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Antimicrobial Use in Australian Hospitals

National Antimicrobial Utilisation Surveillance Program Annual Report

2020

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SA Health

NAUSP
National Antimicrobial Utilisation Surveillance Program

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2020 at a glance

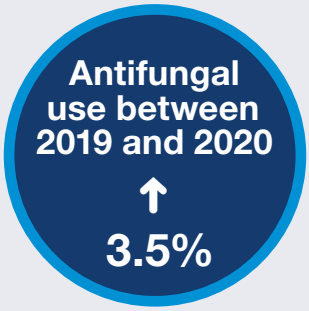
Total antibacterial usage decreased by 2.9% in Australian hospitals in 2020 compared to 2019.

By antibacterial class:

Usage of some broad spectrum antibacterial classes increased in 2020:

Carbapenems – **up 3.1%**
(from 14.7 to 15.2 DDD / 1,000 OBD)

Fourth-generation cephalosporins – up **9.0%**
(from 4.4 to 4.8 DDD / 1,000 OBD)



The number of participating hospitals increased by 6.8% between 2019 and 2020.

In 2020, 231 hospitals submitted data for the inclusion in NAUSP reports.

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DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

Summary

This annual report of the National Antimicrobial Utilisation Surveillance Program (NAUSP) presents a summary of analyses of antimicrobial usage data submitted by 231 public and private hospitals across all states and territories in Australia; and trends for the period 2016 to 2020.

Key findings of the analyses of the 2020 data include the following:

- Total hospital antibacterial usage decreased by 2.9% in Australian public and private hospital contributors in 2020 compared to 2019 – from 884.7 to 859.1 defined daily dose (DDD) / 1,000 occupied bed days (OBD).
- By antibacterial class, there were notable decreases seen in nationwide use of the tetracyclines (–20.6%), macrolides (–15.5%) and the ß-lactamase sensitive penicillins (–10.9%) between 2020 and 2019.
- Substantial differences in prescribing trends continue to be seen between the states and territories in Australia. In 2020, annual aminoglycoside usage in Queensland and the Northern Territory was almost 3 times the annual usage rate in Victoria. South Australian usage of fourth generation cephalosporins is almost twice the national aggregate rate, and more than 3 times the usage rate in Tasmania. Carbapenem usage is highest in Western Australia.
- Use of alimentary antibacterials (oral vancomycin, fidaxomicin, paromomycin and rifaximin) increased from 10.9 DDD / 1,000 OBD to 14.1 DDD / 1,000 OBD – an increase of 28.9% from 2019 to 2020.
- Use of topical chloramphenicol ointment is trending upwards: in 2020, the national aggregate monthly usage rate was on average 0.42 grams (g) of chloramphenicol per 1,000 OBD, equivalent to ten 4 g tubes of 1% ointment per 1,000 OBD. The average monthly usage rate in 2019 was 0.37 g / 1,000 OBD, representing a relative increase of 11.9%. (Note: some of this difference may be due to under-reporting in 2019, which was the first year topical antimicrobials were included in NAUSP data definitions).
- Systemic antifungal usage has increased nationally each year since routine submission of antifungal data began in 2017. Total hospital annual usage increased by 3.5% between 2019 and 2020, to 36.5 DDD / 1,000 OBD.

Implications for antimicrobial stewardship

In 2020 there was an overall reduction in total systemic antibacterial usage in Australian hospitals, from 884.7 DDD / 1,000 OBD in 2019 to 859.1 DDD / 1,000 OBD - a reduction of 2.9%. In February and March of 2020, at the beginning of the COVID-19 pandemic in Australia, there was a surge in antimicrobial usage rates across many contributing hospitals. This may have been due to an initial increase in stock distributed to the wards in anticipation of increased demand. Usage rates then fell across many antibacterial classes in the latter half of 2020.

Antibacterial usage has increased annually between 2016 and 2019 in NAUSP contributor hospitals.[1] The first case of SARS-CoV-2 was recorded in Australia on the 25 January 2020, with initial lockdowns due to the COVID-19 pandemic occurring in Australia from March 2020. Hospital activity was impacted by the COVID-19 pandemic, with non-urgent surgery being suspended for various periods across the states and territories. Wards in some public hospitals were repurposed to accommodate COVID-19 patients and some private hospitals closed temporarily. This annual report includes data from 231 Australian hospitals, which is an increase from 214 hospitals that contributed data in 2019. However, the total activity (as measured by total acute OBD) was 1.4% less in 2020 than in 2019.

The marked variation in antimicrobial usage between the states and territories that has been reported in previous years continues to be seen across multiple antibacterial and antifungal classes. It is expected that some variation will be seen due to differing casemix and acuity between hospitals. However, the large differences in aggregate usage of some broad-spectrum agents across the states and territories is not readily explained by variation in hospital casemix alone. Understanding the underlying reasons for these differences in clinical practice would help inform policies and antimicrobial stewardship strategies to reduce overall use, increase consistency of antimicrobial prescribing in accordance with clinical guidelines, and ultimately limit the development and spread of antimicrobial resistance (AMR).

Issues that require investigation by states, territories, private health service providers and individual hospitals include:

- marked variation between states and territories in the usage rates for a number of antibacterial classes, including the aminoglycosides, the ß-lactamase inhibitor combinations, carbapenems and fourth-generation cephalosporins
- relatively low proportionate use of *Access* category antibacterials (of the Priority Antibacterial List for Antimicrobial Resistance Containment (PAL)[2]) in private hospitals compared to similarly peered public hospitals
- variation between the states and territories in the proportional usage of antibacterials included in the *Curb* category of the PAL
- the increasing use of topical chloramphenicol ointment in NAUSP contributor hospitals and the substantial variation in usage of topical mupirocin between states and territories, particularly in the critical care setting. Inappropriate usage of topical antimicrobials should be a focus of stewardship interventions, because there is inadequate evidence illustrating the benefits outweigh the potential harms[3]
- the variation in usage of systemic antifungals between states and territories, in both the volume of use and the agents used.

What action should be taken?

- The Australian Government Department of Health and Aged Care will continue to collaborate with programs contributing to the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System to strengthen concerted actions to optimise antimicrobial use and mitigate the impact of AMR; and drive awareness and understanding across all sectors.
- State and territory governments should build capacity to control AMR and support evidence-based antimicrobial use. Jurisdictions should ensure hospitals have the resources and expertise to support an antimicrobial stewardship program, including participation in surveillance activities and education of staff.
- The Australian Commission on Safety and Quality in Health Care will continue to provide resources for health providers and consumers to support appropriate antimicrobial use.
- Hospitals should regularly review the antimicrobial usage in their institutions, utilising the NAUSP portal to download usage reports to assist antimicrobial stewardship teams in identifying inappropriate use or unexpected trends in usage. NAUSP reports should be interpreted within the context of the clinical acuity of the hospital, utilising other information (such as National Antimicrobial Prescribing Surveys) to determine appropriateness of use and whether further interventions are necessary.
- NAUSP will continue to support participating hospitals to educate pharmacists or infection control practitioners on how to submit data and extract reports to support antimicrobial stewardship in their hospitals. NAUSP will continue to encourage engagement from private hospitals to facilitate their involvement with the program.
- Priority areas of research should be identified by all stakeholders to inform future interventions to optimise antimicrobial use.

Introduction

Antimicrobial resistance (AMR) is acknowledged by the Australian Government as a major threat to human and animal health. Increasing antimicrobial resistance compromises the safe administration of health care and is associated with an increased risk of hospitalisation and poorer patient outcomes. *Australia's National Antimicrobial Resistance Strategy – 2020 and beyond*[4] aims to provide a nationally coordinated approach to managing the risk of antimicrobial resistance and is aligned with the goals and framework of the World Health Organization (WHO) *Global Action Plan on Antimicrobial Resistance*.[5]

One of the main objectives of the *Australian Government One Health Master Action Plan*, released in 2021, is to integrate surveillance of antimicrobial usage and AMR in all sectors in order to inform policy decision-making.[6] The National Antimicrobial Utilisation Surveillance Program (NAUSP) was established in 2004, and since 2014 has been a collaborative partner of the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System, playing a pivotal role in supporting antimicrobial stewardship (AMS) and informing local, state, territory and national policy to contain AMR.

The NAUSP provides a standardised measurement of antimicrobial use in Australian acute public and private hospitals using the metric of WHO defined daily doses (DDD)[7] per 1,000 occupied bed days (OBD). Hospitals contribute antimicrobial usage data to NAUSP on a voluntary basis via an online portal. Participation in NAUSP supports hospitals in meeting the AMS requirements of the National Safety and Quality Health Service Standards.[8] The number of hospitals participating in NAUSP continues to increase annually.

Table 1 shows the number of contributor hospitals, by Australian Institute of Health and Welfare (AIHW)[9] peer group and by calendar year, that contributed data for the last 5 years (see the glossary for a description of AIHW peer groups). Hospitals are included in the contributor count if they have contributed data at any time in the specified year (note that numbers may differ from previous reports where all registered hospitals were included irrespective of whether they contributed data for a particular year). Contributing hospitals assigned to each AIHW peer group may vary from previous NAUSP reports due to restructure of health services or changes in acuity resulting in reclassification by the AIHW.

Table 1: NAUSP participation by public hospitals (by peer group) and private hospitals, 2016–2020

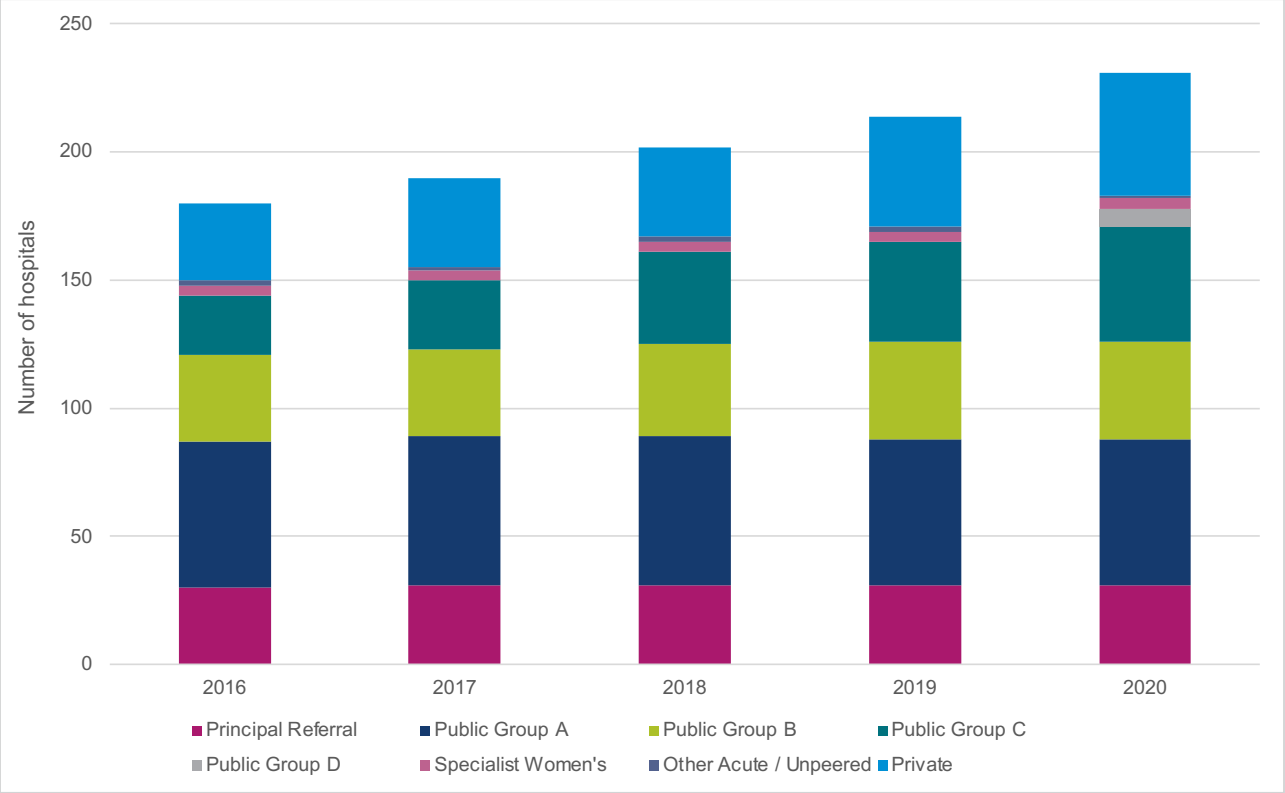
Year ending	Principal referral hospitals	Public Acute Group A hospitals	Public Acute Group B hospitals	Public Acute Group C hospitals	Public Acute Group D hospitals	All private hospitals	Other acute/ unpeered	Specialist women's hospitals	Total
2016	30	57	34	23	0	30	2	4	179
2017	31	58	34	27	0	35	1	4	191
2018	31	58	36	36	0	35	2	4	202
2019	31	57	38	39	0	43	2	4	214
2020	31	57	38	45	7	48	1	4	231

Note: This table shows the number of hospitals registered to participate and who have provided data to the NAUSP. Not all hospitals were able to provide validated data for the analyses in this report. Numbers shown may differ from those previously reported due to hospitals merging, closing or withdrawing from the program.

NAUSP: National Antimicrobial Utilisation Surveillance Program.

The number of private hospitals participating in NAUSP has increased steadily over the last 5 years (Figure 1); in 2020 there were 48 private facilities that contributed data for inclusion in this 2020 annual report.

Figure 1: NAUSP contributors* by peer group, 2016–2020



* A contributor is a hospital registered with NAUSP that contributed data for the specified year.

NAUSP: National Antimicrobial Utilisation Surveillance Program.

Hospitals that did not contribute at least 6 months of data in 2020 have been excluded from the analyses in this 2020 annual report. A complete list of all hospitals that contributed data for this report is provided in Appendix 1. The methods used to interpret NAUSP data are set out in Appendix 2. Limitations and considerations for interpretation of NAUSP data are included in Appendix 3.

Data for this report were extracted from the NAUSP portal between the 22 August and 17 September 2021. Antibacterial usage and antifungal usage are reported separately in this report. Aggregated usage rates are calculated by dividing the total acute DDD by the total OBD. Usage rates may vary slightly from previous reports as a result of retrospective data adjustments, the hospitals included in the analysis, variation in peer group assignment by the AIHW, and changes to DDD values assigned by the WHO. Usage rates in this report reflect distributions to the wards as an estimate of antimicrobial consumption and this limitation does not allow analysis of actual consumption, nor is it possible to know the indications for which antimicrobials are used at a population level.

The coronavirus disease 2019 (COVID-19) pandemic, which commenced in Australia at the end of January 2020, posed a number of challenges that potentially affected AMS programs in Australia.

Annual acute usage rates for all antibacterial classes

Table 2 provides the annual total-hospital systemic antibacterial usage rates reported by NAUSP contributor hospitals from 2016 to 2020. There was a decrease of 2.9% in the total-hospital aggregate usage rate from 2019 to 2020, falling back to 859.1 DDD / 1,000 OBD, which is 1.0% lower than the 2016 aggregate usage rate. The relative change in usage of antibacterial classes is illustrated in Figure 2.

Table 2: Annual total-hospital systemic antibacterial usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, by antibacterial class, 2016–2020

Antibacterial (WHO) classification	2016 (n=168)	2017 (n=187)	2018 (n=200)	2019 (n=214)	2020 (n=231)	% change 2019-2020	% change 2016-2020
Alimentary antibiotics*	1.3	8.2	8.7	10.9	14.1	28.9%	-
Aminoglycosides (excl streptomycin)	31.5	29.8	31.1	28.5	28.2	-1.0%	-10.5%
Amphenicols	0.0	0.0	0.0	0.0	0.0	-	-
ß-lactamase inhibitor combinations	137.9	130.4	125.9	131.7	130.5	-0.9%	-5.4%
ß-lactamase resistant penicillins	95.2	94.5	95.9	91.4	87.9	-3.8%	-7.7%
ß-lactamase sensitive penicillins	34.6	35.2	32.7	29.2	26.0	-10.9%	-24.7%
Carbapenems	13.4	13.5	14.2	14.7	15.2	3.1%	13.3%
Extended spectrum penicillins	54.4	52.5	51.6	57.3	53.6	-6.5%	-1.5%
First-generation cephalosporins	151.0	151.2	153.1	161.1	170.5	5.8%	12.9%
Fluoroquinolones	31.2	30.5	29.0	27.3	26.5	-2.8%	-15.2%
Fourth-generation cephalosporins	3.2	5.8	5.7	4.4	4.8	9.0%	49.4%
Glycopeptides	26.8	25.8	25.8	25.6	25.2	-1.5%	-6.0%
Lincosamides	13.7	13.6	13.3	13.1	13.5	3.2%	-1.8%
Macrolides	57.3	54.5	51.4	51.1	43.2	-15.5%	-24.7%
Monobactams	0.4	0.3	0.4	0.3	0.3	-13.9%	-31.2%
Nitrofurans	1.3	1.5	1.4	1.6	1.8	11.5%	42.7%
Nitroimidazoles (metronidazole, tinidazole)	37.7	35.4	36.6	32.6	32.0	-1.7%	-15.1%
Other antibacterials and combinations#	2.8	3.6	4.8	8.7	10.5	21.3%	273.4%
Other cephalosporins and penems^	0.1	0.1	0.2	0.2	0.2	-5.9%	103.7%
Polymyxins	0.4	0.4	0.3	0.3	0.2	-23.4%	-55.1%
Rifamycins	5.6	5.3	5.0	5.0	4.6	-7.2%	-18.0%
Second-generation cephalosporins	7.2	8.5	8.8	9.9	8.2	-17.7%	13.5%
Steroids (fusidic acid)	1.1	1.0	0.8	0.7	0.7	-3.8%	-40.3%
Streptogramins	0.4	0.4	0.4	0.4	0.3	-36.0%	-21.3%
Sulfonamethoxazole-trimethoprim	17.4	17.9	18.1	19.1	19.4	1.6%	11.9%
Tetracyclines	73.3	79.8	76.8	86.7	68.8	-20.6%	-6.1%
Third-generation cephalosporins	52.7	56.6	60.2	60.5	60.6	0.1%	15.1%
Trimethoprim	15.4	14.0	13.0	12.3	12.3	-0.2%	-20.3%
Grand total	**867.5**	**870.1**	**865.3**	**884.7**	**859.1**	**-2.9%**	**-1.0%**

* Alimentary antibiotics were not included in NAUSP data definitions and data were not routinely collected by NAUSP prior to 2017.

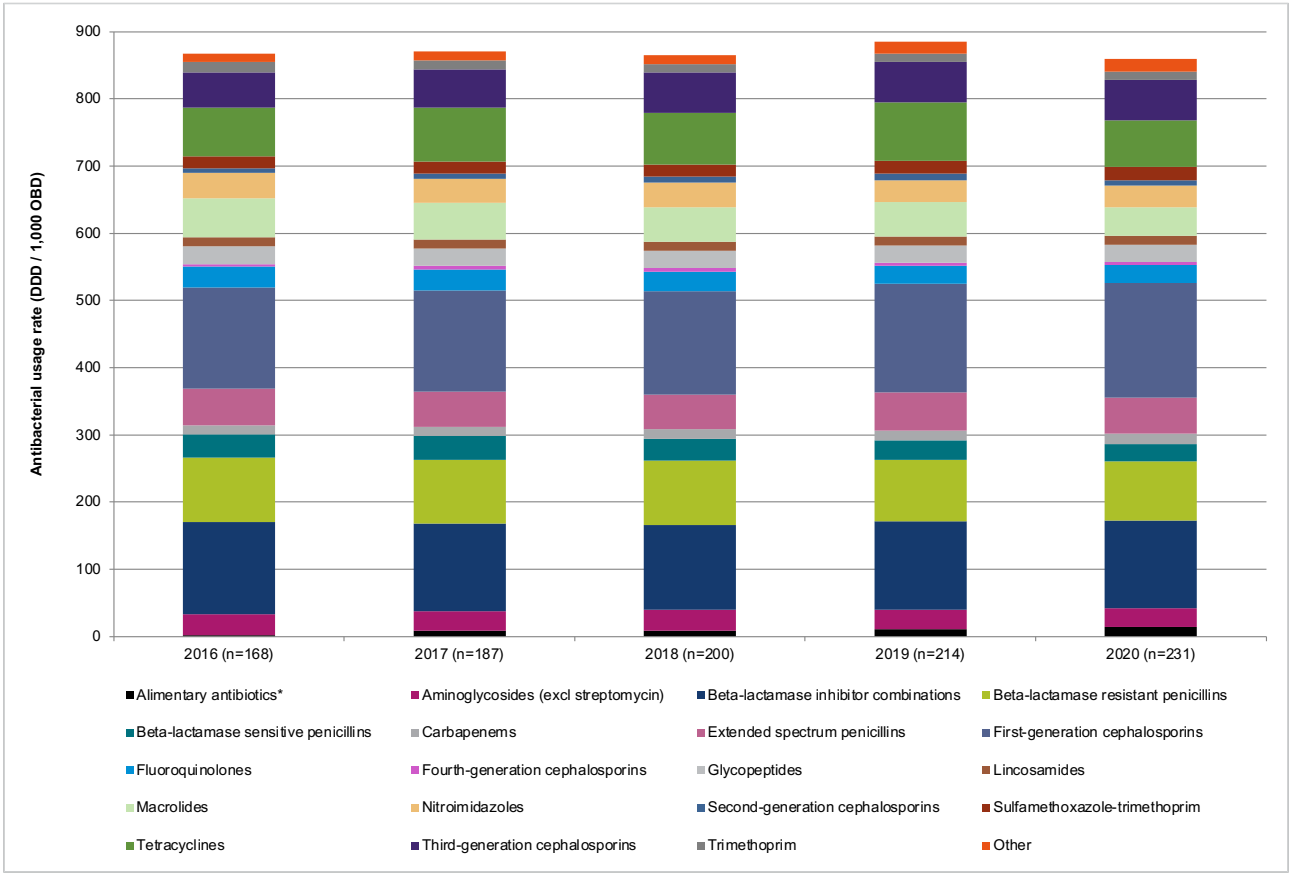
'Other antibacterials and combinations' are fosfomycin, linezolid, daptomycin, tedizolid.

^ 'Other cephalosporins and penems' are ceftaroline, faropenem, cefiderocol, ceftolozane–tazobactam.

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

DDD: defined daily doses; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days; WHO: World Health Organization.

Figure 2: Annual total-hospital systemic antibacterial usage rates (DDD /1,000 OBD) in NAUSP contributor hospitals, by antibacterial class, 2016–2020



* Data on alimentary antibiotics were not collected by NAUSP prior to 2017.

'Other' includes combination products for the eradication of *Helicobacter pylori*, cycloserine, rifampicin, rifabutin, monobactams, nitrofurans, polymyxins, sodium fusidate, streptogramins, other cephalosporins, fosfomycin, linezolid, daptomycin, tedizolid.

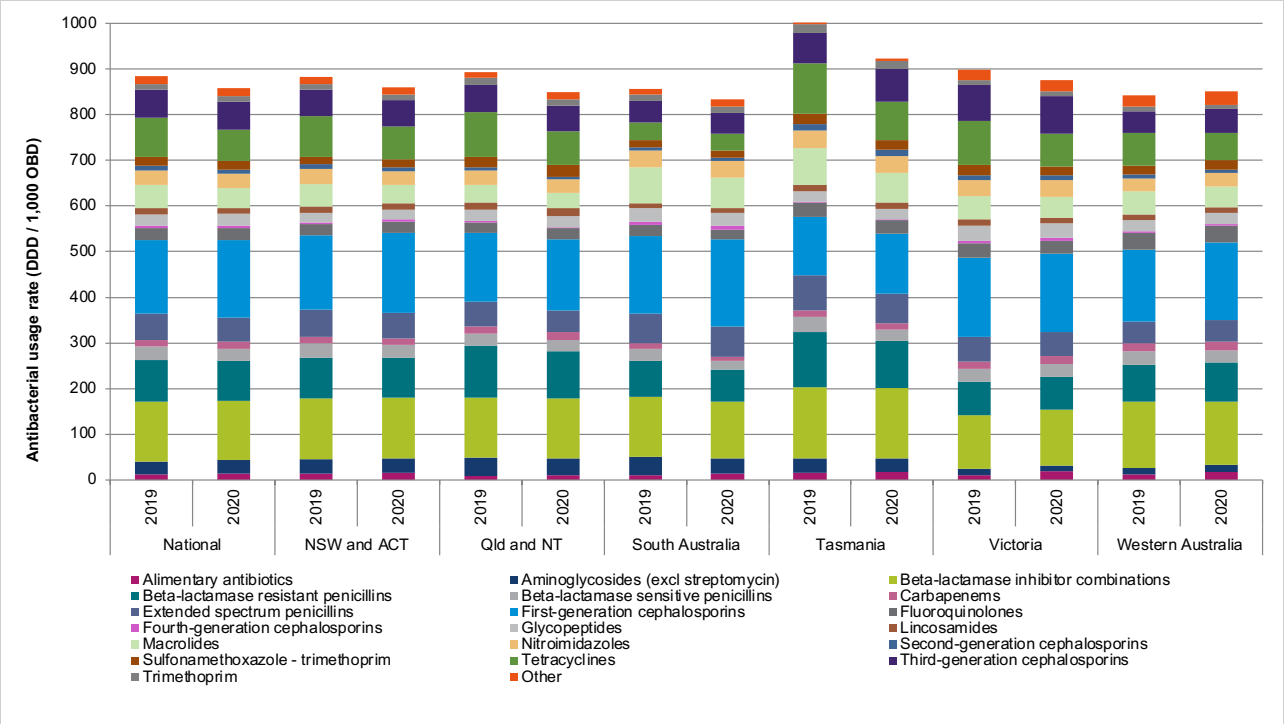
DDD: defined daily doses; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

Notably there was a substantial reduction in the usage of macrolide antibacterials (azithromycin, clarithromycin, roxithromycin, erythromycin) between 2019 and 2020, with the national annual aggregate usage rate falling from 51.1 DDD / 1,000 OBD to 43.2 DDD / 1,000 OBD – a drop of 15.5% (Figure 2). Inpatient tetracycline usage fell 20.6% in 2020 compared to 2019 – from 86.7 DDD / 1,000 OBD to 68.8 DDD / 1,000 OBD. National usage of third- and fourth-generation cephalosporins increased 0.1% and 9.0% respectively between 2019 and 2020 (refer to Table 2 for actual usage rates).

Antibacterial usage rates by state and territory

Figure 3 illustrates total-hospital antibacterial use for NAUSP contributors nationally and by Australian state and territory in 2019 and 2020.

Figure 3: Aggregate total-hospital antibacterial usage rates by class in NAUSP contributor hospitals, by state and territory, 2019–2020



* Data on alimentary antibiotics were not collected by NAUSP prior to 2017.

'Other' includes combination products for the eradication of H. pylori, cycloserine, rifampicin, rifabutin, monobactams, nitrofurans, polymyxins, sodium fusidate, streptogramins, other cephalosporins, fosfomycin, linezolid, daptomycin, tedizolid.

ACT: Australian Capital Territory; DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; NSW: New South Wales; NT: Northern Territory; OBD: occupied bed days; Qld: Queensland.

There is substantial variability in the proportional use of antibacterial classes in 2019 and 2020 across states and territories. With the exception of Western Australia, the aggregate usage rates fell between 2019 and 2020 across all states and territories. The greatest decrease in antimicrobial usage occurred in Tasmania (–9.0 %), followed by Queensland and the Northern Territory (–4.8%).

Table 3 shows usage rates for all states and territories, by antibacterial class from 2019 to 2020. During this period:

- Inpatient usage of tetracyclines fell markedly across all states and territories - for example, total hospital usage in Victoria fell 25.2% from 97.6 DDD / 1,000 OBD in 2019 to 73.0 DDD / 1,000 OBD in 2020. Similar decreases were seen in Queensland and the Northern Territory (-24.0%) and Tasmania (-22.5%).
- Carbapenem usage decreased in Tasmania and South Australia by 16.9% and 14.1% respectively; however, usage increased in all other states. The greatest increase in usage was in Queensland and the Northern Territory, where usage increased from 15.4 DDD / 1,000 OBD in 2019 to 16.6 DDD / 1,000 OBD in 2020 - a rise of 7.9%. Carbapenem usage was highest in Western Australia (19.7 DDD / 1,000 OBD) - Western Australia had twice the usage rate of South Australia.
- Total annual use of the macrolides (azithromycin, clarithromycin, roxithromycin, erythromycin) fell in all states and territories, reflected in the annual decrease of 15.5% nationally. The greatest decrease in macrolide usage was seen in Tasmania, with a decrease from 81.4 DDD / 1,000 OBD in 2019 to 65.9 DDD / 1,000 OBD in 2020 - an annual decrease of 19.0 %.
- Usage of third-generation cephalosporins increased by 8.6% in Western Australia, from 48.6 DDD / 1,000 OBD in 2019 to 52.8 DDD / 1,000 OBD in 2020. Increased usage was also seen in Tasmania (6.6%) and Victoria (4.1%). In contrast, usage fell substantially in Queensland and the Northern Territory, from 60.7 DDD / 1,000 OBD in 2019 to 56.5 DDD / 1,000 OBD in 2020 - a reduction of 7.0%.
- Other notable differences in the usage rates for the various antibacterial classes between the states and territories included the following:
  - Annual aminoglycoside usage in Queensland and the Northern Territory was almost 3 times the annual usage rate in Victoria.
  - South Australia had the highest usage rate for fourth-generation cephalosporins (7.6 DDD / 1,000 OBD) - more than 3 times higher than the annual usage rate in Tasmania, which had the lowest use (2.3 DDD / 1,000 OBD).

Table 3: Total-hospital antibacterial usage rates (DDD / 1,000 OBD) by class in NAUSP contributor hospitals, by state and territory, 2019–2020

Antibacterial	Australia		NSW and ACT		Qld and NT		SA		Tas		Vic		WA	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Alimentary antibiotics	10.9	14.1	13.4	14.7	7.6	8.9	9.7	12.5	14.6	17.3	9.8	18.4	11.8	17.6
Aminoglycosides (excl streptomycin)	28.5	28.2	30.8	32.5	40.1	37.5	40.1	34.0	31.2	29.7	13.5	12.9	13.9	14.2
Beta-lactamase inhibitor combinations	131.7	130.5	133.2	132.5	131.7	131.4	131.1	123.7	157.0	154.7	118.7	121.5	144.7	139.5
Beta-lactamase resistant penicillins	91.4	87.9	91.2	88.4	114.5	104.5	79.7	71.3	121.0	102.7	72.8	72.0	81.3	86.2
Beta-lactamase sensitive penicillins	29.2	26.0	31.6	28.0	26.8	24.0	26.8	18.8	33.1	25.4	27.6	28.7	29.9	25.5
Carbapenems	14.7	15.2	12.9	13.6	15.4	16.6	11.4	9.8	14.9	12.4	16.7	16.8	18.4	19.7
Extended spectrum penicillins	57.3	53.6	60.4	56.4	54.8	47.4	64.8	66.2	76.3	65.2	54.5	52.7	47.1	46.8
First-generation cephalosporins	161.1	170.5	162.1	175.4	150.3	156.9	170.5	190.6	128.3	131.9	173.3	171.8	157.1	169.7
Fluoroquinolones	27.3	26.5	24.6	24.2	23.6	23.8	24.6	21.6	31.8	30.0	31.8	29.6	36.7	37.5
Fourth-generation cephalosporins	4.4	4.8	4.8	5.1	2.2	2.7	6.6	7.6	1.5	2.3	5.1	6.0	4.8	4.5
Glycopeptides	25.6	25.2	21.1	22.0	25.5	25.1	31.1	29.4	22.9	21.8	33.2	31.4	24.0	23.0
Lincosamides	13.1	13.5	12.4	12.8	15.9	16.7	9.6	9.8	13.4	13.8	13.3	12.8	12.1	12.8
Macrolides	51.1	43.2	50.6	41.0	38.9	33.8	78.9	67.0	81.4	65.9	51.1	44.7	50.0	45.2
Nitroimidazoles	32.6	32.0	32.4	30.2	30.3	29.0	37.4	36.2	39.1	37.1	35.3	38.5	27.9	29.8
Second-generation cephalosporins	9.9	8.2	11.3	9.1	6.9	5.9	7.3	6.9	12.4	13.5	11.7	10.0	9.8	7.2
Sulfonamethoxazole-trimethoprim	19.1	19.4	15.9	16.1	24.0	25.3	14.5	17.1	24.4	20.9	21.4	18.7	18.7	20.7
Tetracyclines	86.7	68.8	89.0	72.6	97.1	73.8	39.4	35.5	109.4	84.8	97.6	73.0	71.6	59.9
Third-generation cephalosporins	60.5	60.6	57.3	57.9	60.7	56.5	47.0	46.6	67.0	71.4	78.8	82.1	48.6	52.8
Trimethoprim	12.3	12.3	12.2	11.9	14.8	15.0	14.3	13.6	18.8	17.2	9.6	9.7	9.1	9.0
*Other	17.3	18.7	15.8	15.6	12.5	15.5	11.9	15.4	16.7	6.4	23.6	25.1	25.4	29.3
Grand total	884.7	859.1	882.7	859.9	893.7	850.4	856.6	833.6	1015.2	924.4	899.5	876.3	842.8	851.0

* 'Other' includes amphenicols, combination products for eradication of *Helicobacter pylori*, intermediate-acting sulphonamides, monobactams, nitrofurans, fosfomycin, linezolid, daptomycin, polymyxins, rifamycins, second-generation cephalosporins, steroids, streptogramins, streptomycins.

ACT: Australian Capital Territory; DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; NSW: New South Wales; NT: Northern Territory; OBD: occupied bed days; Qld: Queensland: SA: South Australia; Tas: Tasmania; Vic: Victoria; WA: Western Australia.

Analysis of acute hospital antibacterial use using the Priority Antibacterial List for Antimicrobial Resistance Containment

The 2019 NAUSP report[1] was the first NAUSP report where the Priority Antibacterial List for Antimicrobial Resistance Containment (PAL)[2] was utilised to analyse usage in NAUSP contributor hospitals. The PAL was developed by the Australian Commission for Safety and Quality in Health Care (ACSQHC) in 2020 as a tool to support AMS. Antibacterials available in Australia are stratified according to preferred use categories for containment of AMR in human health in Australia. The definitions of each PAL category are provided in Table 4.

Table 4: Classification framework for the *Access, Review, Curb* and *Contain* categories of the Priority Antibacterial List for Antimicrobial Resistance Containment[2]

Category		Inclusion criteria
Access		Includes: • antibacterials recommended as first-line treatment for common infections with a low antimicrobial resistance (AMR) or Healthcare-associated Infection (HAI) potential • antibacterials not recommended as first-line treatment for common infections but with a low resistance potential.
Review	**Curb**	Includes: • antibacterials recommended as first-line agents for common bacterial infections, despite a high AMR potential • antibacterials not recommended as first-line treatment but with moderate to high AMR or HAI potential • antibacterials only recommended as first-line for prophylaxis as opposed to treatment.
	Contain	Includes antibacterials with high AMR or HAI potential that are not recommended as first-line options for common bacterial infections.

Systemic antimicrobials included in NAUSP are listed in Appendix 4 and antibacterials included in the PAL according to the *Access*, *Curb* and *Contain* classification are listed in Appendix 5.

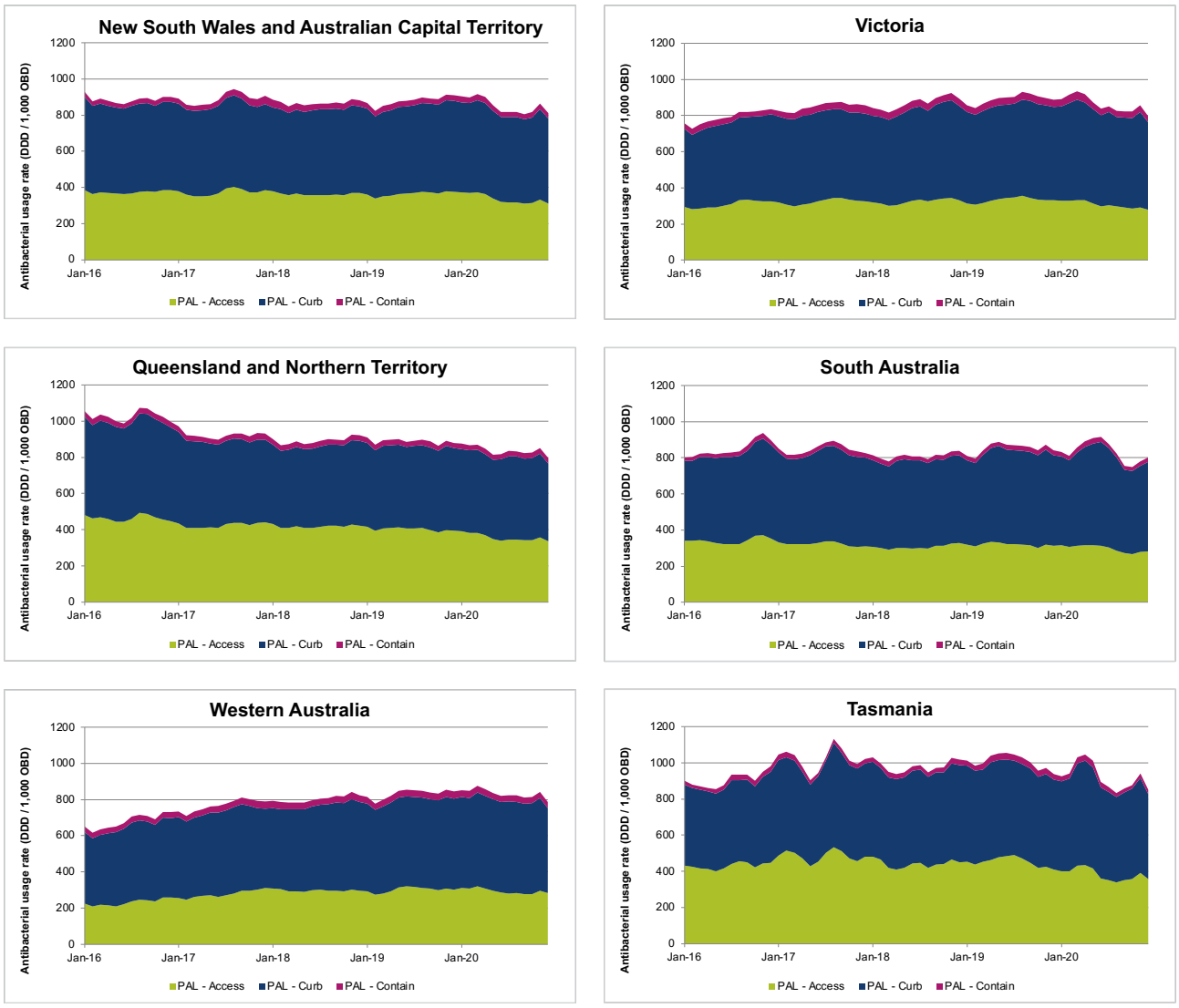
In general, the *Access* category includes antibacterials that are recommended as first-line treatment for infections where there is a low resistance potential. The *Curb* and *Contain* categories include antibacterials that are not generally first-line agents (with the exception of cefazolin for surgical prophylaxis). Stratifying antibacterial usage into PAL categories provides an alternative method of monitoring usage trends over time.

Usage by PAL category, by state and territory, 2016–2020

Figure 4 illustrates the trend in total-hospital antibacterial usage from 2016 to 2020, according to the PAL categories (*Access, Curb, Contain*) for NAUSP contributor hospitals, by state and territory. Figure 5 illustrates the same data according to proportional use.

Most states and territories saw a decrease in total antibacterial usage in 2020 after an initial surge in distributions to wards in March and April, at the start of the COVID-19 pandemic. As seen in Figure 4, much of the surge in usage consisted of antibacterials in the *Curb* category.

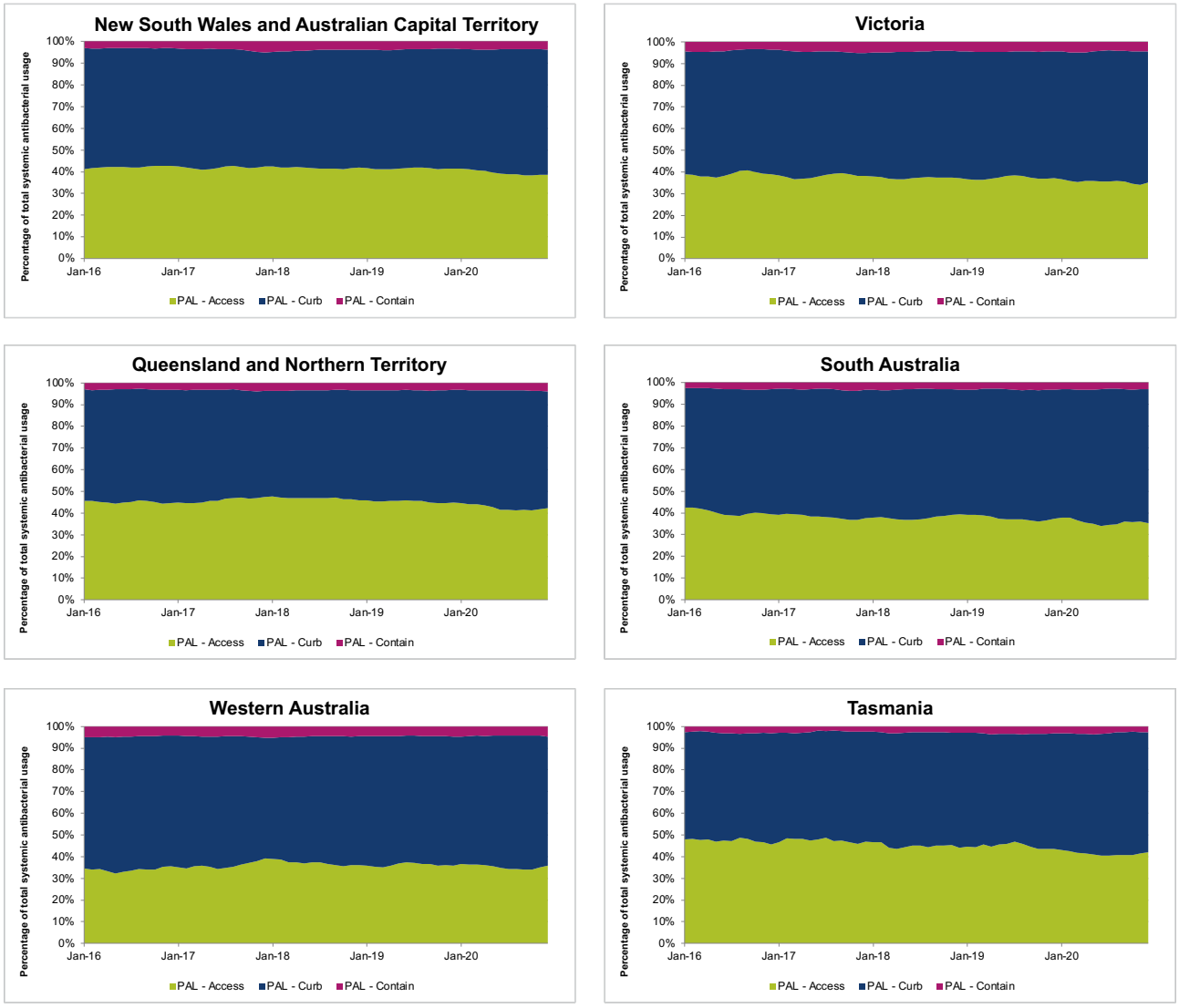
Figure 4: Aggregate antibacterial usage rates by PAL category in NAUSP contributor hospitals, by state and territory, 2016–2020



DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days; PAL: Priority Antibacterial List for Antimicrobial Resistance Containment.

Total proportionate *Curb* usage varies substantially between the states and territories (Figure 5); however, the proportionate usage of the antibacterial agents within the *Curb* category also varies.

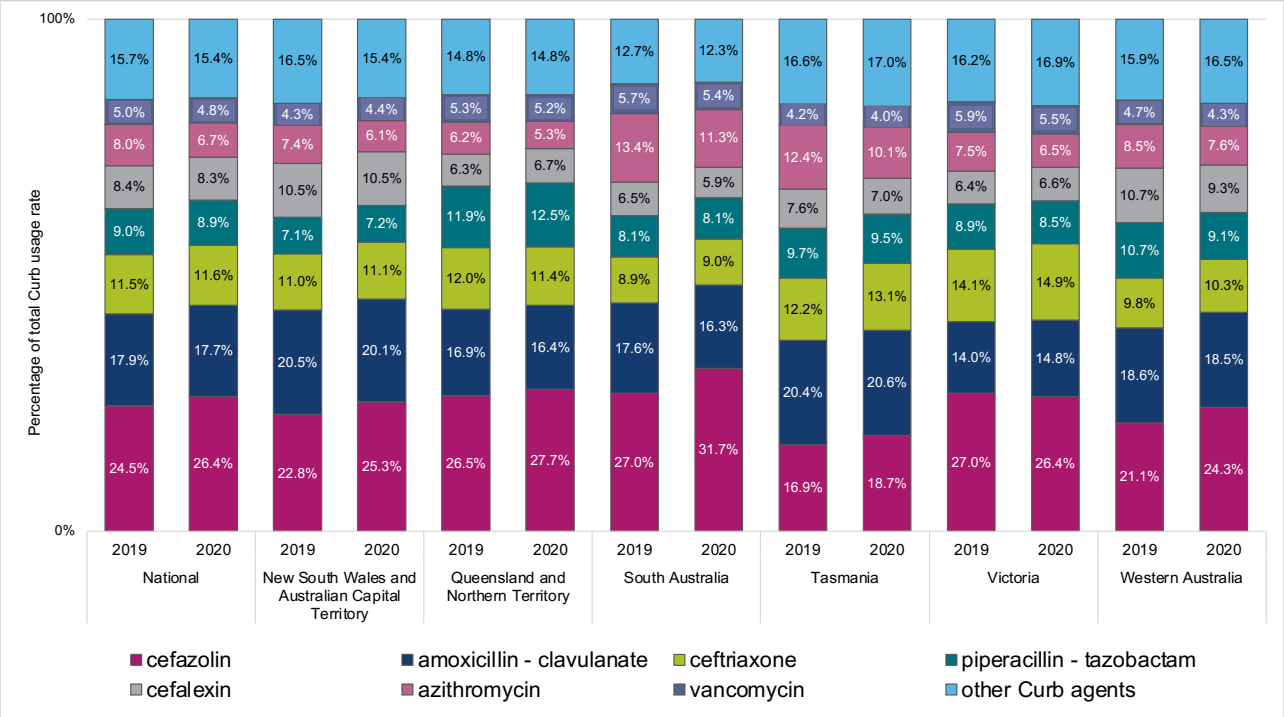
Figure 5: Proportional antibacterial usage by PAL category in NAUSP contributor hospitals, by state and territory, 2016–2020



NAUSP: National Antimicrobial Utilisation Surveillance Program; PAL: Priority Antibacterial List for Antimicrobial Resistance Containment.

A breakdown of the proportionate usage of the antibacterials included in the *Curb* category across the states and territories is shown in Figure 6. Cefazolin is a key driver of the proportionate use of the *Curb* category.[10] Cefazolin comprises approximately one-quarter of the *Curb* usage in Australian hospitals, ranging from 18.7% of *Curb* usage in Tasmania to 31.7% of *Curb* usage in South Australia in 2020. Amoxicillin-clavulanate and ceftriaxone are also key drivers of *Curb* usage.

Figure 6: Proportionate rate of Curb* usage in NAUSP contributor hospitals, by state and territory, 2019–2020



* *Curb* category as defined in the Priority Antibacterial List for Antimicrobial Resistance Containment.

NAUSP: National Antimicrobial Utilisation Surveillance Program.

Usage by PAL category, by peer group: private versus public

Figures 7 to 9 compare antibacterial usage by PAL category between private and public hospitals for Acute Group A, B and C peer groups respectively. AIHW hospital peer groupings define groups of similar hospitals based on shared characteristics, allowing benchmarking within peer groups or comparisons between different AIHW peer groups.[9]

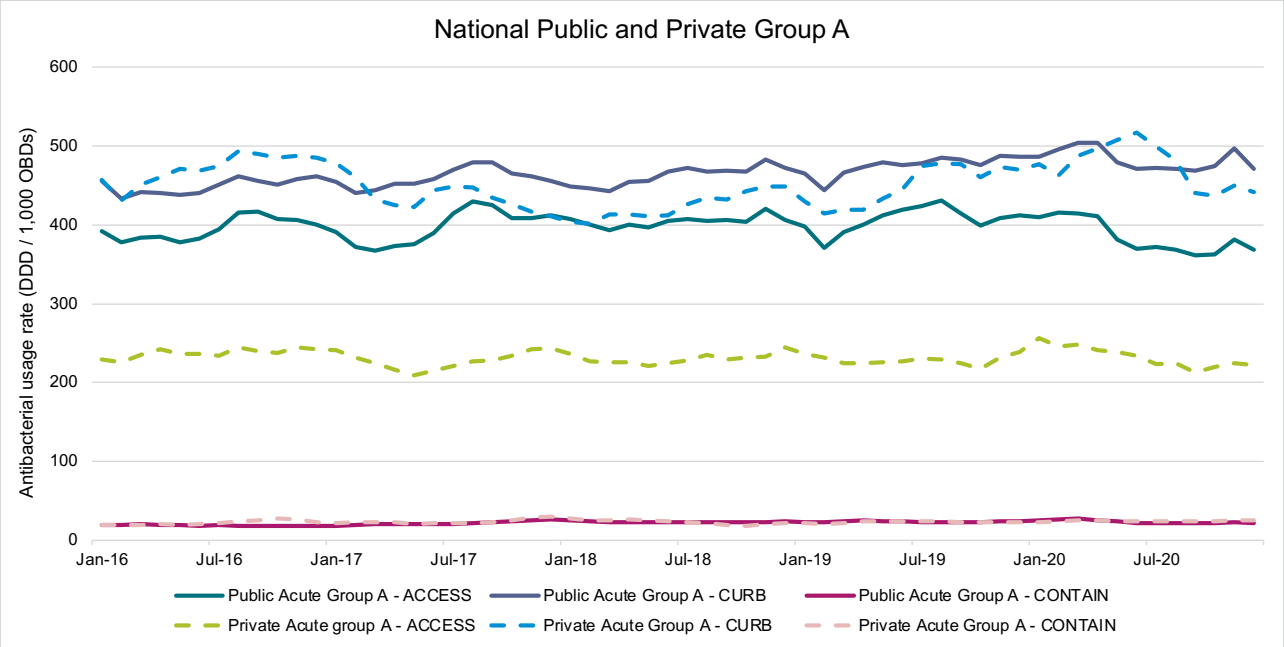
In previous NAUSP reports, because of low rates of participation in NAUSP by private hospitals, their usage was aggregated with the comparable AIHW public hospital peer group for analysis. Private hospital participation has now increased, and this is the first NAUSP report in which private hospital usage has been analysed separately.

Acute Group A hospitals: public versus private

When comparing *Access* category usage between public and private Acute Group A hospitals, *Access* usage in private hospitals is almost half the rate of public hospitals. On average, the monthly *Access* usage in private hospitals was 231.2 DDD / 1,000 OBD between 2016 and 2020 compared to 397.6 DDD / 1,000 OBD in public hospitals (Figure 7). For public hospitals, *Access* usage is on average 44.9% of total monthly antibacterial usage compared to 32.8% in private hospitals.

The monthly usage rates for *Curb* and *Contain* category antibacterials is similar in both private and public Acute Group A facilities (AIHW categorisation) (Figure 7).

Figure 7: Aggregate total-hospital antibacterial usage by PAL category in public Acute Group A hospitals compared to private Acute Group A hospitals, 2016–2020

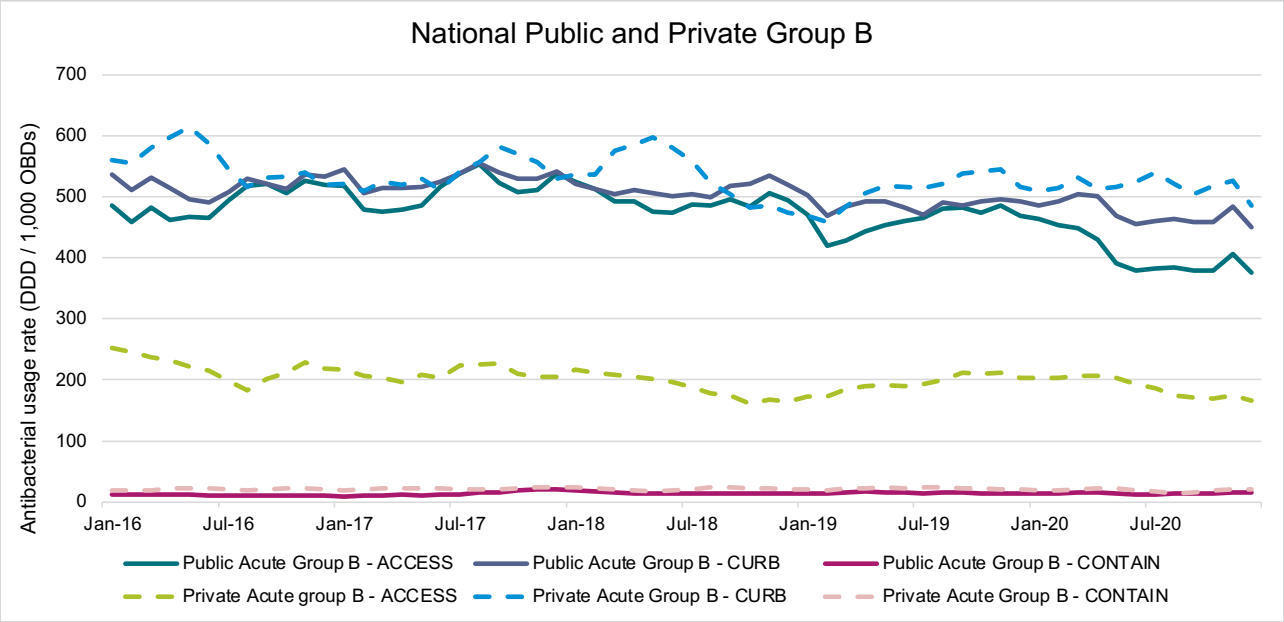


DDD: defined daily dose; OBD: occupied bed days; PAL: Priority Antibacterial List for Antimicrobial Resistance Containment.

Acute Group B hospitals: public versus private

In Acute Group B hospitals, the proportion of usage in the *Access* category in public hospitals is almost twice that of private hospitals (Figure 8). In the 60-month period from January 2016 to December 2020, the proportion of total usage of antibacterials in the *Access* category in Acute Group B public hospitals was on average 47.6%. In comparison, the proportion of monthly usage in the *Access* category in Acute Group B private hospitals was only 26.6% on average. Overall usage, however, is higher in the public Acute Group B hospitals with the monthly usage in 2020, averaging 893.2 DDD / 1,000 OBD compared to 724.6 DDD / 1,000 OBD in private Acute Group B hospitals. *Curb* usage in private Acute Group B hospitals is approximately two and a half times higher than *Access* usage.

Figure 8: Aggregate total-hospital antibacterial usage by PAL category in public Acute Group B hospitals compared to private Acute Group B hospitals, 2016–2020

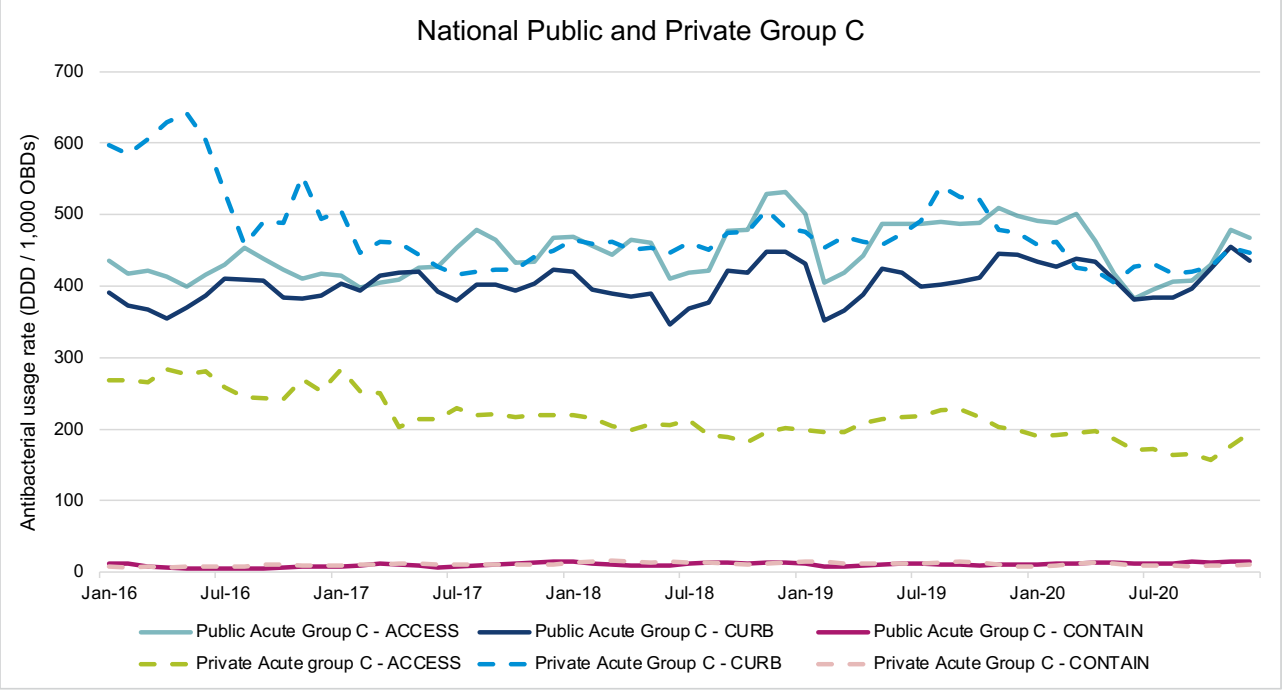


DDD: defined daily dose; OBD: occupied bed days; PAL: Priority Antibacterial List for Antimicrobial Resistance Containment.

Acute Group C hospitals: public versus private

Similar to Acute Groups A and B, the monthly usage rate for *Access* antibacterials in private Acute Group C hospitals is approximately half the *Access* usage rate seen in public Acute Group C hospitals (Figure 9). For public Acute Group C hospitals, usage of *Access* antibacterials is trending higher than usage of *Curb* agents. In private Acute Group C hospitals, however, usage of *Curb* agents is more than twice the usage of *Access* agents.

Figure 9: Aggregate total-hospital antibacterial usage by PAL category in public Acute Group C hospitals compared to private Acute Group C hospitals, 2016–2020

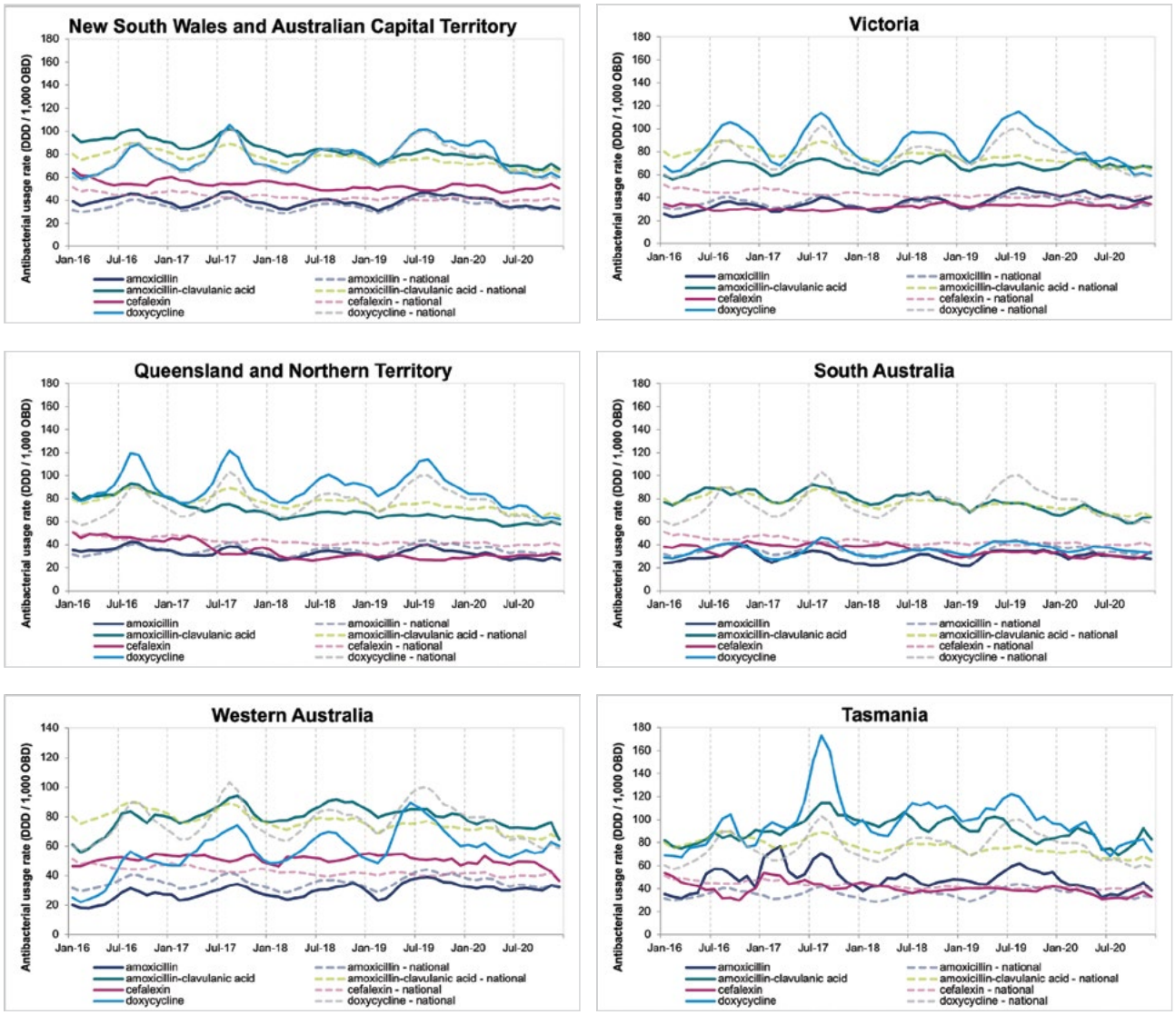


DDD: defined daily dose; OBD: occupied bed days; PAL: Priority Antibacterial List for Antimicrobial Resistance Containment.

Usage rates for high-volume oral antibacterials, 2016–2020

Amoxicillin–clavulanic acid, doxycycline, cefalexin and amoxicillin continue to be the most commonly prescribed oral antibacterials in NAUSP contributor hospitals. Figure 10 illustrates the usage rates for these 4 antibacterials across the states and territories between 2016 and 2020. Doxycycline usage between 2016 and 2019 shows seasonal variation, with higher usage rates seen in the winter months; however, in 2020, during the COVID-19 pandemic, there was a decline in usage and the seasonal peak in winter was not observed. Monthly usage of oral amoxicillin–clavulanic acid is highest in Tasmania and Western Australia. Cefalexin usage in New South Wales and Australian Capital Territory and in Western Australia is higher than the average usage across all NAUSP contributors.

Figure 10: High-volume antibacterial usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2016–2020 (3-month moving average)



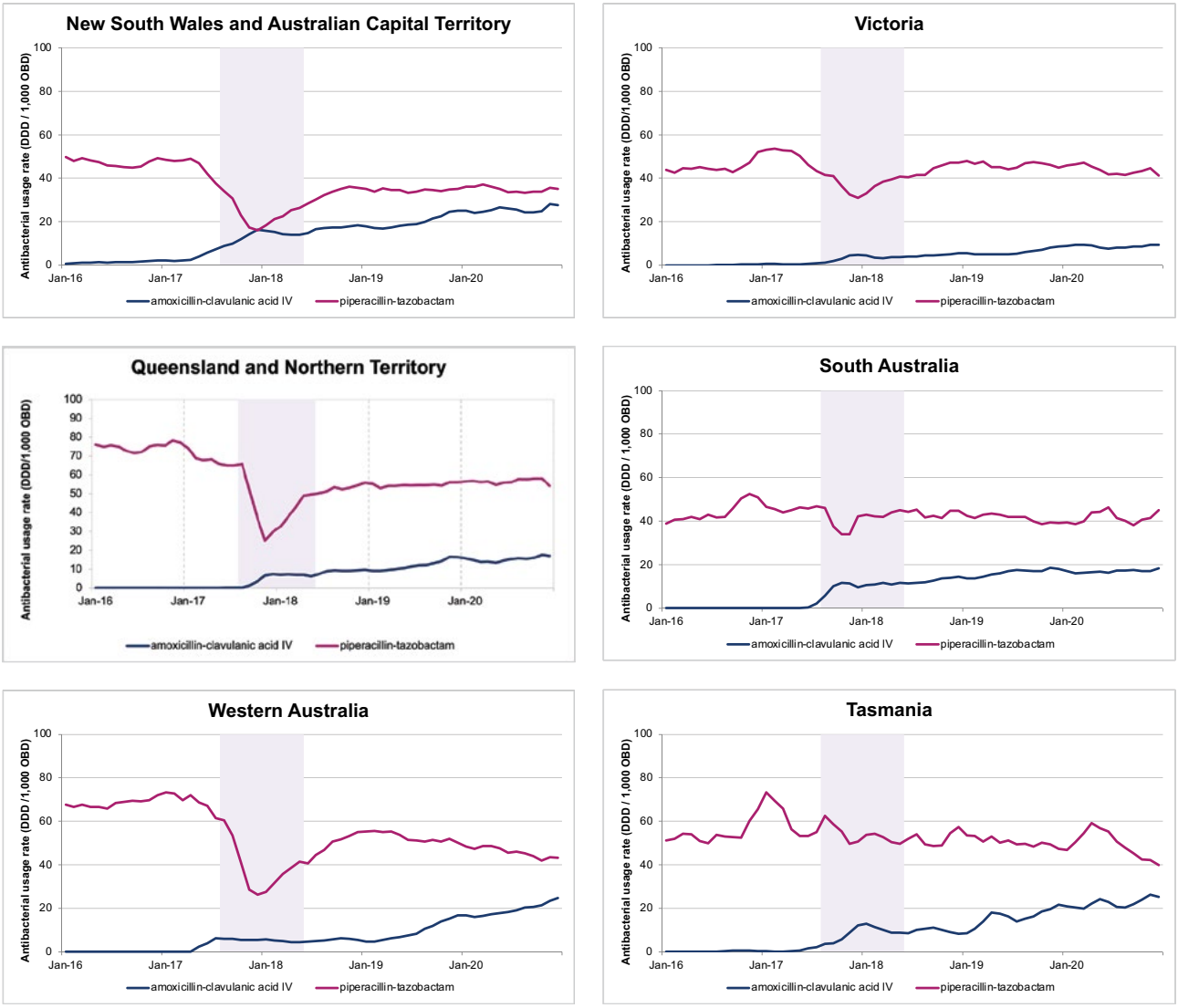
DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

Usage rates for intravenous broad-spectrum antimicrobials, 2016–2020

There was little change in the total aggregate usage of piperacillin-tazobactam between 2019 and 2020, although there was an initial increase in distributions to the wards at the beginning of the COVID-19 pandemic, in March and April 2020 (Figure 11). The global shortage of piperacillin-tazobactam, which began during 2017, coincided with the introduction of intravenous amoxicillin-clavulanate into the Australian market. Usage of intravenous amoxicillin-clavulanate has increased markedly since 2018; the annual national usage rate in 2020 was 79.7% higher than in 2018 (Table 5).

Penicillin-ß-lactamase inhibitor combinations: intravenous amoxicillin–clavulanic acid and piperacillin-tazobactam

Figure 11: Penicillin-ß-lactamase inhibitor combination usage rates in NAUSP contributor hospitals, by state and territory, 2016–2020 (3-month moving average)



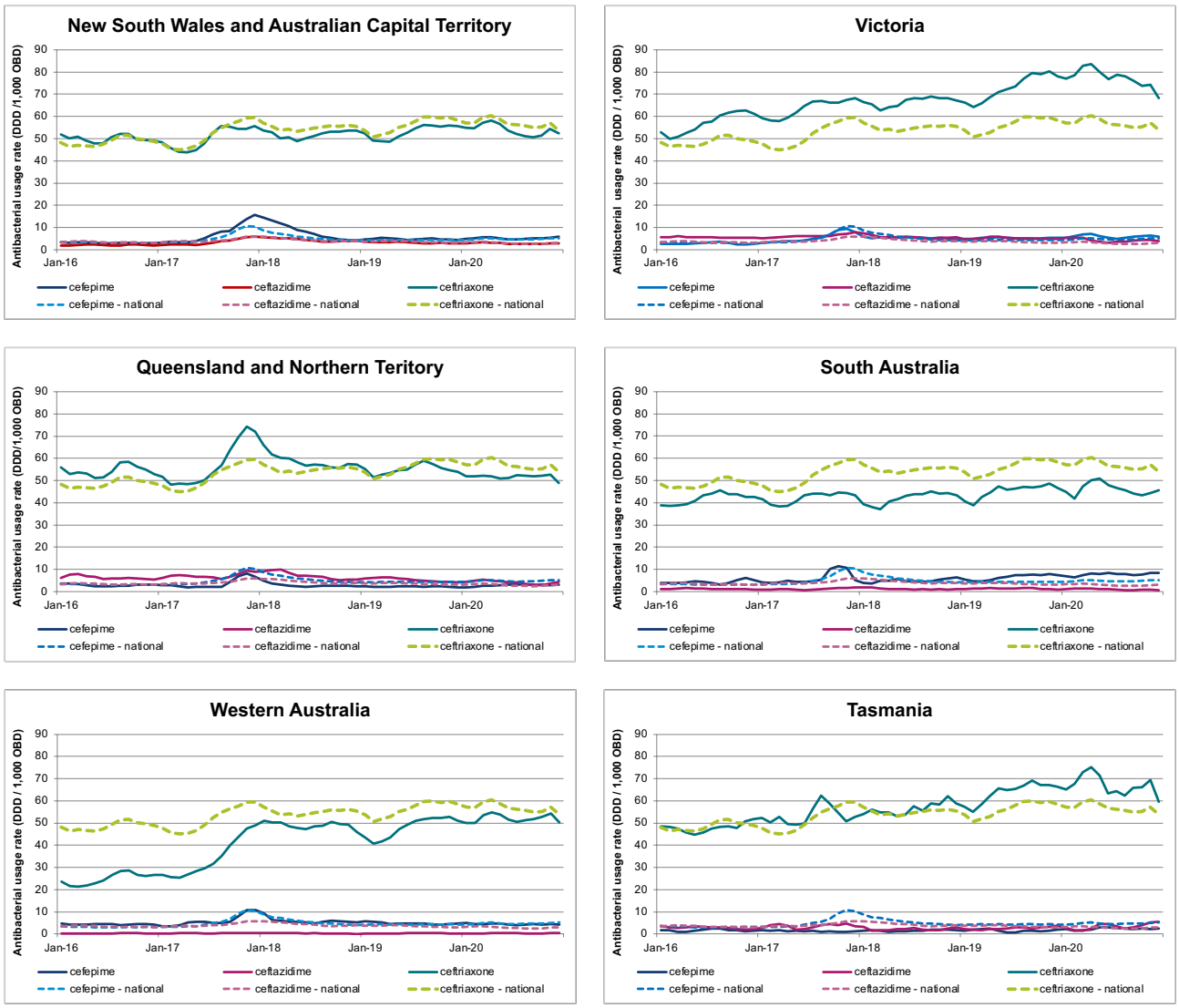
Notes: Shaded area represents the period of piperacillin-tazobactam shortage. Intravenous amoxicillin–clavulanic acid was registered in Australia in January 2017.[11]

DDD: defined daily dose; IV: intravenous; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

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

The national usage rate for ceftriaxone has increased over the last 5 years (Figure 12). Usage in Victoria and Tasmania is above the national average. Although ceftriaxone usage in Western Australia is below the national average, the monthly usage has more than doubled in the last 5 years. Apart from the brief increase in usage during the nationwide piperacillin-tazobactam shortage during 2017–2018, use of cefepime remains relatively low, although monthly usage is increasing in South Australia.

Figure 12: Cephalosporin usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2016–2020 (3-month moving average)



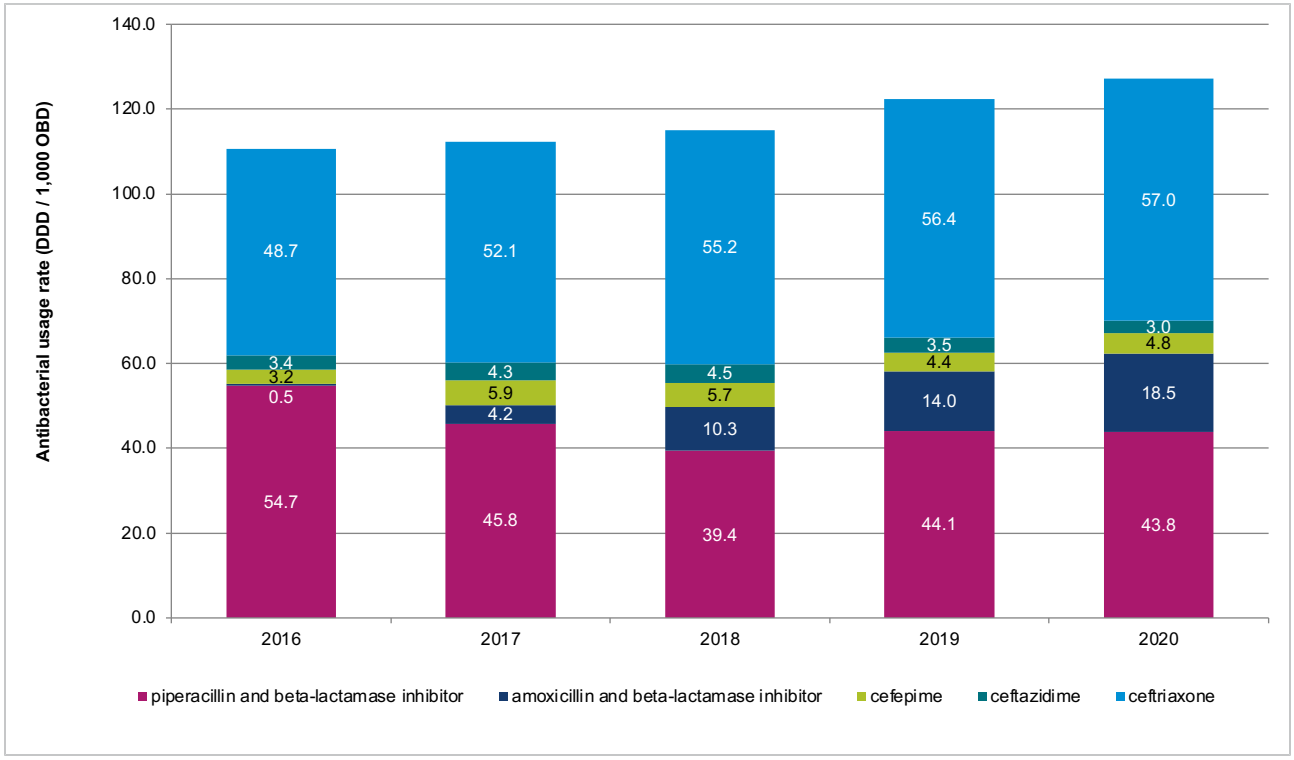
DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

National proportional annual use of penicillin-ß-lactamase inhibitor combinations and third- and fourth-generation cephalosporins, 2016–2020

The consumption of piperacillin-tazobactam, intravenous amoxicillin—clavulanic acid and third- and fourth-generation cephalosporins is of critical interest due to their important role in the treatment of severely ill patients but also due to the correlation between their use and the rates of resistance. Figure 13 illustrates the proportional change in annual use in NAUSP contributor hospitals over the last 5 years. (Note that there was a piperacillin-tazobactam shortage in 2017–2018.) Combined usage of these broad-spectrum agents has increased annually since 2016, with an increase in usage of 3.9% from 2019 to 2020.

Piperacillin-tazobactam and amoxicillin–clavulanic acid are the 2 intravenous penicillin-ß-lactamase inhibitors available in Australia. Since the registration in Australia of intravenous amoxicillin–clavulanic acid in January 2017, the proportionate usage has increased annually. In 2020, the total hospital usage rate for NAUSP contributor hospitals of intravenous amoxicillin–clavulanic acid was 18.5 DDD / 1,000 OBD, which accounted for 29.7% of overall intravenous penicillin-ß-lactamase inhibitor use.

Figure 13: National aggregate total-hospital usage rates for intravenous penicillin-ß-lactamase inhibitor combinations and third- and fourth-generation cephalosporins in NAUSP contributor hospitals, 2016–2020

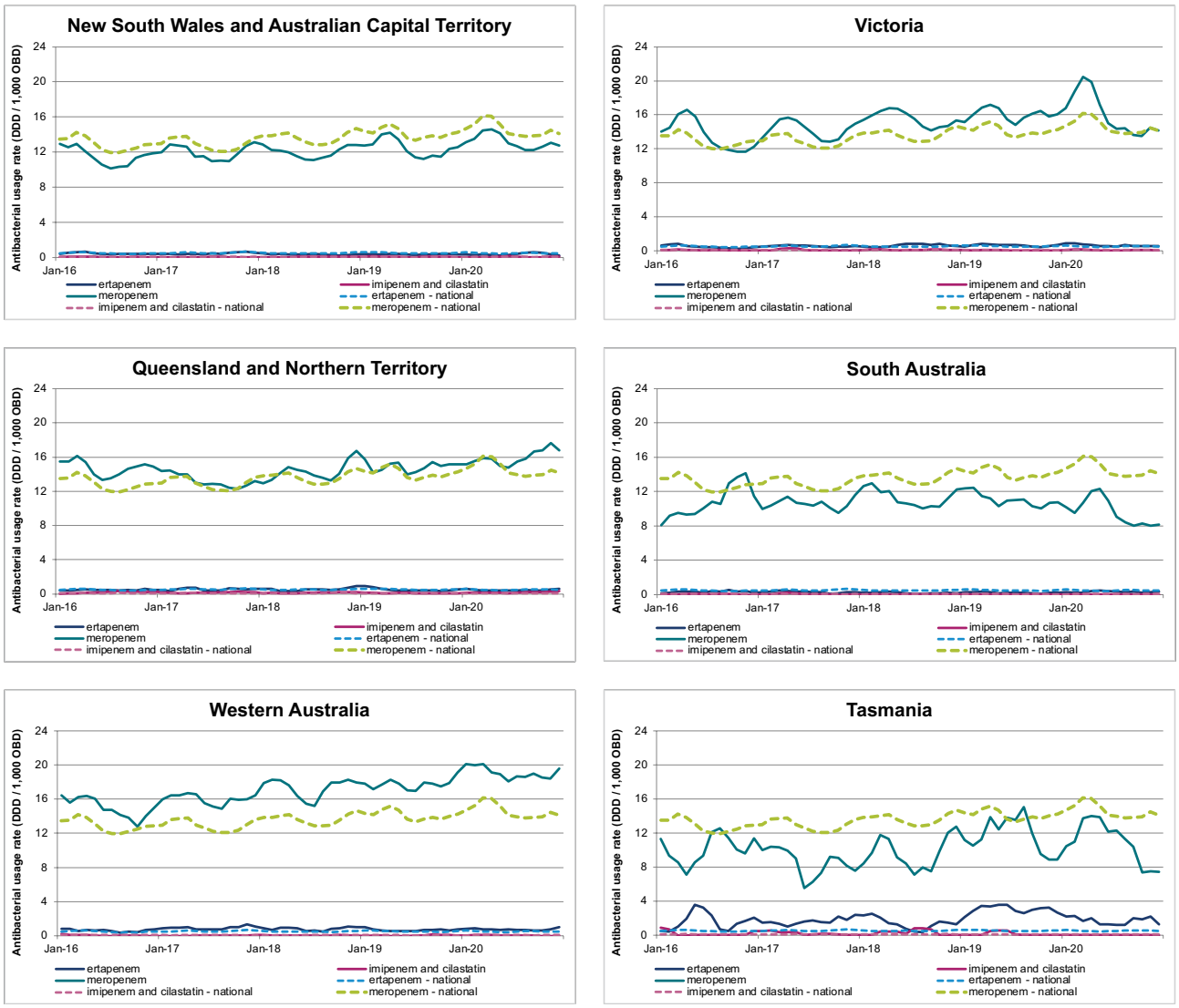


Note: Intravenous amoxicillin–clavulanic acid was registered in Australia in January 2017.[11]
DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

Carbapenems – meropenem and ertapenem

Meropenem is the most commonly used carbapenem in Australian hospitals. Nationally, meropenem use has increased annually for the last 5 years, increasing from 12.9 DDD / 1,000 OBD in 2016 to 14.6 DDD / 1,000 OBD in 2020 – a rate increase of 13.4% over 5 years. There was a surge in pharmacy dispensings and distributions of meropenem in February and March 2020, coinciding with the onset of the COVID-19 pandemic; however, usage fell back again across most states in the middle of 2020. Total annual usage of meropenem in 2020 was 3.5% higher than in 2019. Doripenem, an intravenous carbapenem that is rarely used in Australia, has not been included in the figure below. Meropenem-vaborbactam is a new antimicrobial product combining meropenem with a non-ß-lactam ß-lactamase inhibitor which is active against *Klebsiella pneumoniae* carbapenemase (KPC)-producing Enterobacteriaceae.[12] Usage of meropenem-vaborbactam was first reported in NAUSP contributor hospitals in February 2020, but usage remains extremely low and is not included in Figure 14.

Figure 14: Carbapenem usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2016–2020 (3-month moving average)



DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

Impact of COVID-19

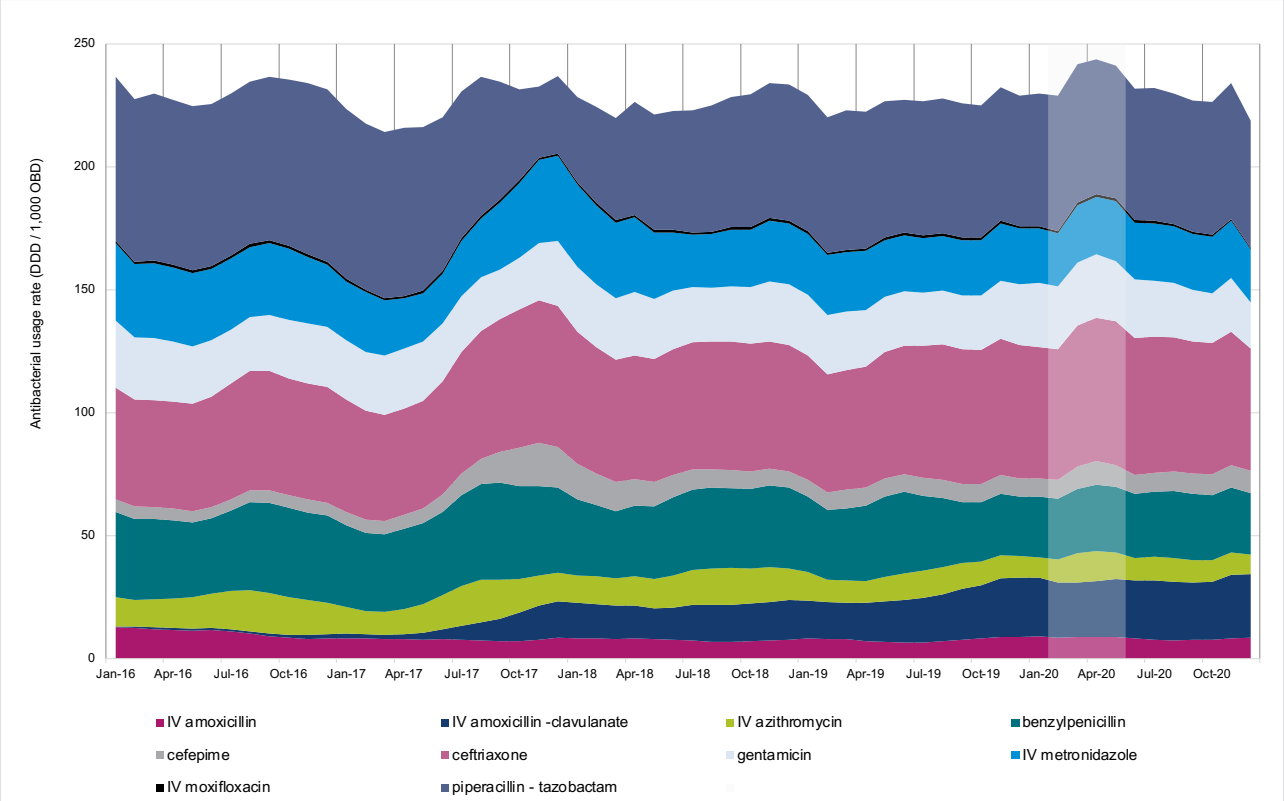
At the beginning of the COVID-19 pandemic in Australia (February-March 2020), marked changes in 'usage' were seen in some hospitals. Some reasons for the fluctuations include the establishment and stocking of new wards to accommodate COVID-19 patients, repurposing of some wards as additional emergency wards, and closure of some hospitals or wards due to temporary suspension/delay of elective surgery.

National usage of broad-spectrum parenteral antibacterials used to treat bacterial pneumonia

Internationally there have been reports of increased usage of broad-spectrum antibacterials during the COVID-19 pandemic. Despite a number of studies reporting a low incidence of bacterial co-infection with COVID-19, the use of empiric antibacterial therapy for possible community-acquired bacterial pneumonia has impacted usage rates in some settings.

Figure 15 illustrates the monthly total usage of broad-spectrum intravenous antibacterials commonly used to treat bacterial pneumonia in NAUSP contributor hospitals over the last 5 years. The shaded area illustrates the period from March to May 2020, when dispensings/distributions to the wards increased initially at the beginning of the pandemic.

Figure 15: Total hospital use of intravenous antibacterials used to treat bacterial pneumonia, Australian principal referral hospitals, 2016–2020

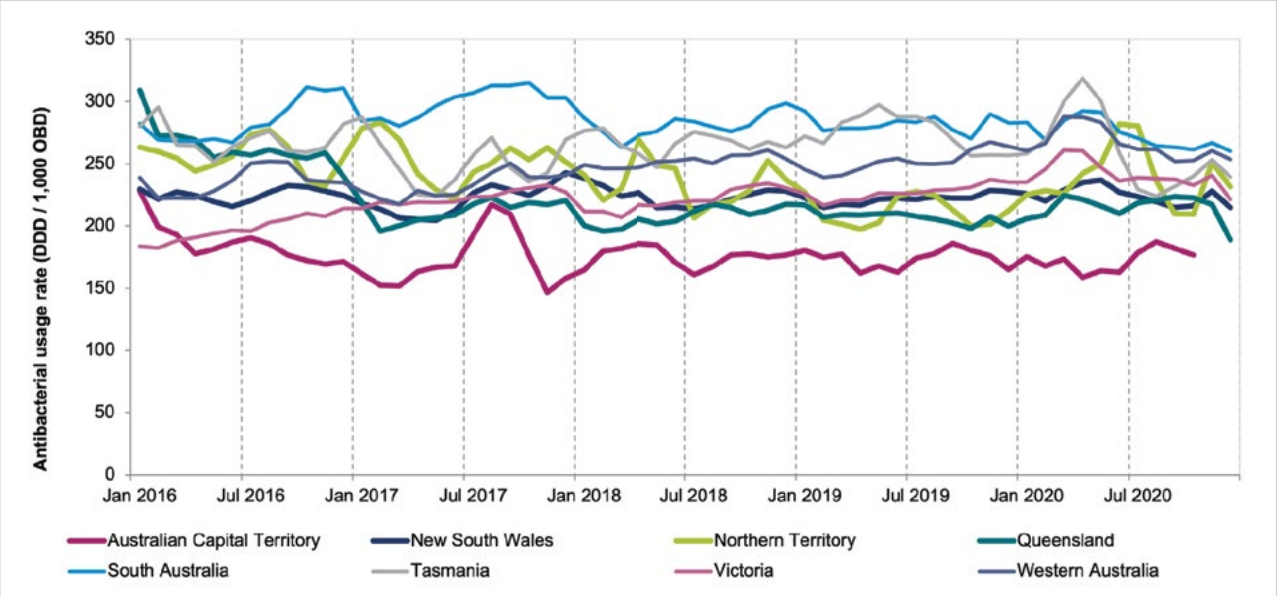


Note: Shaded area represents the beginning of the COVID-19 pandemic in Australia.
DDD: defined daily dose; OBD: occupied bed days.

Usage of broad-spectrum parenteral antibacterials used to treat bacterial pneumonia by state or territory

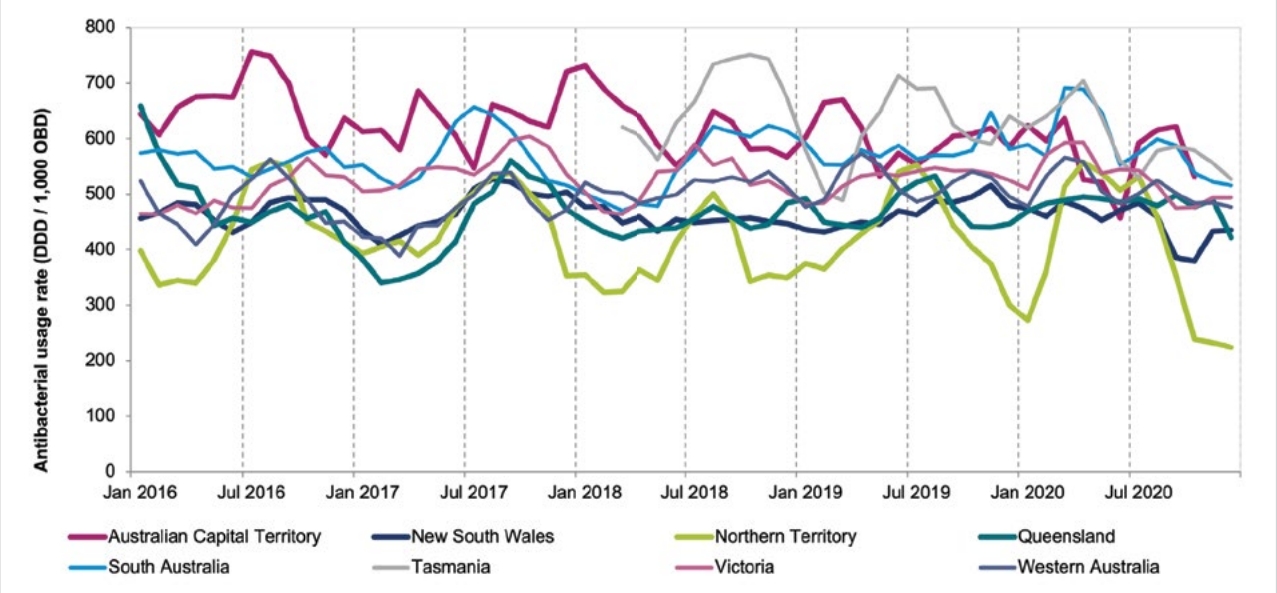
Figure 16 illustrates the sum of the usage rates for the same intravenous antibacterials in principal referral hospitals for (a) the total hospital and (b) the critical care setting compared across states and territories. The aggregate usage rate for these broad-spectrum agents in critical care units is approximately double the usage rate for the total hospital.

Figure 16: Total hospital use of intravenous antibacterials used to treat bacterial pneumonia, by state and territory, principal referral hospitals, 2016–2020



Principal referral hospitals, total acute hospital usage*

Principal referral hospitals, critical care*



* Rates in (a) and (b) represent a sum of the rates for intravenous (IV) amoxicillin, IV amoxicillin–clavulanic acid, IV azithromycin, benzylpenicillin, cefepime, ceftriaxone, gentamicin, IV metronidazole, IV moxifloxacin.

Note: Data for critical care in Tasmanian principal referral hospitals is from February 2018.

DDD: defined daily dose; OBD: occupied bed days.

Table 5 illustrates the change in annual usage of broad-spectrum intravenous antibacterials used to treat bacterial pneumonia, comparing 2020 usage (during the COVID-19 pandemic) to both 2018 and 2019 (prior to the onset of COVID-19 in Australia), across NAUSP contributor hospitals in all Australian states and territories.

Table 5: National aggregate usage rates for broad-spectrum antibacterials used to treat bacterial pneumonia, all NAUSP contributors, 2018-2020

	Usage rate (DDD / 1,000 OBD)			% change 2018 to 2020	% change 2019 to 2020
	2018	2019	2020		
IV amoxicillin	7.5	7.0	7.4	–0.7%	5.6%
IV amoxicillin-clavulanate	10.3	14.0	18.5	79.7%	32.4%
IV azithromycin	14.8	10.7	9.9	–33.1%	–7.6%
Benzylpenicillin	31.2	27.8	24.7	–21.0%	–11.0%
Cefepime	5.7	4.4	4.8	–15.8%	9.0%
Ceftriaxone	55.1	56.4	57.0	3.5%	1.1%
Gentamicin	27.5	25.5	25.8	–6.3%	1.1%
IV metronidazole	27.4	24.1	24.2	–11.5%	0.6%
IV moxifloxacin	0.9	1.0	0.8	–7.4%	–13.6%
Piperacillin-tazobactam	39.3	44.1	43.7	11.4%	–0.8%

DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days; IV: intravenous.

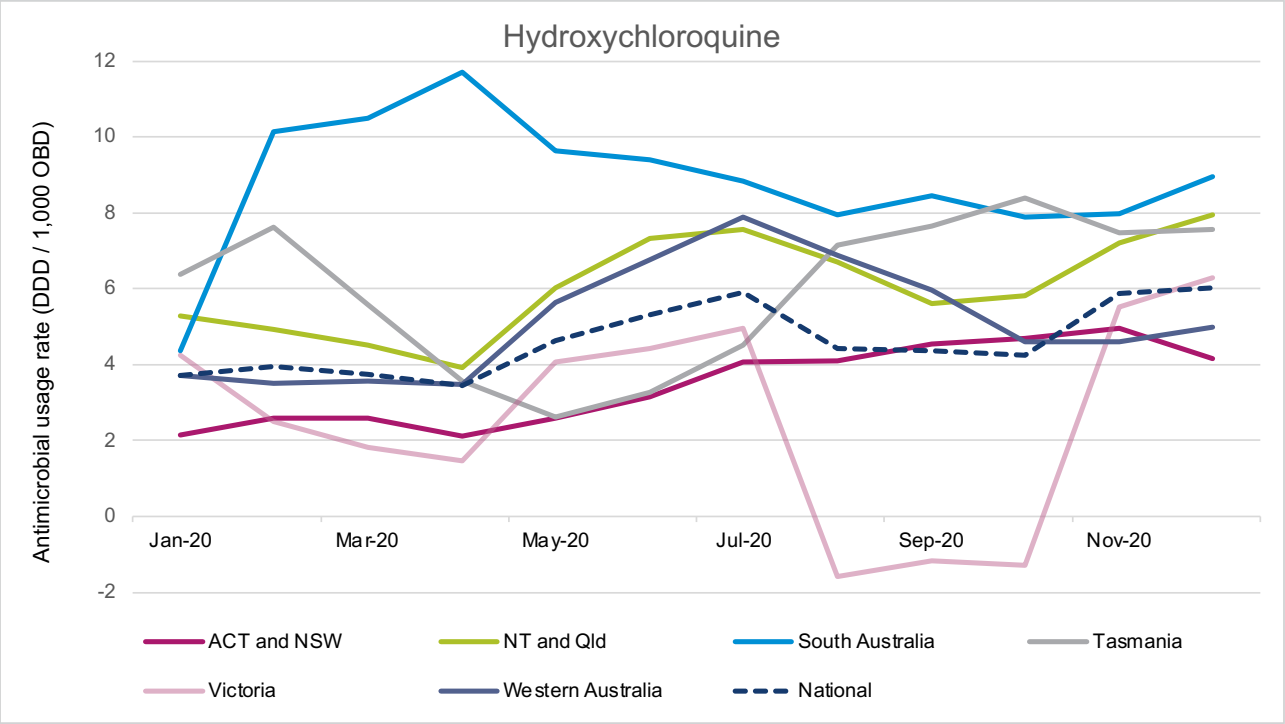
In 2020 there was a decrease in the hospital usage of antibacterials typically used in the treatment of community-acquired pneumonia (CAP); however, as seen in Table 5, there was increased usage of some broad-spectrum agents such as cefepime. These findings may reflect a possible decrease in the incidence of CAP due to the public health interventions, such as social distancing, implemented due to COVID-19. The increased use of broad-spectrum agents may reflect the use of these agents for treatment of secondary bacterial infections in hospitalised COVID-19 patients.[13]

Larger tertiary hospitals that are classified as principal referral hospitals by the AIHW[9] provided hospital care for the majority of patients requiring hospitalisation for COVID-19.[13] The changes in usage in principal referral hospitals in 2020 compared to 2019 largely reflected the changes seen across all NAUSP contributor hospitals.[13] A more detailed analysis of the utilisation of antimicrobials used to treat bacterial pneumonia in 31 Australian principal referral hospitals during the first year of the COVID-19 pandemic was published in 2022.[13]

Remdesivir, hydroxychloroquine, ivermectin

In March 2020, at the beginning of the COVID-19 pandemic, the NAUSP data inclusions were expanded to capture agents that were being used experimentally in patients diagnosed with SARS-CoV-2 infection (the coronavirus responsible for COVID-19), including (but not limited to) remdesivir, hydroxychloroquine and ivermectin. Of the 231 hospitals included in this report, 173 submitted hydroxychloroquine usage data in 2020, 24 reported remdesivir usage and 1 hospital reported systemic ivermectin use. Hydroxychloroquine is commonly used as an anti-inflammatory in autoimmune diseases; however, usage in COVID-19 patients may have contributed to the increasing trend in usage in 2020, shown in Figure 17.

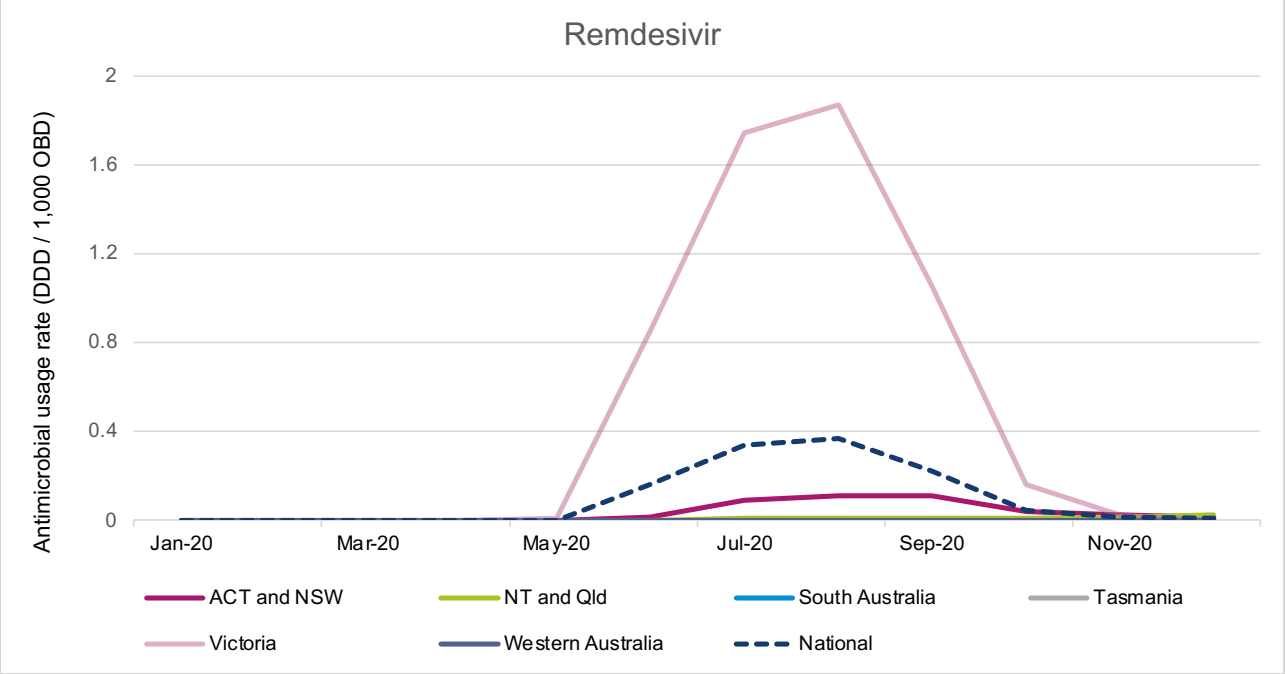
Figure 17: Hydroxychloroquine usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals (n=173), by state and territory, 2020 (3-month moving average)



ACT: Australian Capital Territory; DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; NSW: New South Wales; NT: Northern Territory; OBD: occupied bed days; Qld: Queensland.

The intravenous antiviral remdesivir was provisionally registered by the Therapeutic Goods Administration in July 2020 for the treatment of COVID-19. Statewide usage of remdesivir in NAUSP contributor hospitals is shown in Figure 18. Victoria experienced a protracted second wave of COVID-19 in the second half of 2020, which may explain the higher usage of remdesivir in these months in Victoria.

Figure 18: Remdesivir usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals (n=24), by state and territory, 2020 (3-month moving average)



Note: DDD for remdesivir of 0.1 g assigned by NAUSP, as there is no WHO-assigned DDD at the time of writing.

ACT: Australian Capital Territory; DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; NSW: New South Wales; NT: Northern Territory; OBD: occupied bed days; Qld: Queensland.

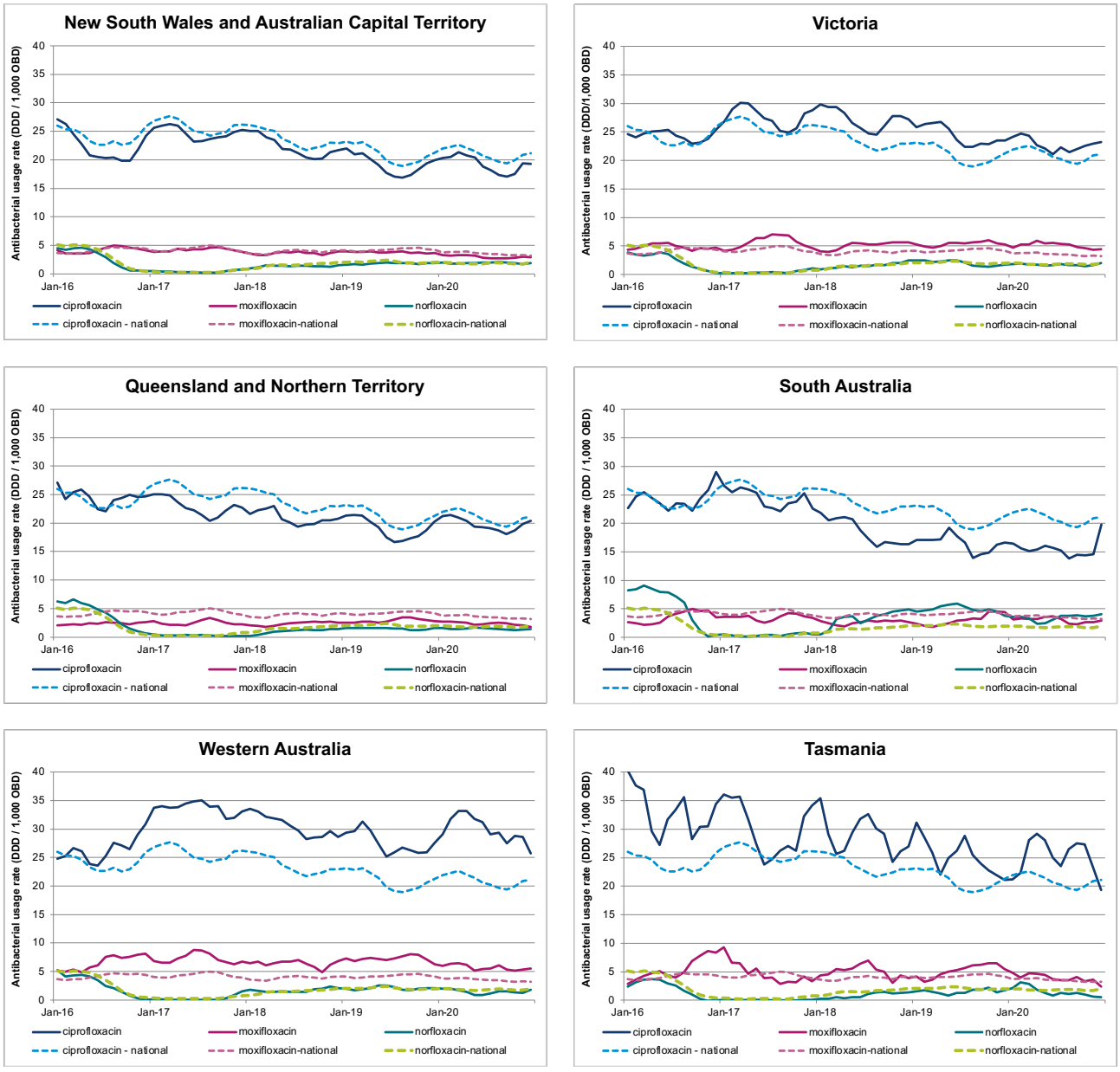
Usage rates for reserve-line antibacterials, 2016–2020

Reserve-line antibacterials are generally restricted to infections caused by organisms resistant to first-line treatment options commonly recommended in clinical guidelines.

Fluoroquinolones – ciprofloxacin, moxifloxacin, norfloxacin

Figure 19 shows the comparative usage rates of the fluoroquinolones registered for use in Australia. Usage of ciprofloxacin has declined nationally over the last 5 years. Usage of fluoroquinolones is higher in Western Australia, Tasmania and Victoria compared to the other states and territories.

Figure 19: Fluoroquinolone usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2016–2020 (3-month moving average)



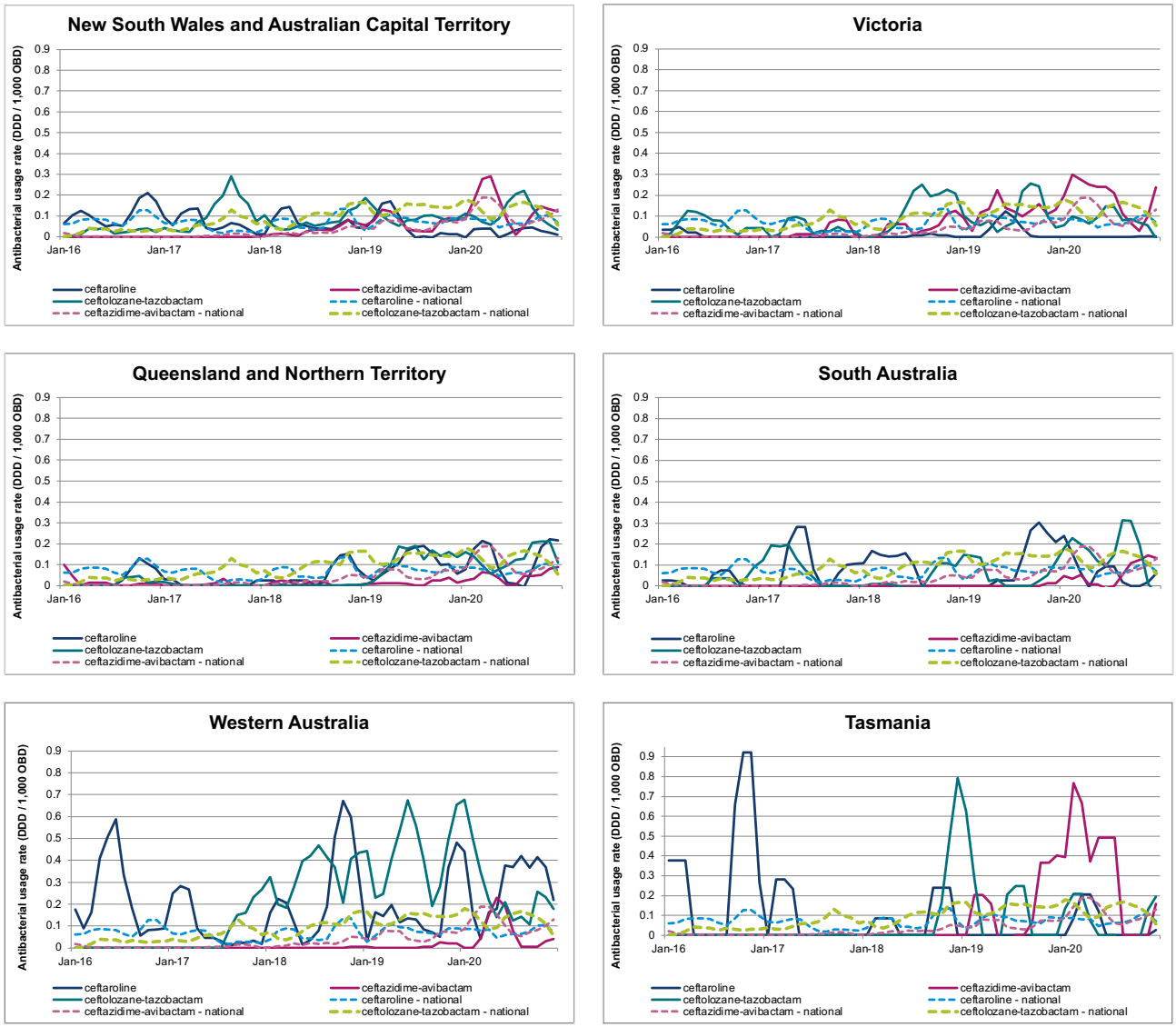
Note: Usage of levofloxacin, which is not registered in Australia, is negligible and is not shown.

DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

Ceftaroline, ceftazidime-avibactam, ceftolozane–tazobactam

Although usage of reserve-line, newly introduced cephalosporins remains low (Figure 20), average monthly usage in Western Australia and Tasmania is greater in 2020 than in the other states and territories. In Tasmania, the average monthly usage rate for ceftazidime-avibactam in 2020 was twice that of the other states. The average monthly usage of ceftaroline in Western Australia was more than 3 times higher than that of most other states in 2020, and the average monthly usage of ceftolozane–tazobactam in Western Australia was almost double that of South Australia, the second highest user of this new cephalosporin. Ceftolozane–tazobactam usage was increasing, especially in Western Australia, until a global shortage occurred at the end of 2020.

Figure 20: Reserve-line cephalosporin usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2016–2020 (5-month moving average)*



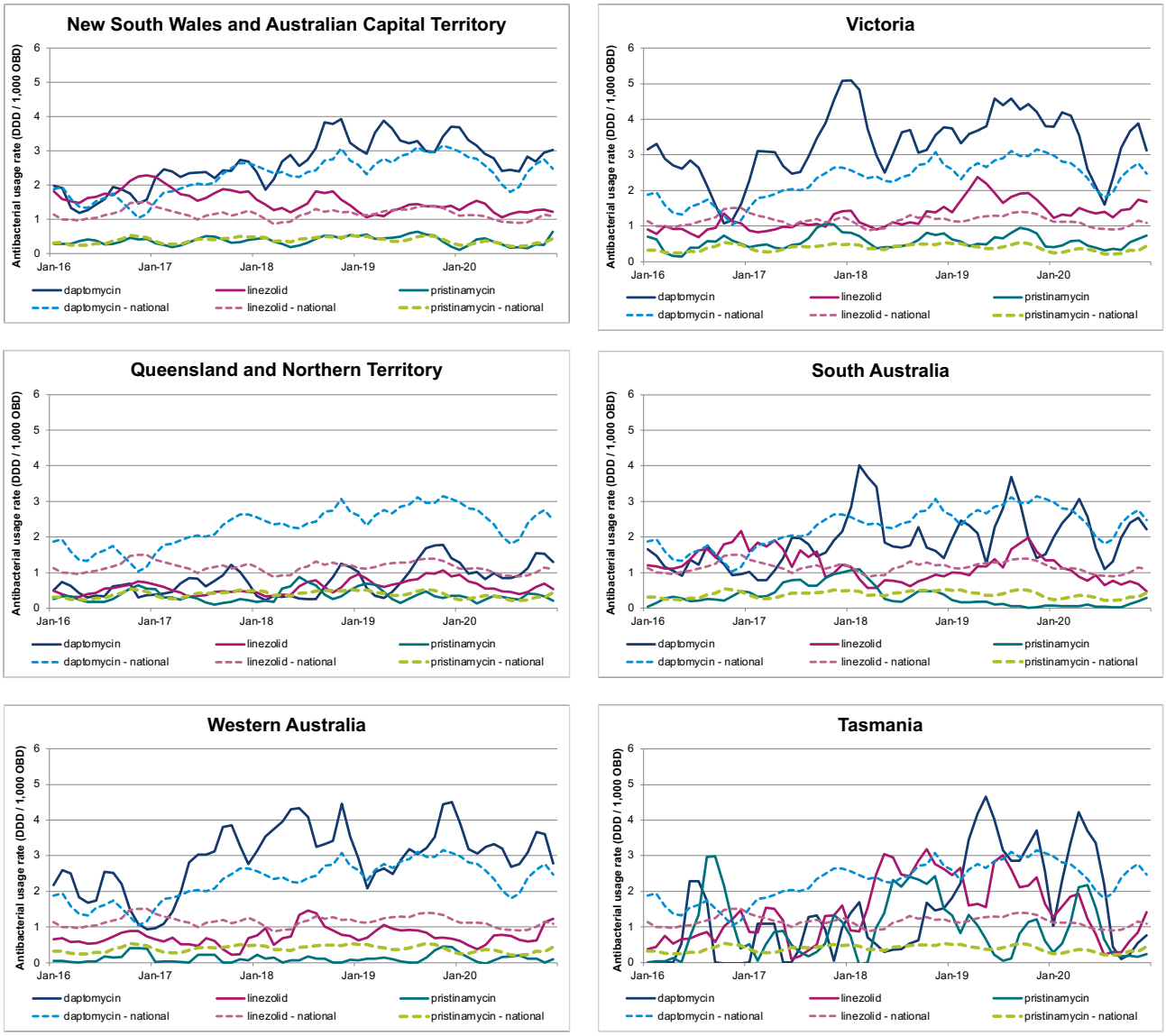
* Low-usage antimicrobials have a 5-month moving average, rather than a 3-month moving average, to optimise the visual trends.

DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

Daptomycin, linezolid, pristinamycin

Although the use of daptomycin remains low, annual use increased nationally between 2016 to 2019 but fell back slightly in 2020 (Figure 21). On average in NAUSP contributor hospitals, the total hospital usage rate of daptomycin in 2020 was 2.5 DDD / 1,000 OBD. Usage of linezolid, which is a reserve-line antimicrobial commonly used for treatment of vancomycin-resistant enterococci (VRE), has been higher in Tasmania than other states from 2018 but fell below the national average in 2020. Usage of pristinamycin, an oral streptogramin antimicrobial used for treatment of methicillin-resistant *Staphylococcus aureus* (MRSA) and VRE, remains very low, with the average annual rate across all NAUSP contributors being just 0.39 DDD / 1,000 OBD over the last 5 years. Usage of pristinamycin in Tasmania is higher than in the other states and territories; the 2020 annual usage rate in Tasmania was 0.78 DDD / 1,000 OBD.

Figure 21: Daptomycin, linezolid and pristinamycin usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2016–2020 (5-month moving average)*



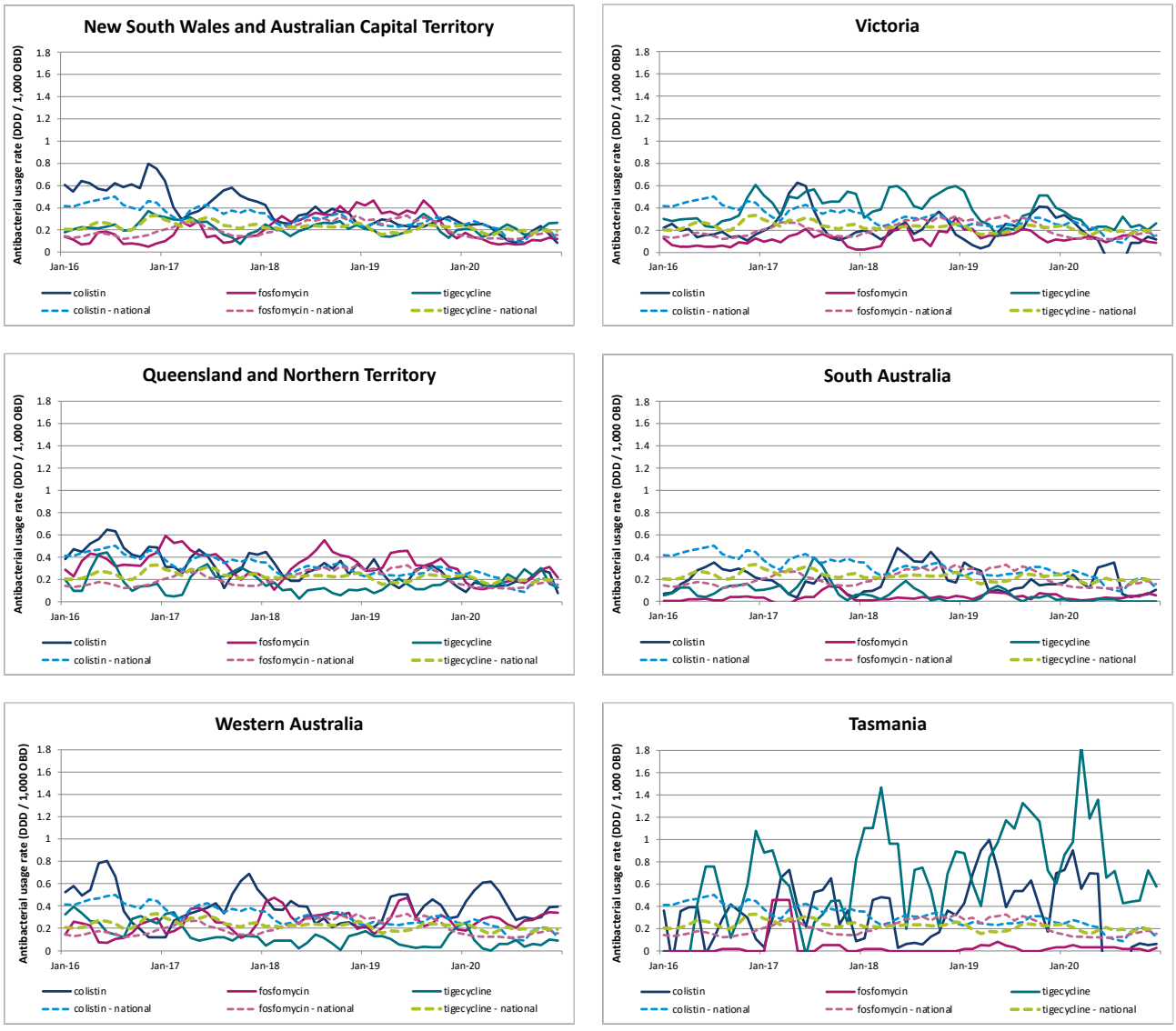
* Low-usage antimicrobials have a 5-month moving average, rather than a 3-month moving average, to optimise the visual trends.

DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

Colistin, tigecycline, fosfomycin

Fosfomycin is a last-line broad-spectrum antibiotic with activity against many strains of multidrug-resistant gram-negative bacteria, but it is inactive against *Pseudomonas aeruginosa*. Oral fosfomycin is used to treat multidrug-resistant urinary tract infections.[14] Fosfomycin use is generally low; however, it is increasing in Western Australia (Figure 22). Colistin and tigecycline are reserve-line antibacterials used as salvage treatment for multidrug-resistant infections. Colistin is bactericidal against gram-negative bacteria that are resistant to other drug classes, including strains of *P. aeruginosa* and *Acinetobacter baumannii*.[15,16] Colistin usage was much higher in Tasmania than in other states and territories during 2019 and the first half of 2020. Monthly tigecycline usage in Tasmania in 2020 was on average more than 4 times higher than in other states and territories. The average monthly usage rate in Tasmania was 0.85 DDD / 1,000 OBD compared to 0.19 DDD / 1,000 OBD nationally.

Figure 22: Colistin, fosfomycin and tigecycline usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2016–2020 (5-month moving average)*



* Low-usage antimicrobials have a 5-month moving average, rather than a 3-month moving average, to optimise the visual trends.

DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

Topical antimicrobial usage in Australian hospitals

Topical antimicrobial usage has been included in NAUSP data inclusions since January 2019. Very few clinical situations require treatment with topical antibacterials.[17] Topical antibacterials should not be used routinely on surgical wounds post-operatively, as their use contributes to the antimicrobial burden and increases the risk of antimicrobial resistance.[18]

There are no DDDs for topical antimicrobials; topical usage has been reported as the number of grams of active ingredient per 1,000 OBD.

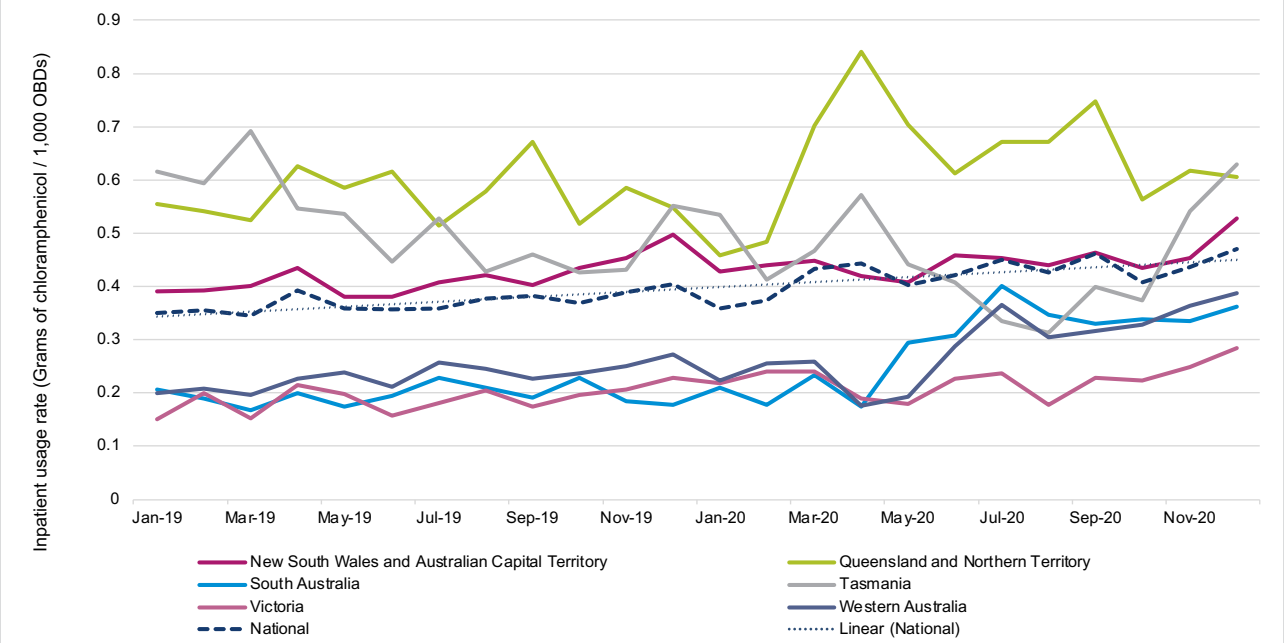
High-volume topical antimicrobials

This section provides the usage rates for some of the high-volume topical antimicrobials used in Australian hospitals for 2019 and 2020.

Chloramphenicol eye ointment

Chloramphenicol ointment should not be used routinely on post-operative wounds. Topical chloramphenicol is appropriate, however, for use in confirmed or suspected ophthalmological infections and is also used for surgical prophylaxis in ophthalmology. A limitation of the NAUSP dataset is that it is not possible to differentiate chloramphenicol usage in ophthalmology from other usage. Comparative inpatient usage of chloramphenicol 1% ointment across the states and territories is shown in Figure 23. Inpatient usage is highest in Queensland and the Northern Territory; on average, over the 2-year period, monthly usage in Queensland and the Northern Territory was 1.5 times higher than the national average.

Figure 23: Inpatient use of chloramphenicol 1% eye ointment (grams of active ingredient* / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2019–2020 (3-month moving average)



* 1 g of chloramphenicol is contained in 25 four gram tubes of 1% ointment.

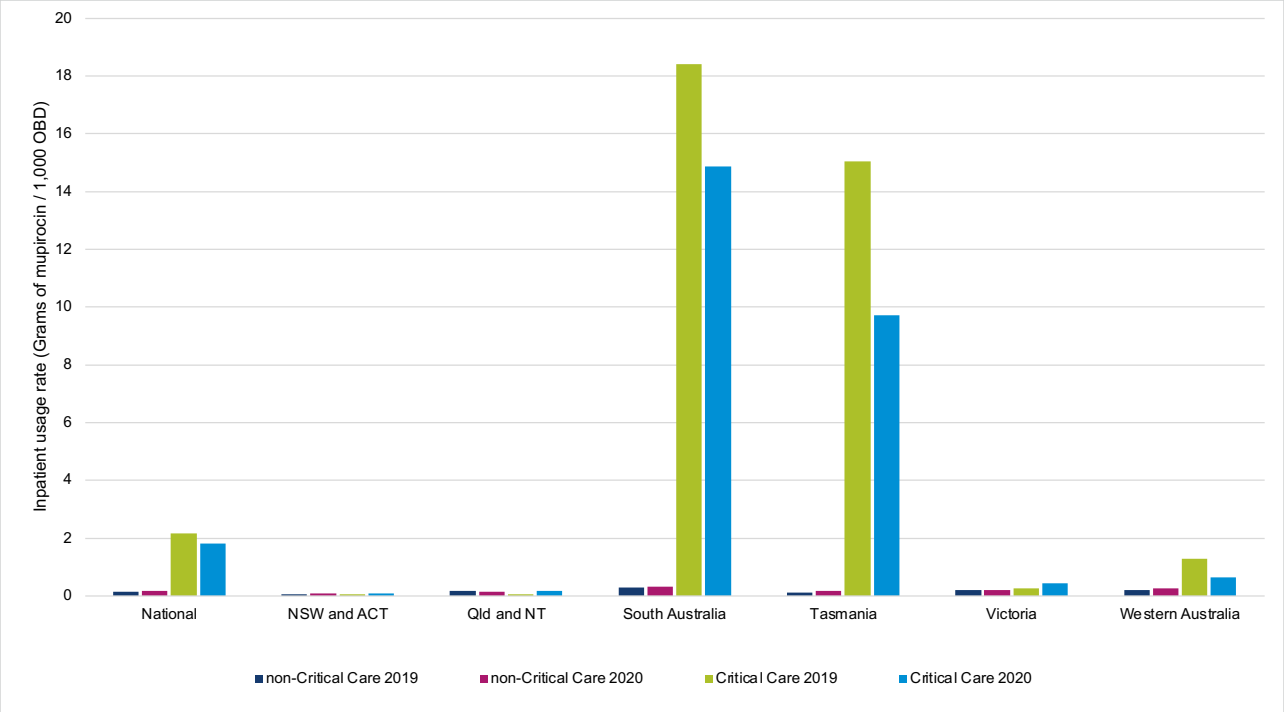
NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

Mupirocin

Mupirocin is available in Australia as a 2% cream or ointment, including an intranasal ointment. The prevalence of mupirocin-resistant *S. aureus* varies globally, and a number of studies have reported increased rates of resistance associated with overuse in the community.[19,20] Use of mupirocin to treat MRSA skin infections has been associated with emergence of mupirocin-resistant community-associated strains of MRSA.[19] Reported mupirocin resistance in MRSA in Australia is currently 1.9%.[21]

Figure 24 illustrates the comparative annual usage of mupirocin between the states and territories for 2019 and 2020, for both the critical care and non-critical care inpatient settings. Critical care includes intensive care units and high dependency units. Non-critical care incorporates all other acute inpatient settings that are not critical care.

Figure 24: Usage of topical mupirocin (grams of active ingredient* / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, critical care versus non-critical care, 2019 and 2020



* 1 g of mupirocin is contained in 50 g of mupirocin 2% ointment (17 x 3 g tubes).

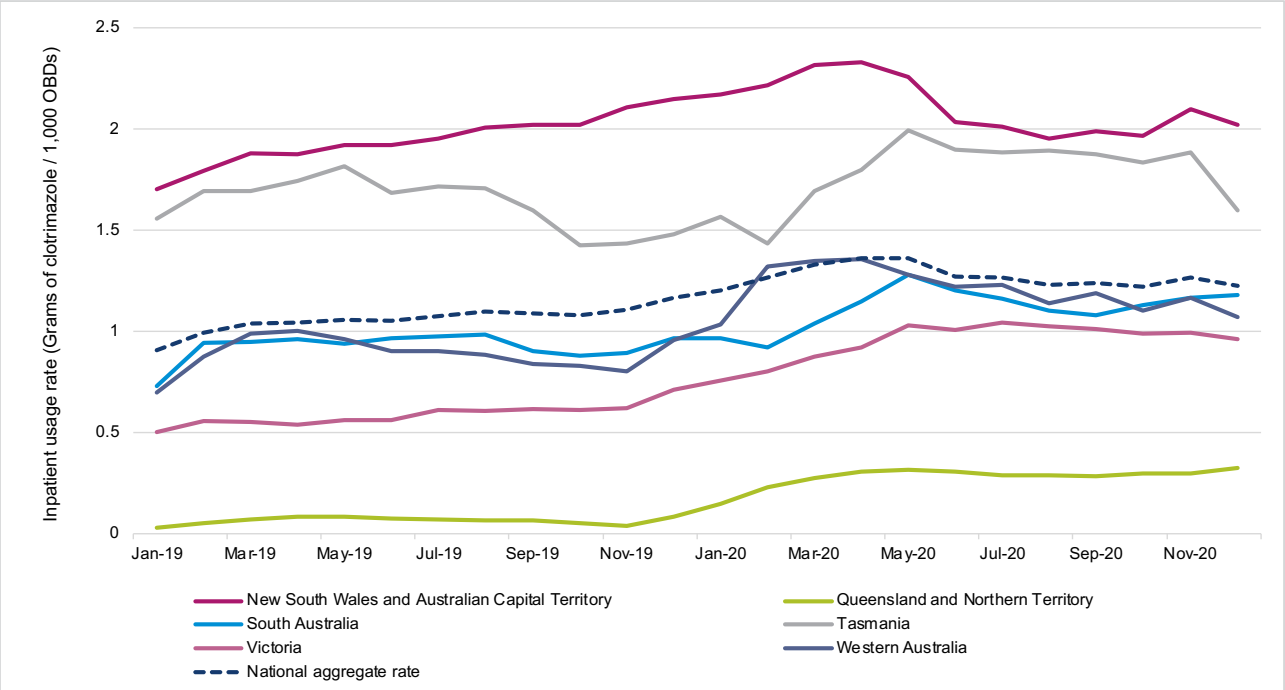
NAUSP: National Antimicrobial Utilisation Surveillance Program.

Usage of mupirocin is relatively low nationwide in the non-critical care inpatient setting, with the national usage rate being 0.2 g of mupirocin / 1,000 OBD. That is equivalent to 10 g of 2% ointment per 1,000 OBD. In contrast, there is wide variability of use in the critical care setting, with South Australia and Tasmania having much higher usage than other states. Usage rates did decrease in critical care in both states between 2019 and 2020, with a 35.4% decrease in Tasmania and a 19.2% decrease in South Australia. Despite this reduction in usage, the statewide critical care usage in South Australia is over 8 times higher than the national aggregate rate in critical care.

Clotrimazole and miconazole

Inpatient use of clotrimazole and miconazole is extremely variable across the states and territories, as illustrated in Figures 25 and 26. Notably Queensland and the Northern Territory has the highest dermatological usage of miconazole and very low clotrimazole usage. Inpatient clotrimazole usage was highest in New South Wales and the Australian Capital Territory in 2019 and 2020 (Figure 25).

Figure 25: Dermatological usage# of clotrimazole (grams of active ingredient* / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2019–2020 (3-month moving average)

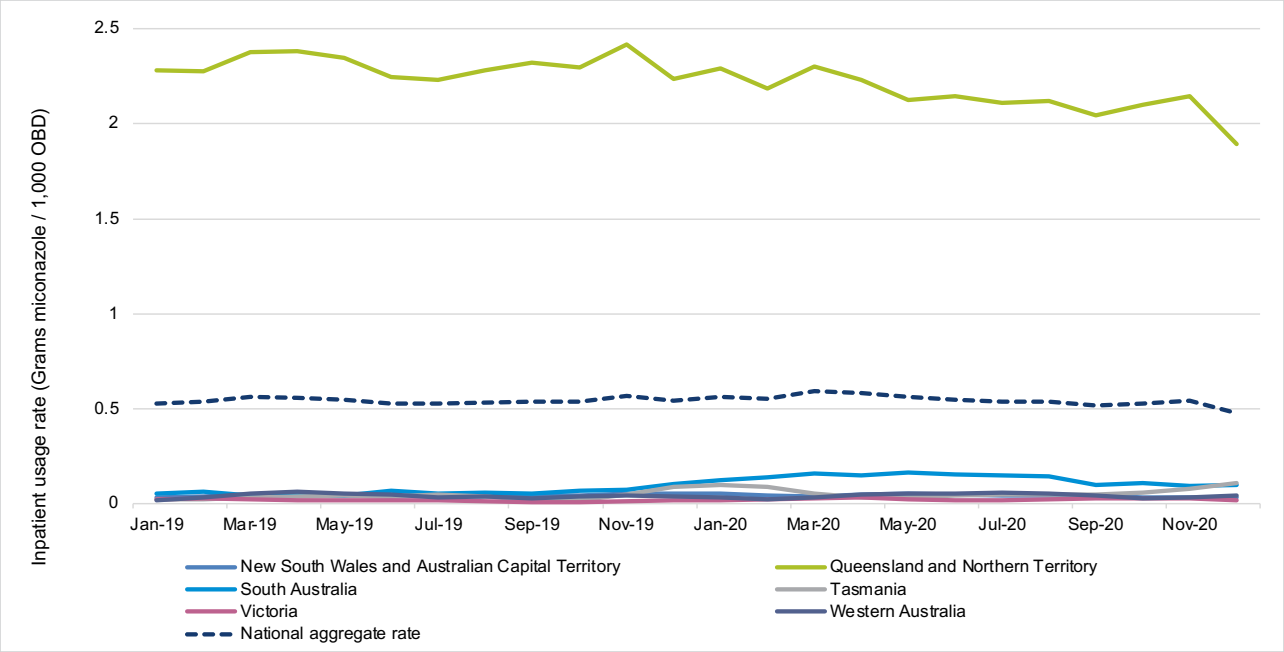


Excludes vaginal usage.

* 1 g of clotrimazole is contained in 100 g of 1% cream/ointment.

NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

Figure 26: Dermatological usage# of miconazole (grams of active ingredient* / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2019–2020 (3-month moving average)



Excludes vaginal usage.

* 1 g of miconazole is contained in 50 g of 2% cream/ointment.

NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

Systemic antifungal use

NAUSP contributors began routine submission of data on antifungal usage from 2017, when NAUSP data definitions were updated to include systemic antifungal agents. Antifungal resistance is increasing globally, including to the azole antifungals, which are commonly used in both human health as well as in agriculture.[22] Overuse and inappropriate use of antifungals in both humans and the environment are leading to the emergence of resistant fungi globally, which is associated with increased treatment costs and higher risk of mortality for patients with infections caused by these pathogens.[23]

National antifungal usage

Total antifungal use in NAUSP contributor hospitals increased 3.5% in 2020 compared to 2019. In 2020 the total systemic antifungal usage rate across NAUSP contributor hospitals was 36.5 DDD / 1.000 OBD (Table 6). Triazole antifungals (fluconazole, itraconazole, isavuconazole, ketoconazole, posaconazole and voriconazole) accounted for approximately 85% of total hospital inpatient antifungal usage in 2020. Fluconazole remains the most used antifungal agent in the NAUSP contributor hospitals, comprising 51.6% of total antifungal use in 2020. Annual posaconazole use has increased annually since 2017, and in 2020 it made up 17.0% of total systemic antifungal inpatient use nationally. Usage of posaconazole increased from 5.8 DDD / 1,000 OBD in 2019 to 6.2 DDD / 1,000 OBD in 2020 – an increase of 7.0%.

Echinocandin (anidulafungin, caspofungin and micafungin) use comprised 6.9% of total systemic antifungal use in NAUSP contributor hospitals in 2020. Anidulafungin has the highest annual usage of the echinocandins at 1.5 DDD / 1,000 OBD. Although anidulafungin usage fell slightly in 2020 compared to 2019, caspofungin usage increased from 0.36 DDD / 1,000 OBD to 0.83 DDD / 1,000 OBD. Overall hospital usage of echinocandins remains low; however, usage has increased by 33.0% since 2017.

Liposomal amphotericin is the most commonly used amphotericin formulation in Australian hospitals; the annual usage rate in 2020 was 1.4 DDD / 1,000 OBD - a decrease of 10.7% compared to 2019. Liposomal amphotericin comprised 3.9% of total systemic antifungal use in NAUSP contributor hospitals in 2020.

Table 6: Annual antifungal usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, 2017–2020

Antifungal	Usage rate (DDD / 1,000 OBD)				% change 2019–2020
	2017	2018	2019	2020	
Amphotericin B	0.26	0.25	0.24	0.22	-5.9%
Amphotericin, lipid complex	0.03	0.01	0.01	0.00	-
Amphotericin, liposomal*	1.01	1.05	1.58	1.41	-10.7%
Anidulafungin	1.16	1.56	1.65	1.46	-12.0%
Caspofungin	0.64	0.51	0.36	0.83	126.6%
Fluconazole	18.45	18.89	18.58	18.83	1.4%
Flucytosine	0.15	0.14	0.16	0.19	15.3%
Griseofulvin	0.03	0.15	0.13	0.11	-20.1%
Isavuconazole	0.01	0.01	0.01	0.02	90.9%
Itraconazole	3.07	2.45	2.38	2.78	16.6%
Ketoconazole	0.09	0.08	0.05	0.06	22.0%
Micafungin	0.11	0.18	0.24	0.25	4.2%
Posaconazole	5.20	5.73	5.79	6.19	7.0%
Terbinafine	0.92	0.95	0.90	1.01	11.7%
Voriconazole	3.16	3.13	3.14	3.11	-0.9%
Total	**34.28**	**35.10**	**35.23**	**36.47**	**3.5%**

* DDD for liposomal amphotericin is assigned by NAUSP as 0.21 g.

DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

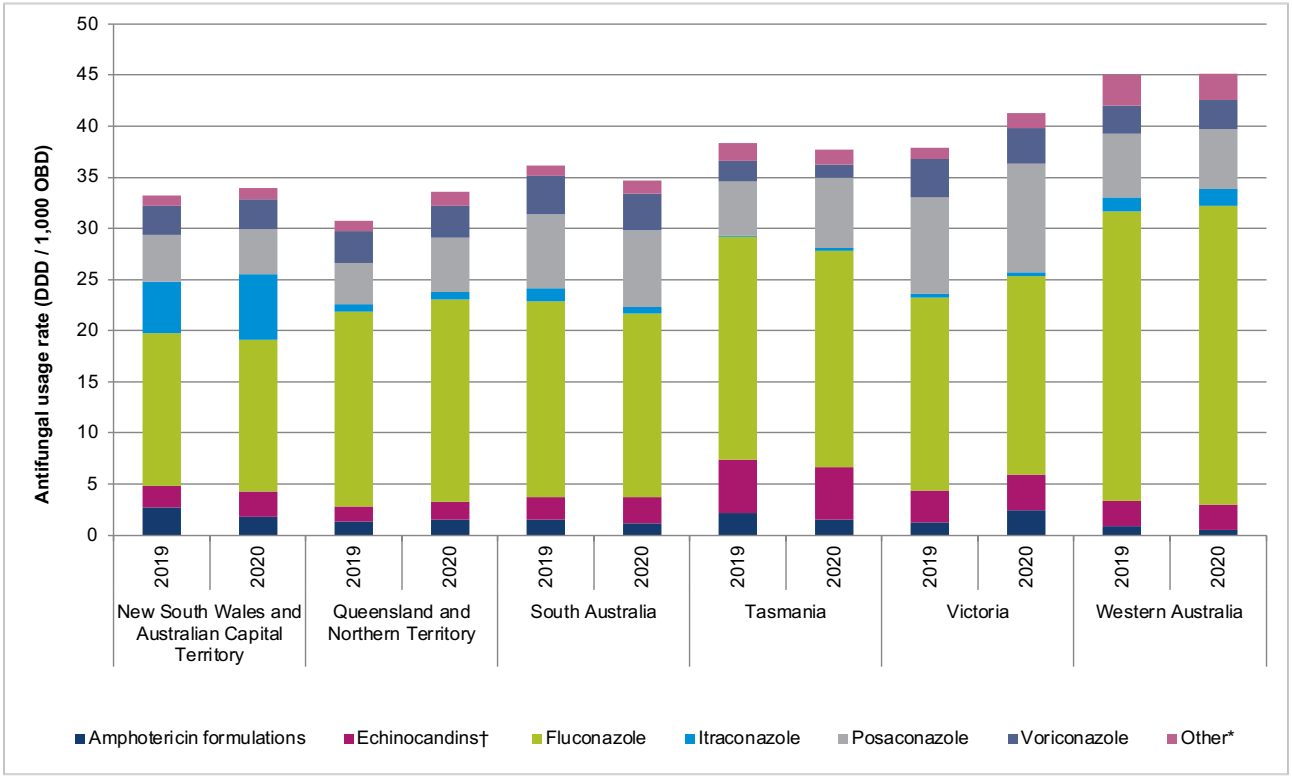
Antifungal usage in Australian hospitals by state and territory

The increase in the national antifungal usage rate of 3.5% between 2019 and 2020 (Table 6) was driven by an increase of 9.3% in Queensland and the Northern Territory and a similar annual increase of 9.0% in Victoria. Western Australia continues to have the highest inpatient use of antifungals – it has a total annual usage of 45.1 DDD / 1,000 OBD, with no change in the total usage seen between 2019 and 2020. Usage decreased in both South Australia and Tasmania, by 4.0% and 1.7% respectively.

There continue to be notable differences in the antifungal agents used, between states and territories (Figure 27). For 2020, key findings included the following:

- Usage of itraconazole in New South Wales and the Australian Capital Territory was 6.5 DDD / 1,000 OBD, which was almost 4 times greater than Western Australia, which had the next highest usage rate.
- Western Australia had the highest fluconazole usage rate in 2020, at 29.22 DDD / 1,000 OBD, followed by Tasmania (21.2 DDD / 1,000 OBD). Both states had higher usage than the national average of 20.4 DDD / 1,000 OBD annually.
- Posaconazole usage increased markedly in Queensland and the Northern Territory, up by 30.8% in 2020 to 5.3 DDD / 1,000 OBD. Tasmania also saw a large increase of 29.5%; however, total annual usage of posaconazole continued to be highest in Victoria at 10.6 DDD / 1,000 OBD in 2020, which was almost 2.5 times more than the usage rate in New South Wales and the Australian Capital Territory (4.4 DDD / 1,000 OBD).
- Tasmania had the highest use of the echinocandins in both 2019 and 2020; annual usage in 2020 was 5.2 DDD / 1,000 OBD, which was 71.9% higher than the average annual usage rate across the states and territories.

Figure 27: Antifungal usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2019–2020



† 'Echinocandins' includes anidulafungin, caspofungin and micafungin.

* 'Other' includes flucytosine, griseofulvin, isavuconazole, ketoconazole and terbinafine.

DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

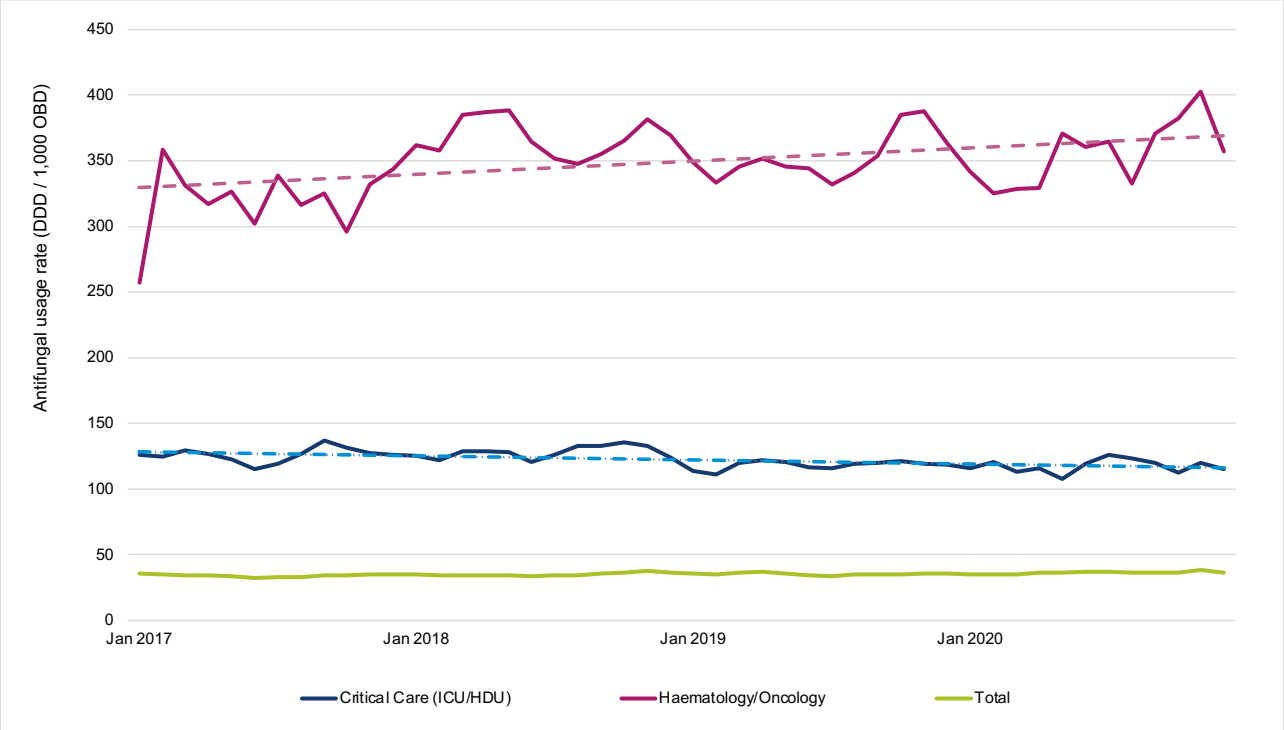
Total antifungal usage in critical care, haematology/oncology and total hospital

Figure 28 shows the use of antifungal agents used in the inpatient haematology/oncology units or wards, as well as critical care units, compared to the total hospital usage rates. (Note that total hospital usage rates are inclusive of haematology/oncology and critical care locations.) The number of hospitals contributing data for these locations is shown in Table 7.

Antifungal usage rates continue to increase in the inpatient haematology/oncology locations, trending upwards in the period between 2017 and 2020. Specialist cancer wards use antifungals both prophylactically for immunocompromised patients and for treatment of invasive fungal disease. Monthly usage rates for the 4-year period were on average almost 10 times higher in haematology/oncology units compared to total hospital usage rates.

Usage rates in the critical care setting are on average approximately 3.5 times higher than total hospital usage rates. Patients in critical care are often immunocompromised and frequently have a number of other risk factors for invasive fungal infections – for example, surgery, total parenteral nutrition and mechanical ventilation.

Figure 28: Antifungal usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals (total hospital, critical care and haematology/oncology), 2017–2020 (3-month moving average)



Note: Dotted lines are included to indicate trends.

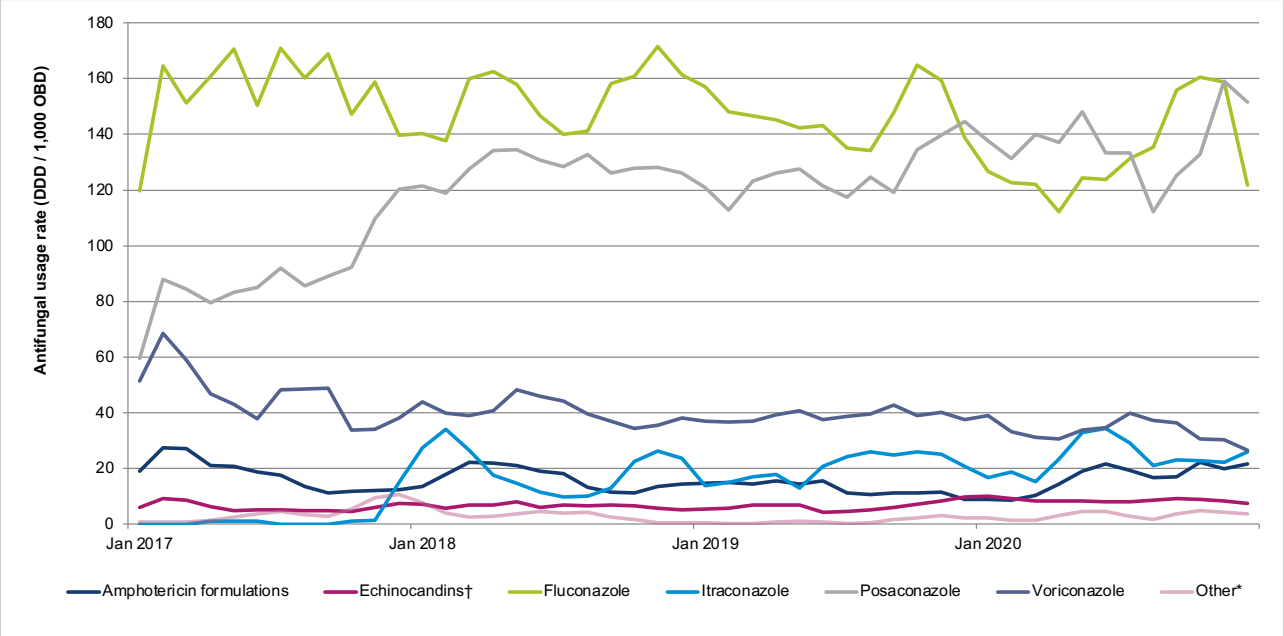
DDD: defined daily dose; HDU: high dependency unit; ICU: intensive care unit; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

Table 7: Number of contributors submitting location-specific data for critical care and haematology/oncology, 2017–2020

	Haematology/oncology	Critical care
2017	9/187	90/187
2018	12/200	93/200
2019	12/214	103/214
2020	13/231	107/231

Figure 29 illustrates the antifungal usage in haematology/oncology inpatient units, by class or agent. Posaconazole usage has increased markedly over the 4-year period from 2017 to 2020. The average monthly usage rate in haematology/oncology hospital locations was 136.8 DDD / 1,000 OBD in 2020 compared to 80.1 DDD / 1,000 OBD in 2017 – an increase in average monthly usage rates in this setting of 53.5%. Posaconazole has a slightly broader spectrum than voriconazole and is used to treat serious fungal infections, including invasive aspergillosis, mucormycosis and mycetoma.

Figure 29: Antifungal usage rates (DDD / 1,000 OBD) in haematology/oncology specialty units in NAUSP contributor hospitals, by agent or class, 2017–2020 (3-month moving average)



† 'Echinocandins' includes anidulafungin, caspofungin and micafungin.

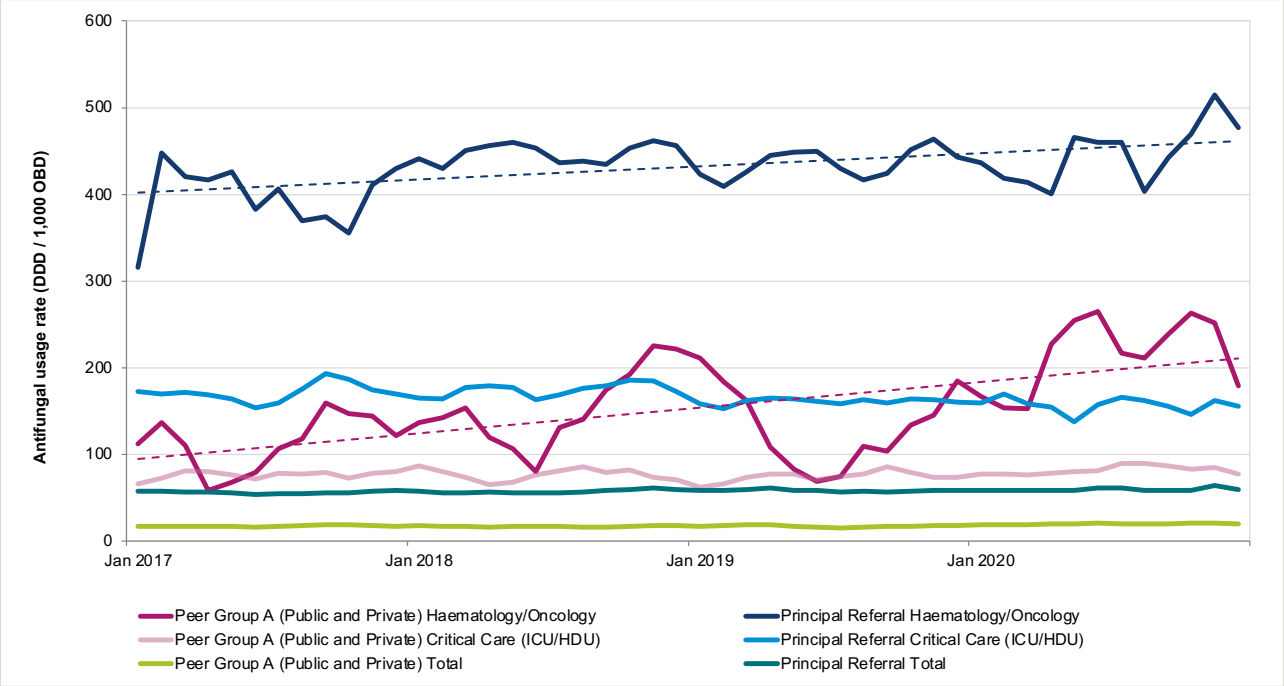
* 'Other' includes flucytosine, griseofulvin, isavuconazole, ketoconazole and terbinafine.

DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

Antifungal usage in Australian hospitals by AIHW peer group

Usage rates for antifungal agents are highly dependent on the casemix of the hospital, including whether the hospital provides transplant services. As would be expected, usage of systemic antifungals is higher in larger hospitals, particularly principal referral and public Acute Group A NAUSP contributors. Figure 30 illustrates the antifungal usage rates in these AIHW peer groups, comparing usage in critical care and haematology/oncology units and the total hospital usage rates. For haematology/oncology units, monthly antifungal usage in principal referral hospitals is on average almost 3 times higher than haematology/oncology inpatient use in AIHW peer Acute Group A (public and private combined) hospitals.

Figure 30: Antifungal usage rates (DDD / 1,000 OBD) in principal referral hospitals and Acute Group A hospitals contributing to NAUSP (total hospital, critical care and haematology/oncology), 2017–2020 (3-month moving average)



Note: Dotted lines are included to indicate trends.

DDD: defined daily dose; ICU: intensive care unit; HDU: high dependency unit; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

Discussion and conclusions

Hospitals contributing to the NAUSP are able to extract usage reports and rate calculations to monitor their antimicrobial usage over time and also benchmark their usage against other similar hospitals. Surveillance of antimicrobial usage supports AMS teams and enables them to identify possible inappropriate prescribing or concerning trends, allowing them to investigate and intervene. Monitoring usage over time also enables evaluation of stewardship or policy interventions implemented at a local or state level. NAUSP is administered by SA Health and until December 2020 was funded by the Australian Commission on Safety and Quality in Health Care, after which the program transitioned to the Australian Government Department of Health as part of a broader transition to a One Health surveillance system.

In 2020 there were a number of disruptions in submissions to NAUSP due to the COVID-19 pandemic, including fluctuations in distributions of antimicrobials to the wards, particularly where wards were repurposed for COVID-19 patients. Hospital activity also fluctuated in NAUSP contributor hospitals, with some facilities closing for a number of months during the first wave of the pandemic (March–May 2020). Some hospitals found keeping up with NAUSP data submissions challenging, particularly in facilities where AMS pharmacists were redistributed to other duties in response to the pandemic.

Antibacterial usage in NAUSP contributor hospitals decreased by 2.9% in 2020 compared to 2019 – the first decrease in total annual usage since 2016. Usage increased annually between 2016 and 2019; however, some of this increase may be attributed to an increasing number of hospitals contributing usage data from the operating theatre location over this period. Reported usage rates are higher in hospitals with a higher number of day surgery cases due to the lower number of OBD or denominator data. The increasing participation of private hospitals, some with a large proportion of day surgery, may therefore have contributed to the reported increases in antibacterial usage between 2016 and 2019.

The large reductions in the inpatient usage of some classes of antibacterials in 2020 – for example, the macrolides and tetracyclines – parallels the reductions seen in the outpatient sector. The recently published *AURA 2020: Fourth Australian report on antimicrobial use and resistance in human health* reported reduced community prescribing for amoxicillin, amoxicillin-clavulanate, cefalexin, doxycycline and roxithromycin during 2020 compared to 2019.[24] A number of reasons for the decreased prescribing during the COVID-19 pandemic have been proposed, including improved infection control and public campaigns for physical distancing during the pandemic. These public health measures have seen a reduction in other acute viral infections – for example, influenza.[25] The reduction in hospital usage of antibacterials commonly used to treat community-acquired pneumonia, such as doxycycline and azithromycin, may be due to a reduction in the number of pneumonia cases in 2020.

As seen in previous NAUSP reports, there is ongoing substantial variation in antimicrobial usage across the states and territories for multiple antimicrobial classes. Although some variation is to be expected due to different hospital casemix, the reasons for the wide variation in clinical practice are unclear. Interpretation of NAUSP data in conjunction with data on appropriateness of use is required to accurately inform stewardship programs. In summary, states and territories should utilise NAUSP reports in conjunction with data from the National Antimicrobial Prescribing Survey to inform AMS interventions to improve antimicrobial prescribing and use.

Appendix 1: Contributors

Table A1: Hospitals that contributed data included in the analyses for the National Antimicrobial Utilisation Surveillance Program Annual Report 2020

State or territory	Hospital		
New South Wales	Armidale Hospital	Grafton Base Hospital	Parkes Hospital
	Auburn Hospital	Griffith Base Hospital	Port Macquarie Base Hospital
	Bankstown Hospital	Gunnedah Hospital	Prince of Wales Hospital
	Batemans Bay District Hospital	Hornsby Ku-Ring-Gai Hospital	Queanbeyan Hospital
	Bathurst Base Hospital	John Hunter Hospital	Quirindi Hospital
	Belmont Hospital	Kareena Private Hospital	Royal North Shore Hospital
	Blacktown Hospital	Kempsey District Hospital	Royal Prince Alfred Hospital
	Bourke Multipurpose Service	Lake Macquarie Private Hospital	Ryde Hospital
	Bowral Hospital	Lismore Base Hospital	Scott Memorial Hospital
	Broken Hill Base Hospital	Lithgow Hospital	Shellharbour Hospital
	Calvary Riverina Hospital	Liverpool Hospital	Shoalhaven Hospital
	Campbelltown Hospital	Maclean District Hospital	Singleton District Hospital
	Canowindra Soldiers Memorial Hospital	Maitland Hospital	South East Regional Hospital
	Canterbury Hospital	Manning Base Hospital	St George Hospital
	Cessnock District Hospital	Mater Hospital North Sydney	St Vincent's Hospital Sydney
	Chris O'Brien Lifehouse	Milton-Ulladulla Hospital	St Vincent's Private Hospital Sydney
	Coffs Harbour Hospital	Moree Hospital	Sutherland Hospital
	Concord Hospital	Moruya Hospital	Sydney Adventist Hospital
	Cooma Hospital	Mt Druitt Hospital	Tamworth Hospital
	Deniliquin Hospital	Mudgee District Hospital	The Tweed Hospital
	Dubbo Base Hospital	Muswellbrook Hospital	Wagga Wagga Base Hospital
	Fairfield Hospital	Narrabri Hospital	Warren Multipurpose Service
	Forbes District Hospital	Nepean Hospital	Westmead Hospital
	Gilgandra Multipurpose Service	Nepean Private Hospital	Westmead Private Hospital
	Gosford Hospital	Newcastle Mater	Wollongong Hospital
	Gosford Private Hospital	Northern Beaches Hospital	Wyong Hospital
	Goulburn Base Hospital	Orange Health Service	Young Health Service
Australian Capital Territory	Calvary Public Hospital Bruce	Canberra Hospital	

State or territory	Hospital		
Queensland	Atherton Hospital	Mackay Base Hospital	Redcliffe Hospital
	Buderim Private Hospital	Mareeba Hospital	Redland Hospital
	Bundaberg Hospital	Maryborough Hospital	Robina Hospital
	Caboolture Hospital	Mater Bundaberg	Rockhampton Hospital
	Cairns Base Hospital	Mater Hospital Brisbane	Royal Brisbane and Women's Hospital
	Gladstone Hospital	Mater Mackay	St Andrew's War Memorial Hospital
	Gold Coast Private Hospital	Mater Mothers' Hospital	St Stephen's Hospital Hervey Bay
	Gold Coast University Hospital	Mater Private Hospital Brisbane	St Vincent's Private Hospital Brisbane
	Greenslopes Hospital	Mater Private Hospital Springfield	St Vincent's Private Hospital Northside
	Gympie Health Service	Mater Redland Private	Sunshine Coast University Hospital
	Hervey Bay Hospital	Mater Rockhampton	The Prince Charles Hospital
	Innisfail Hospital	Mt Isa Hospital	Toowoomba Hospital
	Ipswich Hospital	Nambour General Hospital	Townsville Hospital
	Kingaroy Hospital	Princess Alexandra Hospital	Warwick Hospital
	Logan Hospital	Queen Elizabeth 2 Jubilee Hospital	Wesley Hospital
Northern Territory	Alice Springs Hospital	Katherine District Hospital	Royal Darwin Hospital
	Darwin Private Hospital	Palmerston Regional Hospital	Tennant Creek Hospital
	Gove District Hospital		
South Australia	Ashford Hospital	Lyell McEwin Hospital	Queen Elizabeth Hospital
	Berri Hospital	Memorial Hospital	Royal Adelaide Hospital
	Calvary Adelaide Private Hospital	Modbury Hospital	South Coast District Hospital
	Calvary Central Districts Hospital	Mount Barker District Soldiers Memorial Hospital	St Andrew's Hospital
	Calvary North Adelaide Hospital	Mt Gambier Hospital	Whyalla Hospital
	Flinders Medical Centre	Noarlunga Hospital	Women's and Children's Hospital
	Flinders Private Hospital	Port Augusta Hospital	
	Gawler Health Service	Port Lincoln Hospital	
Tasmania	Hobart Private Hospital	Mersey Community Hospital	Royal Hobart Hospital
	Launceston General Hospital	North West Regional Hospital	

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

Appendix 2: Methods

This section describes data elements, quality assurance processes and analyses.

Data elements

Pharmacy departments of Australian hospitals that participate voluntarily in the National Antimicrobial Utilisation Surveillance Program (NAUSP) supply monthly antimicrobial utilisation data based on dispensing and distribution reports for the different clinical departments or wards for inpatient use. They upload the data via an online portal. Hospital occupancy data are collected on a monthly basis in the form of occupied bed days (OBD).

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

Data quality

Each contributing hospital is responsible for the accuracy of antimicrobial usage data submitted to NAUSP, including compliance with NAUSP data definitions.[26] Alerts are generated automatically during the data submission process if quantities fall outside a usual or expected range. This enables validation of data at an early stage of data submission.

The NAUSP team performs periodic quality assurance processes to validate the accuracy and integrity of the data uploaded into the online portal managed by SA Health.[27] 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, with OBD being the denominator used. Consumption data submitted to NAUSP are aggregated into the total number of grams used each month for each individual antimicrobial. Proprietary drug names and product descriptions extracted by hospital dispensing software are mapped to a standardised list as part of the analysis. Antimicrobial usage is then converted from total grams used into the defined daily dose (DDD) metric assigned for each antimicrobial by the World Health Organization (WHO). These 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 always reflect the usual daily doses used in Australian clinical practice (see Appendix 3, 'Limitations').

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 9 broad-spectrum antimicrobials (Table A1).

Due to small numbers of hospitals participating in NAUSP in the 2 Australian territories, they have been grouped with larger states for the purposes of this report. For usage rates reported at a jurisdictional level, hospitals in the Northern Territory have been grouped with Queensland; and hospitals in the Australian Capital Territory have been grouped with New South Wales.

Table A2: Changes to DDD values from 1 January 2019[28]

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

Utilisation rates in this report have been calculated using the DDD values as at 1 January 2019.[29] As a result, rates reported will differ from previous NAUSP reports that used the DDD values that applied prior to 1 January 2019. In addition to changes to the DDD values in Table A1, care is required when interpreting NAUSP data because of historical changes to DDD definitions for various other antimicrobial agents.

There are no DDDs for topical antimicrobials; topical usage has been reported as the number of grams of active ingredient per 1,000 OBD.

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 OBD supplied by individual contributors. Minor discrepancies between NAUSP reports may occur as a result of data submitted retrospectively by contributing hospitals or by the inclusion of hospitals that were excluded from previous reports due to issues regarding data validity.

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 an individual hospital's usage rates.

Appendix 3: Limitations

The antimicrobial usage rates calculated for this report are correct at the time of publication and are contingent on the accuracy of the antibacterial and antifungal quantities and OBD supplied by individual contributors, including compliance with NAUSP data definitions. Minor discrepancies between annual reports may occur as a result of data submitted retrospectively by contributing hospitals or by the inclusion of hospitals that were excluded from previous reports due to issues regarding data validity.

Due to smaller numbers of private hospitals contributing data to NAUSP, data from private hospitals has been benchmarked with public hospitals of similar size and acuity. Data from public Acute Group D, private Acute Group D, public Acute Group C and private Acute Group C have been combined as a single benchmarking group.

Usage reflects antimicrobials distributed or dispensed from pharmacy and does not reflect actual antimicrobial consumption at patient level. Reported usage rates are limited to acute-hospital usage only and does not include antimicrobial use in subacute specialties. Outpatient usage and day-only usage is currently not included in NAUSP data. Inpatient theatre usage is included in NAUSP on the assumption a corresponding OBD is recorded in the inpatient ward where the patient is transferred to following theatre. For hospitals that are not able to differentiate between usage for inpatient surgery as opposed to usage for day surgery, this introduces a level of uncertainty into the rates calculated.

Antimicrobials currently included in the NAUSP dataset are the most commonly used antibacterials and antifungals in Australian hospitals. The DDDs assigned by the WHO Anatomical Therapeutic Classification (ATC) system are used to calculate the usage rates. Care is required when interpreting NAUSP data where the WHO DDD does not accurately reflect the Australian setting. If routine doses used in the Australian setting are higher or lower than the WHO-assigned DDD, this may contribute to an over- or under-estimation of usage rates.

Appendix 4: Antimicrobial agents – WHO Anatomical Therapeutic Classification for antimicrobial agents included in NAUSP analyses

Table A3: 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	ß-lactam antibacterials, penicillins		
J01CA	Penicillins with extended spectrum		
J01CA01	Ampicillin	6*	O, P
J01CA04	Amoxicillin	1.5*	O
J01CA04	Amoxicillin	3*	P
J01CA17	Temocillin	4	P
J01CE	ß-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	ß-lactamase-resistant penicillins		
J01CF01	Dicloxacillin	2	O, P
J01CF05	Flucloxacillin	2	O, P
J01CR	Combinations of penicillins, including ß-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 ß-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

ATC classification	Generic name	DDD (g)	Route
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
J01DD08	Cefixime	0.4	O
J01DD52	Ceftazidime and enzyme inhibitor	6	P
J01DE	Fourth-generation cephalosporins		
J01DE01	Cefepime	4	P
J01DH	Carbapenems		
J01DH02	Meropenem	3	P
J01DH03	Ertapenem	1	P
J01DH04	Doripenem	1.5	P
J01DH51	Imipenem and enzyme inhibitor	2	P
J01DF	Monobactam		
J01DF01	Aztreonam	4	P
J01DI	Other cephalosporins and penems		
J01DI02	Ceftaroline	1.2	P
J01DI03	Faropenem	0.75	O
J01DI54	Ceftolozane and ß-lactamase inhibitor	3	P
J01E	Sulfonamides and trimethoprim		
J01EA01	Trimethoprim	0.4	O, P
J01EC02	Sulfadiazine	0.6	O
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
J01FA02	Spiramycin	3	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		
J01GA01	Streptomycin	1	P

ATC classification	Generic name	DDD (g)	Route
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
J01MA12	Levofloxacin	0.5	O, P
J01MA14	Moxifloxacin	0.4	O, P
J01XA	Glycopeptide antibacterials		
J01XA01	Vancomycin	2	O, P
J01XA02	Teicoplanin	0.4	P
J01XA04	Dalbavancin	1.5	P
J01XA05	Oritavancin	1.2	P
J01XB	Polymyxins		
J01XB01	Colistin	3MU	Inh
J01XB01	Colistin	9MU	P
J01XB02	Polymyxin B	0.15	P
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

Source: World Health Organization, Anatomical Therapeutic Chemical (ATC) Classification.

ATC: Anatomical Therapeutic Classification; DDD: defined daily dose; Inh: inhalation; MU: million units; O: oral; P: parenteral; R: rectal.

Table A4: 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

*DDD assigned by NAUSP.

Source: WHO (2019).28

ATC: Anatomical Therapeutic Classification; DDD: defined daily dose; MR: modified release; NAUSP: National Antimicrobial Utilisation Surveillance Program; O: oral; P: parenteral.

Table A5: Topical antimicrobials: dermatological

ATC classification	Generic name
D01AA01	Nystatin
D01AC01	Clotrimazole
D01AC02	Miconazole
D01AC03	Econazole
D01AC08	Ketoconazole
D01AC10	Bifonazole
D01AC20	Imidazoles / triazoles in combination with corticosteroids
D01AC52	Miconazole, combinations
D01AC60	Bifonazole, combinations
D01 AE14	Ciclopirox
D01AE15	Terbinafine
D01AE16	Amorolfine
D01AE18	Tolnaftate
D06AX01	Sodium fusidate
D06AX09	Mupirocin
D06BA01	Silver sulfadiazine
D06BB01	Idoxuridine
D06BB03	Aciclovir
D06BB06	Penciclovir
D06BX01	Metronidazole
D07CB01	Triamcinolone and antibiotics, combinations
D10AF01	Clindamycin

Source: World Health Organization, Anatomical Therapeutic Chemical (ATC) Classification.
ATC: Anatomical Therapeutic Classification.

Table A6: Topical antimicrobials: vaginal

ATC classification	Generic name
G01AA01	Nystatin (gynaecological)
G01AA10	Clindamycin (gynaecological)
G01AF01	Metronidazole (gynaecological)
G01AF02	Clotrimazole (gynaecological)
G01AF04	Miconazole (gynaecological)

Source: World Health Organization, Anatomical Therapeutic Chemical (ATC) Classification.
ATC: Anatomical Therapeutic Classification.

Appendix 5: Antibacterials included in the Priority Antibacterial List[2], according to the Access and Review (Curb and Contain) classification

Table A7: Antibacterial classifications in the Priority Antibacterial List

Access	Review	
	Curb	Contain
Amoxicillin	Amoxicillin–clavulanic acid	Amikacin
Ampicillin	Azithromycin	Aztreonam
Benzathine benzylpenicillin	Cefaclor	Cefepime
Benzylpenicilli	Cefalexin	Ceftaroline
Chloramphenicol	Cefalotin	Ceftazidime
Dicloxacillin	Cefazolin	Ceftazidime-avibactam
Doxycycline	Cefotaxime	Ceftolozane–tazobactam
Flucloxacillin	Cefoxitin	Colistin
Gentamicin	Ceftriaxone	Daptomycin
Metronidazole	Cefuroxime	Doripenem
Minocycline	Clarithromycin	Ertapenem
Nitrofurantoin	Ciprofloxacin	Fosfomycin
Phenoxymethylpenicillin	Clindamycin	Imipenem–cilastatin
Procaine benzylpenicillin	Erythromycin	Linezolid
Streptomycin	Fidaxomicin	Meropenem
Sulfamethoxazole–trimethoprim	Lincomycin	Moxifloxacin
Tetracycline	Norfloxacin	Pivmecillinam
Tinidazole	Piperacillin-tazobactam	Polymyxin B
Tobramycin	Rifampicin	Pristinamycin
Trimethoprim	Rifaximin	Tigecycline
	Roxithromycin	
	Sodium fusidate	
	Spiramycin	
	Teicoplanin	
	Vancomycin	

Appendix 6: Glossary

Term	Definition
AIHW	Australian Institute of Health and Welfare
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.
AMS	antimicrobial stewardship
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. When specifically referring to a type of antimicrobial, the term 'antibacterial' or 'antifungal' will be used.
AURA	Antimicrobial Use and Resistance in Australia
Critical care	intensive care units and high dependency units
Defined daily dose (DDD)	The average maintenance dose per day for an average adult for the main indication of the medicine.
Hospital peer groups (AIHW)	Hospital groups as defined by shared characteristics reflecting the services and resources for the purposes of analysing or comparing performance. Peer groups are defined in Australian Institute of Health and Welfare (2015) Australian hospital peer groups. Health services series no. 66. Cat no. HSE 170. Canberra, AIHW.
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.
NAUSP	National Antimicrobial Utilisation Surveillance Program
Occupied bed days (OBD)	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 AIHW). Day patients (including dialysis, day surgery), outpatients, Hospital in the Home, and mental health and rehabilitation units are excluded.
SA Health	South Australian Department of Health and Wellbeing
Usage rate	The number of DDDs used per 1,000 OBD. Data for day patients (including dialysis, day surgery), outpatients, Hospital in the Home, and mental health and rehabilitation units are excluded. The rate is calculated as follows: $\text{Usage (density) rate} = \frac{\text{Number of DDDs / time period x 1,000}}{\text{OBD / time period}}$
Total hospital usage rate	Aggregated usage rate for all acute care locations in a hospital (inclusive of critical care).
WHO	World Health Organization

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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 and on the Australian Government One Health AMR website at https://www.amr.gov.au.

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