSP during 2018, compared to rates published in the 2018 surveillance reports for Denmark[14], Norway[15] and Sweden.[16] Rates for all four countries were calculated using the 1 January 2019 DDD values.

Figure 25: 2018 antibacterial usage rates (DDDs/1,000 OBD) in NAUSP contributor hospitals, and hospitals in Denmark, Norway and Sweden



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

There is considerable variation in Australian antibacterial prescribing patterns compared to northern European countries. There is a notable preference for narrower-spectrum penicillins in Denmark and Sweden, and relatively lower cephalosporin use compared to Autralia. As reported in the NAUSP Biennial Report, rates of fluoroquinolone usage in Australia are lower than northern European countries, and are continuing to decrease.[1]

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).[18] 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 DDD per 1,000 OBDs.

Discussion

The analyses presented in this Supplement reflect the impact of the revised WHO DDD values on previously reported antibacterial usage rates. This resulted in a reduction in the calculated usage rates for a number of antibacterial classes, most notably the carbapenems, aminopenicillins, β-lactamase inhibitor combinations, fourth-generation cephalosporins and polymyxins. Although there was no change in trends due to this recalculation, the total annual aggregate use calculated for 2018 was 10.7% lower using the new DDD values for the analyses compared to previously reported volumes. Inclusion of Queensland data that was not previously available had little impact on overall trends between 2014 and 2018, despite small fluctuations by year.

Over the five-year period from 2014 to 2018, there were some notable differences in antimicrobial use in Queensland/Northern Territory compared to other states and territories. The total ciprofloxacin usage rate in Queensland/Northern Territory is one of the lowest in Australia. Conversely, the usage rate for meropenem is one of the highest. This could be due to its use for the treatment of melioidosis, but should be examined by Queensland/Northern Territory AMS programs to ensure this is the case. Ceftriaxone use increased in November 2017, then decreased in 2018 after resolution of the piperacillin–tazobactam shortage, and the implementation of a statewide approach to support containment of antimicrobial use. Doxycycline usage is seasonal, generally being higher in winter months due to its use as a first-line treatment for mild community-acquired pneumonia. However, overall doxycycline usage rates trended upwards in Queensland/Northern Territory between 2014 and 2018.

Analysis of usage rates by peer group using the revised DDD values with additional Queensland/Northern Territory public hospital data illustrated similar trends between hospital peer groups to those reported in the NAUSP Biennial Report. There was an increasing trend in the usage of fluoroquinolones in Public Acute Group C hospitals over the five-year period 2014 to 2018; the rate was similar to Principal Referral hospitals (Figure 15). Possible explanations for increased fluoroquinolone use include less AMS support during antimicrobial shortages to provide guidance on the prescribing of alternative agents. Ceftriaxone usage rates were higher in Public Acute Group A and Public Acute Group B hospitals than in Principal Referral hospitals. Another concerning trend was the increasing use of reserve-line narrow spectrum antibacterials in Public Acute Group C hospitals (Figure 17).

There were increases in the use of some reserve ‘last-line’ antimicrobial agents in Public Acute Group B and C facilities, which may be due to the transfer of patients closer to home to finish therapy for an antimicrobial-resistant infection acquired during treatment in a tertiary setting and/or a higher incidence of antimicrobial-resistant infections in rural and regional centres. This illustrates the importance of ensuring technical expertise across all peer groups, to ensure optimal and safe use of antimicrobials, including assistance with the complexity of prescribing these agents in non-tertiary centres.

The analyses presented in this Supplement confirm the importance of providing smaller hospitals with support for antimicrobial stewardship. 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.

Appendix 1 Contributor information

State or territory	Hospital		
Australian Capital Territory	Canberra Hospital and Health Services	Calvary Public Hospital Bruce	
New South Wales	Armidale Hospital	Griffith Base Hospital	Prince of Wales Hospital
	Auburn Hospital	Hornsby Ku-Ring-Gai Hospital	Queanbeyan Hospital
	Bankstown - Lidcombe Hospital	John Hunter Hospital	Royal North Shore Hospital
	Batemans Bay District Hospital	Kareena Private Hospital	Royal Prince Alfred Hospital
	Bathurst Base Hospital	Kempsey District Hospital	Ryde Hospital
	Belmont Hospital	Lismore Base Hospital	Scott Memorial Hospital
	Blacktown Hospital	Liverpool Hospital	Shellharbour Hospital
	Bowral Hospital	Maclean District Hospital	Shoalhaven Hospital
	Broken Hill Base Hospital	Maitland Hospital	Singleton District Hospital
	Calvary Riverina Hospital	Manly Hospital	South East Regional Hospital (Bega Hospital)
	Campbelltown Hospital	Manning Base Hospital	St George Hospital
	Canterbury Hospital	Mater Hospital North Sydney	St Vincent's Hospital Sydney
	Cessnock District Hospital	Milton-Ulladulla Hospital*	St Vincent's Private Hospital Sydney
	Coffs Harbour Hospital	Mona Vale Hospital	Sutherland Hospital
	Concord Hospital	Moruya Hospital	Sydney Adventist Hospital
	Cooma Health Service	Mt Druitt Hospital	Tamworth Hospital
	Dubbo Base Hospital	Mudgee District Hospital	The Tweed Hospital
	Fairfield Hospital	Muswellbrook Hospital	Wagga Wagga Base Hospital
	Forbes District Hospital	Nepean Hospital	Westmead Hospital
	Gosford Hospital	Newcastle Mater	Westmead Private Hospital
	Gosford Private Hospital	Orange Health Service	Wollongong Hospital
	Goulburn Base Hospital	Parkes Hospital	Wyong Hospital
	Grafton Base Hospital	Port Macquarie Base Hospital	Young Health Service
Queensland	Atherton Hospital	Mackay Base Hospital	Princess Alexandra Hospital
	Bundaberg Hospital	Mareeba Hospital	Queen Elizabeth II Jubilee Hospital
	Caboolture Hospital	Maryborough Hospital	Redcliffe Hospital
	Cairns Base Hospital	Mater Hospital Bundaberg	Redland Hospital
	Gladstone Hospital	Mater Hospital Gladstone	Robina Hospital
	Gold Coast Private Hospital	Mater Hospital Mackay	Rockhampton Base Hospital
	Gold Coast University Hospital	Mater Mothers' Hospital	Royal Brisbane & Women's Hospital
	Greenslopes Private Hospital	Mater Hospital Brisbane	St Vincent's Private Brisbane
	Gympie Hospital	Mater Private Hospital Brisbane	St Vincent's Private Northside
	Hervey Bay Hospital	Mater Private Hospital Redland	Sunshine Coast University Hospital
	Innisfail Hospital	Mater Private Hospital Rockhampton	The Prince Charles Hospital
	Ipswich Hospital	Mater Private Hospital Springfield	Toowoomba Hospital
	Kingaroy Hospital	Mount Isa Hospital	Townsville Hospital
	Logan Hospital	Nambour General Hospital	Warwick Hospital
Northern Territory	Alice Springs Hospital	Katherine Hospital	
	Gove Hospital	Royal Darwin Hospital	
South Australia	Ashford Hospital	Gawler Health Service	Port Lincoln Hospital
	Berri Hospital	Lyell McEwin Hospital	Port Pirie Hospital
	Calvary Central Districts	Memorial Hospital	Royal Adelaide Hospital
	Calvary North Adelaide Hospital	Modbury Hospital	St Andrew's Hospital
	Calvary Wakefield Hospital	Mount Gambier Hospital	The Queen Elizabeth Hospital
	Flinders Medical Centre	Noarlunga Hospital	The Women's & Children's Hospital
	Flinders Private Hospital	Port Augusta Hospital	Whyalla Hospital
Tasmania	Calvary Lenah Valley	Launceston General Hospital	North West Regional Hospital
	Hobart Private Hospital	Mersey Community Hospital	Royal Hobart Hospital

State or territory	Hospital		
Victoria	Albury Wodonga Health - Albury Campus	Frankston Hospital	St Vincent's Private Hospital Fitzroy
	Albury Wodonga Health - Wodonga Campus	Geelong Hospital	St Vincent's Private Hospital Kew
	Angliss Hospital	Maroondah Hospital	St Vincent's Private Werribee
	Austin Hospital	Mercy Hospital for Women	The Alfred Hospital
	Ballarat Base Hospital	Monash Medical Centre Clayton	The Northern Hospital
	Bendigo Hospital	Monash Moorabbin Hospital	Warrnambool Base Hospital
	Box Hill Hospital	Northeast Health Wangaratta	Werribee Mercy Hospital
	Cabrini Hospital Brighton	Peter MacCallum Cancer Centre	West Gippsland Hospital
	Cabrini Hospital Malvern	Royal Melbourne Hospital	Western Hospital Footscray
	Casey Hospital	Sandringham & District Memorial Hospital	Western Health Sunshine Hospital
	Central Gippsland Health Service	St Vincent's Hospital Melbourne	
	Dandenong Hospital	St Vincent's Private Hospital East Melbourne	
Western Australia	Albany Hospital	Fremantle Hospital	Northam Hospital*
	Armadale Kalamunda Group	Geraldton Hospital	Osborne Park Hospital
	Bentley Hospital	Hedland Health Campus	Rockingham General Hospital
	Broome Hospital	Joondalup Health Campus	Royal Perth Hospital
	Bunbury Hospital	Kalgoorlie Hospital	Sir Charles Gairdner Hospital
	Busselton Hospital	King Edward Memorial Hospital for Women	St John of God Hospital Bunbury
	Derby Hospital	Kununurra Hospital	St John of God Hospital Midland
	Esperance Hospital	Mount Hospital	St John of God Hospital Subiaco
	Fiona Stanley Hospital	Narrogin Hospital*	St John of God Murdoch Hospital

*Hospital commenced NAUSP participation in July 2018 – 6 months' data included in this supplement

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

Antibacterial agents

ATC classification	Generic name	DDD (g)	Route
J01AA	Tetracyclines		
J01AA02	Doxycycline	0.1	O, P
J01AA08	Minocycline	0.2	O, P
J01AA12	Tigecycline	0.1	P
J01B	Amphenicols		
J01BA01	Chloramphenicol	3	O, P
J01C	β–lactam antibacterials, penicillins		
J01CA	Penicillins with extended spectrum		
J01CA01	Ampicillin	6*	O, P
J01CA04	Amoxicillin	1.5*	O
J01CA04	Amoxicillin	3*	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	B-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	1.5*	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	4*	P
J01DI	Other cephalosporins and penems		
J01DI02	Ceftaroline	1.2	P
J01DI54	Ceftolozane and tazobactam	3	P
J01DH	Carbapenems		
J01DH02	Meropenem	3*	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

ATC classification	Generic name	DDD (g)	Route
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	0.8*	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	9MU*	P, Inh
J01XC	Steroid antibacterials		
J01XC01	Fusidic acid	1.5	O, P
J01XD	Imidazole derivatives		
J01XD01	Metronidazole	1.5	P
P01AB01	Metronidazole	2	O, R
P01AB02	Tinidazole	2	O
J01XX	Other antibacterials		
J01XX01	Fosfomycin	3	O
J01XX01	Fosfomycin	8	P
J01XX08	Linezolid	1.2	O, P
J01XX09	Daptomycin	0.28	P
J04	Antimycobacterials		
J04AB03	Rifampicin	0.6	O, P
A07AA	Intestinal anti-infectives		
A07AA11	Rifaximin	0.6	O
A07AA12	Fidaxomicin	0.4	O

ATC = Anatomical Therapeutic Classification; DDD = defined daily dose; Inh = inhalation; MU = Million units; O = oral; P = parenteral; R = rectal
*DDD value updated 1 January 2019

Antifungal agents

ATC classification	Generic name	DDD (g)	Route
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
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; MR = Modified Release; O = oral; P = parenteral
* DDD assigned by NAUSP
Source: WHO (2019)[12]

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 Wellbeing
WHO	World Health Organization

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 anti-parasitic 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: Usage density rate = $\frac{\text{Number of DDDs/time period}}{\text{}}$ x 1,000 OBDs/time period

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Additional NAUSP data are available at www.sahealth.sa.gov.au/nausp and a range of information and AURA Surveillance System reports is available at https://www.safetyandquality.gov.au/our-work/antimicrobial-resistance/antimicrobial-use-and-resistance-australia-surveillance-system.

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