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Antimicrobial Use in Australian Hospitals

National Antimicrobial Utilisation Surveillance Program Annual Report

2021

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SA Health

NAUSP
National Antimicrobial Utilisation Surveillance Program

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NAUSP
National Antimicrobial Utilisation Surveillance Program

Timeline

2004 Pilot National Surveillance; Usage rates reported as defined daily doses (DDD) per 1,000 occupied bed days (OBD) for intensive care (ICU) and non-ICU acute hospital settings; Paediatric data excluded.

2005 First national annual report - included data from 15 Australian hospitals.

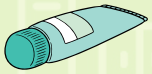
2008 Increasing participation; all Australian states and territories represented.

2014 Establishment of AURA by ACSQHC; NAUSP inclusion as an AURA program partner.

2016 Portal upgrade; data stratification of usage in haematology / oncology wards and respiratory wards.

2017 Data inclusions expanded to include antifungals; Operating theatre usage specified as an inclusion.

2019 Data inclusions expanded to include topical antimicrobials.



2021 Oversight and program funding moved to the Department of Health and Aged Care.
Program expansion and changes to data inclusions:

- Emergency department (ED) usage reported separately per 1,000 ED Presentations.
- Theatre usage reported separately per 1,000 theatre cases; inclusion of day surgery procedures.
- All antimicrobials included in NAUSP (e.g. unregistered drugs, antimycobacterials).
- Usage reports for subacute hospital settings and Hospital in the Home (HITH) possible.

AURA: Antimicrobial Use and Resistance in Australia; ACSQHC: Australian Commission on Safety and Quality in Health Care; NA USP: National Antimicrobial Utilisation Surveillance Program.

Summary

This annual report of the National Antimicrobial Utilisation Surveillance Program (NAUSP) presents a summary of analyses of antimicrobial usage data submitted by public and private hospitals across all states and territories in Australia. Longitudinal trends in systemic antibacterial and antifungal usage are illustrated for the 5-year period 2017 to 2021, and topical antimicrobial usage is reported for 3 years from January 2019.

Participation in NAUSP continues to increase. In 2021, 31 new hospitals registered to participate, bringing the current number of registered hospitals to 265. From January 2021, changes were made to NAUSP methodology with the objective of making the data more useful at facility level, whereby usage in both the emergency department (ED) and operating theatre (OT) were reported relative to patient presentations rather than occupied bed days (OBD). Many hospitals are unable to separate antimicrobial usage for inpatients from that for day cases, including usage from the ED and OT. This skewed aggregate usage rates for hospitals with a high proportion of day-only patients. This change of reporting methodology in these settings has enabled sites with a high proportion of day surgery (in addition to day-only facilities) to participate in NAUSP. Increased compliance with requirements for submission of theatre data from existing contributors has also been seen.

For some participating hospitals, the COVID-19 pandemic put a strain on resources dedicated to antimicrobial stewardship (AMS), resulting in several larger hospitals not submitting data for this report. As the pandemic subsides, it is hoped that resourcing can be refocused to AMS and participation in the surveillance program.

The program's surveillance expansion, implemented in 2021, has enabled hospitals to report on antimicrobial usage in sub-acute locations, including mental health, rehabilitation, palliative care and long-stay aged care, as well as Hospital in the Home (HITH). There are currently 155 registered hospitals that submit antimicrobial data for at least one of the sub-acute locations or HITH.

The change in methodology implemented in January 2021 necessitates careful interpretation of the usage rates presented in this report. The stratification of ED and OT has not affected longitudinal usage rates in the critical care setting; however, usage rates outside of critical care have been impacted by the exclusion of ED and OT, resulting in a 'reset' of the reported total acute usage rates from 2021. In 2021, 78.0 % of total acute antibacterial use (by total volume of defined daily doses (DDDs)) was in settings outside of the ED and OT. ED and theatre usage (by volume of DDDs) comprised 13.8% and 8.2% respectively. Removing and reporting ED and OT usage rates separately from aggregate usage elsewhere in the hospital resulted in a reduction of 14.2% in the acute care hospital usage rate in 2021 (739.4 DDD / 1,000 OBD) compared with 2020 (862.0 DDD / 1,000 OBD). The stratification of usage in the ED has allowed benchmarking of antimicrobial use in this setting for the first time. ED activity is increasing nationally, and on average ED presentations have increased by 3.2% per year since 2017.[1]

Implications for antimicrobial stewardship

Stratification of antimicrobial use in the emergency department and operating theatre settings from acute usage elsewhere in the hospital has enabled hospitals to identify concerning prescribing and undertake focused stewardship activities in these high-use locations. Benchmarking ED usage between similarly peered hospitals has highlighted wide variation in usage in this setting. While some variation is likely to be justified by variable casemix, NAUSP reports enable outlying prescribing rates to be targeted for audit. Surgical prophylaxis has been highlighted as an area of antimicrobial prescribing with low compliance with guidelines.[2]

Hospitals that conduct a large volume of day-only surgical procedures can now participate in NAUSP and monitor their theatre usage over time.

What action should be taken?

- The Australian Government Department of Health and Aged Care should continue to support and collaborate with the Antimicrobial Use and Resistance in Australia (AURA) program partners to facilitate and expand the surveillance of antimicrobial use and resistance in Australia in order to optimise use and mitigate the impact of resistance. Public health messaging that educates consumers, and the funding of interventions to support appropriate prescribing by prescribers, should be a priority. Collaboration with the Australian Institute for Health and Welfare and provision of monthly theatre activity data could help facilitate benchmarking of antimicrobial use between hospitals that undertake similar surgical procedures.
- State and territory governments should prioritise the stewardship of antimicrobial use in their jurisdictions and ensure adequate resourcing to support the optimisation of antimicrobial prescribing and use. At jurisdictional level, interventions to optimise antimicrobial use should be implemented based on AURA data and other targeted audits and research. Data from NAUSP can be utilised by all stakeholders to identify areas for further research and possible associations between antimicrobial consumption and antimicrobial resistance. Users of the NAUSP portal can access data for their hospital/s at any time.
- Hospitals should ensure their AMS teams are adequately resourced to participate in both quantitative and qualitative surveillance of antimicrobial use. AMS committees should regularly review antimicrobial usage in their facilities, utilising the NAUSP portal to download usage reports and/or rate calculations. The reallocation of some AMS pharmacist resourcing during the COVID-19 pandemic resulted in some major teaching hospitals being without any AMS pharmacist cover. This has highlighted the issue of under-resourcing at hospital level to support surveillance and stewardship of antimicrobial use - a problem that should be addressed at hospital management level.
- The NAUSP administrative team will continue to support participating hospitals and advocate for increased participation in the surveillance program. In addition, NAUSP will continue to advocate for user-friendly reporting functionality to assist interpretation of data at hospital level. Ongoing education and one-on-one online support will continue to be provided by NAUSP to assist pharmacists and infection control practitioners' participation and optimal utilisation of the program.

Introduction

NAUSP was established in 2004 in response to recommendations arising from a report by the Joint Expert Technical Advisory Committee on Antibiotic Resistance in 1999.[3] The report contained a series of recommendations to address the risk of antimicrobial resistance (AMR) in Australia, with surveillance of antimicrobial use being identified as a key tool to monitor the effectiveness of policy interventions to optimise antimicrobial use. Access to relevant and timely data on AMR and antimicrobial use is a key objective of Australia's National Antimicrobial Resistance Strategy - 2020 and Beyond.[4]

Ensuring judicious use of antimicrobials in the hospital and healthcare settings is an important factor in minimising the risk of multi-drug resistant organisms. The number of public and private Australian hospitals contributing antimicrobial usage data to NAUSP on a voluntary basis continues to increase annually. Since 2014 NAUSP 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. Participation in NAUSP supports hospitals in meeting the AMS requirements of the National Safety and Quality Health Service standards.[5]

Table 1 shows the number of hospitals, classified by their Australian Institute of Health and Welfare (AIHW)[6] peer group (see glossary for description of AIHW peer groups), by jurisdiction. Not all registered hospitals have provided sufficient data, or validated data, for inclusion in this report. 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: Hospitals registered to participate in National Antimicrobial Utilisation Surveillance Program by state or territory, 2021

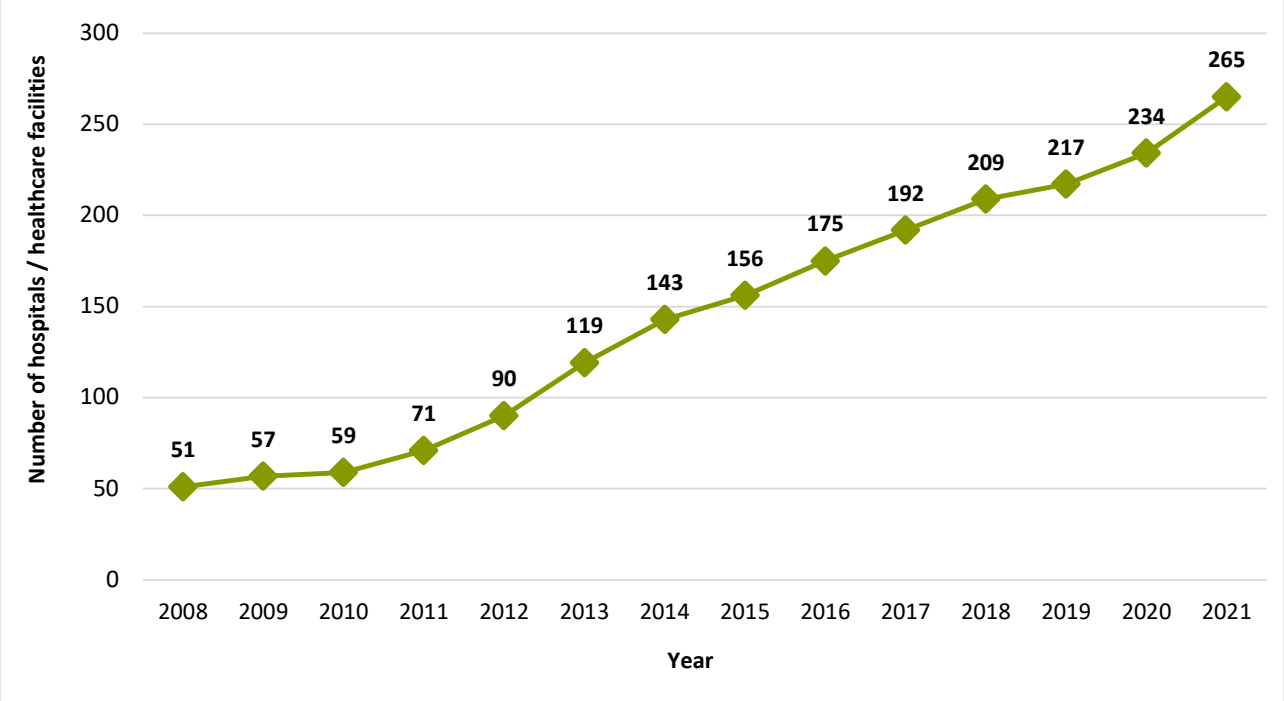
Hospital AIHW peer group	NSW and ACT*	Qld and NT*	SA	Tasmania	Victoria	WA
Principal referral	12	7	2	1	6	3
Public Acute Group A	21	13	3	2	13	5
Private Acute Group A	2	6	2	1	1	1
Public Acute Group B	16	7	4	1	7	4
Private Acute Group B	6	2	4	0	2	2
Public Acute Group C	28	9	9	0	2	14
Private Acute Group C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

* Jurisdictions with only a small number of participating hospitals are grouped with a larger jurisdiction for benchmarking.

Note: This table shows the number of hospitals registered to participate and that have provided data to the National Antimicrobial Utilisation Surveillance Program. 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.

The number of hospitals registered to participate in NAUSP continues to increase, with more private and remote hospitals enrolling in the program in 2021. In addition, rehabilitation facilities were able to participate, with the inclusion of sub-acute facilities from January 2021.

Figure 1: Number of hospitals or healthcare facilities registered to participate in NAUSP



Note: Not all participating hospitals have provided data consistently for the duration of their registration with the program.
NAUSP: National Antimicrobial Utilisation Surveillance Program.

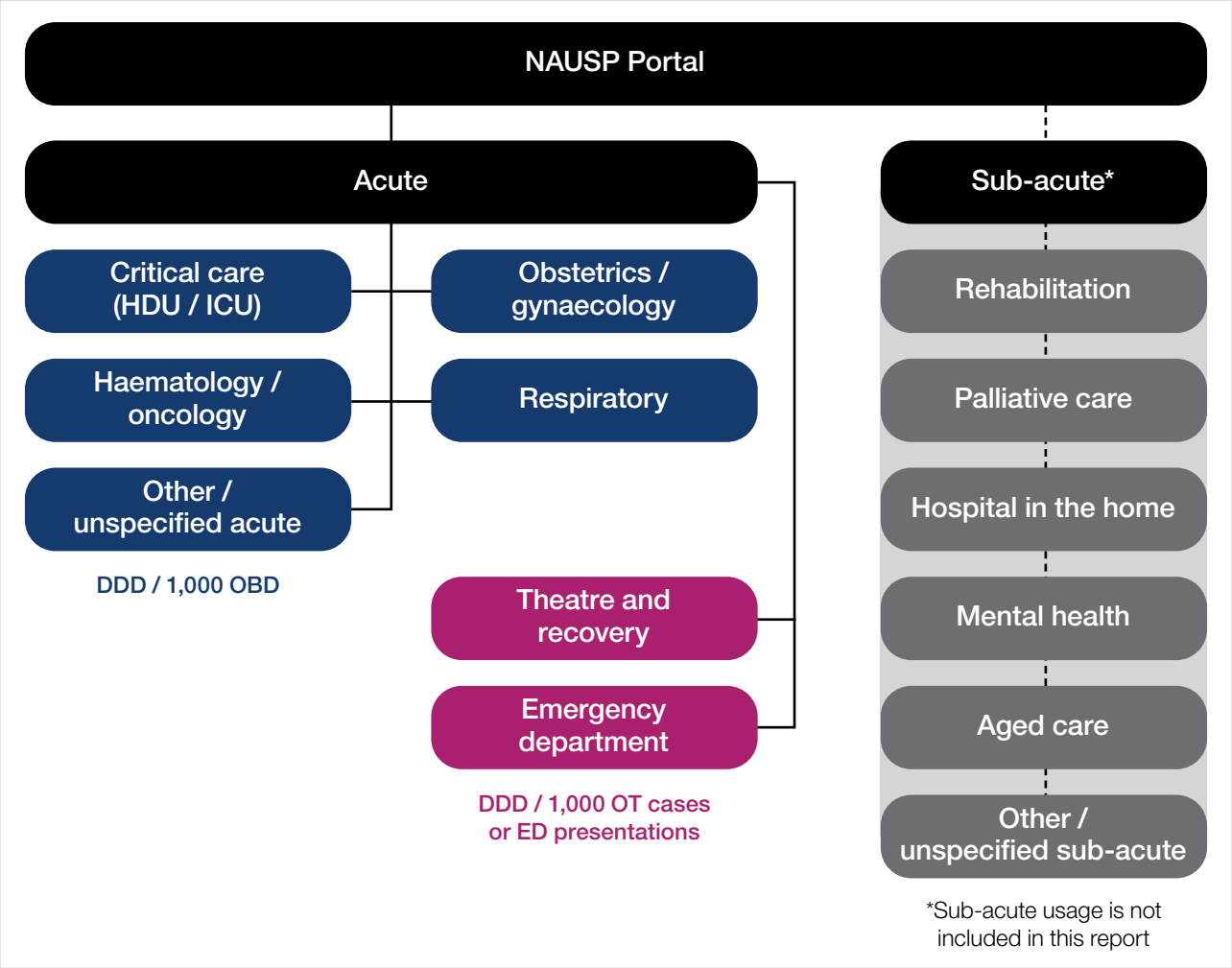
Not all participating hospitals have consistently provided data for the duration of their participation in the program, and others have participated intermittently depending upon local resourcing. Hospitals that did not contribute at least 6 months' data in 2021 have been excluded from the analyses in this 2021 annual report. A complete list of all hospitals that contributed data for this report is provided in Appendix 1. The methods, limitations and considerations for interpretation of NAUSP data are included in Appendices 2 and 3 respectively.

Data for this report were extracted from the NAUSP database between 23 May 2022 and 17 June 2022. Usage rates in this report reflect distributions to the wards as an estimate of antimicrobial consumption. This limitation does not allow analysis of actual consumption. Also, it is not possible to know the indications for which antimicrobials are used at a population level.

Summary of changes to NAUSP introduced in 2021

In January 2021, NAUSP underwent a suite of upgrades to capture antimicrobial usage in more hospital settings. It also introduced new denominators that enable benchmarking in settings where occupied bed days (OBD) do not accurately measure hospital activity, such as operating theatres (OTs) and emergency departments (EDs). Figure 2 illustrates NAUSP data stratification for reporting purposes from January 2021.

Figure 2: NAUSP data stratification for reporting purposes



DDD: defined daily dose; HDU: high dependency unit; ICU: intensive care unit; OBD: occupied bed days; NAUSP: National Antimicrobial Utilisation Surveillance Program; OT: operating theatre; ED: emergency department

In summary, the changes introduced to NAUSP include:

1. **Data definitions expanded to capture all antimicrobials:**
    - Historically, some antimicrobials were excluded from surveillance, such as agents used for the treatment of tuberculosis and malaria, and some antimicrobial agents not registered in Australia. These antimicrobials were not considered to be a focus of stewardship, as they are usually used under the oversight of infectious diseases / clinical microbiology specialists, with their usage being microbiologically guided treatment. As Australia moves towards a One Health model of surveillance, it is increasingly important to have a clearer understanding of *all* antimicrobials used for human health.

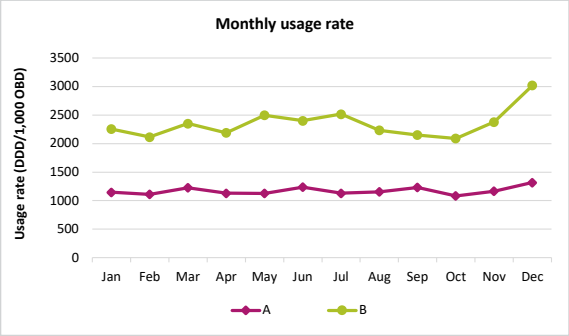
2. **Alternative denominators for benchmarking usage in the ED and OT / recovery:**
    - OBD are a good measure of hospital inpatient activity. However, they do not accurately measure activity in hospital settings where the majority or a large proportion of patients do not routinely stay overnight, such as the OT or ED. Theatre data has been included in NAUSP data definitions for the last 5 years, with the assumption a corresponding OBD is recorded in the inpatient ward where the patient is transferred following theatre. Many hospitals cannot separate antimicrobial use for day-only surgery from that used for inpatient surgery.
    - ED presentations and OT case numbers are a more appropriate denominator to benchmark usage between sites and for hospitals to monitor their own usage over time without having to interpret rates subject to proportional day surgery rates. The new denominators for calculating usage in these settings from January 2021 are:
        - ED usage reported relative to ED presentations
        - OT usage reported relative to the number of OT cases or procedures.
    - The use of OT cases as a denominator for antimicrobial benchmarking in OTs enables day-only surgical facilities to participate in NAUSP.
3. **Surveillance of sub-acute antimicrobial use / inclusion of rehabilitation facilities:**
    - Until December 2020, NAUSP exclusively reported all antimicrobial usage in the acute care setting. Usage in the sub-acute setting was a data exclusion because low or erratic usage in these ward locations made benchmarking difficult.
    - Despite historically being classified as 'sub-acute' for the purposes of antimicrobial surveillance, it has become apparent that some settings, such as extended-stay aged-care (where patients are often not acutely unwell but are awaiting transition to residential care), may not be low users of antimicrobials.[7] Expanding NAUSP functionality to enable contributors to monitor use in long stay aged care fills the gap in Australian hospital antimicrobial surveillance that required addressing.
    - From January 2021, hospitals can elect to submit data for sub-acute settings. Antimicrobial usage in the sub-acute settings is not included in acute aggregate rates reported in publicly available reports.[8] However, hospitals can download their own reports for the sub-acute settings to monitor their own use over time. The inclusion of these ward locations enables dedicated rehabilitation hospitals to join NAUSP and fulfil accreditation requirements - specifically, the requirement to collect data on the volume of antimicrobial use and to monitor and assess that data to support appropriate antimicrobial prescribing.[9]
    - Sub-acute settings that hospitals can voluntarily elect to submit data for include mental health, palliative care, long-term rehabilitation and long-stay aged care wards.
4. **Inclusion of Hospital in the Home (HITH) as a standalone location:**
    - Similar to sub-acute ward locations, antimicrobial usage for HITH is an additional option for hospitals to monitor their usage over time. However, this usage is not included in aggregate acute care usage rates in publicly available NAUSP reports.[8]
    - Although HITH enables earlier discharge from the hospital setting, there is a risk that more broad-spectrum agents may be chosen in preference to agents with a narrower spectrum that are unable to be administered in the home setting. There is also a risk that the switch from intravenous (IV) to oral treatment is delayed in the HITH environment. Surveillance of antimicrobial use in HITH will enable identification of focus areas for AMS.
5. **Critical care (combining intensive care unit (ICU) and high dependency unit (HDU) surveillance data):**
    - From January 2021, ICU and HDU antimicrobial usage data has been combined in the NAUSP portal and has been renamed 'Critical Care (ICU/HDU)' for reporting purposes. Only a very small number of hospitals have historically provided HDU data, often with too few contributors to create meaningful benchmarking reports. The acuity of patients treated in the ICU of some hospitals is very similar to those treated in the HDU of larger facilities. It is anticipated that this change will have limited to no effect on hospitals currently submitting ICU data.

Rationale for stratification of operating theatre and emergency department

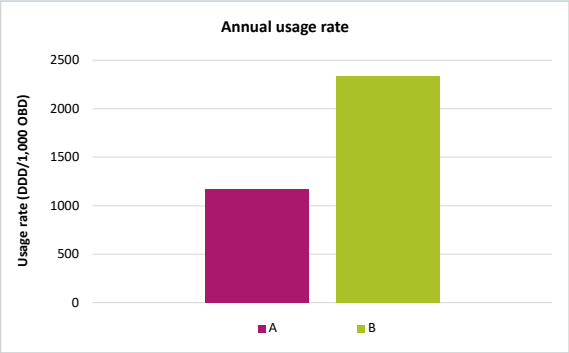
The National Antimicrobial Utilisation Surveillance Program (NAUSP) provides a standardised measurement of antimicrobial use in Australian acute public and private hospitals using the metric of World Health Organization defined daily doses (DDDs)[10] per 1,000 occupied bed days (OBD). This metric has been used since the program was established in 2004, and for over 10 years it was used to compare non-critical care use to critical care use, as well as a combined total usage rate. As the program expanded to include more private facilities and hospitals that predominantly provide short-stay surgical procedures, some contributors became reluctant to provide operating theatre and emergency department data, as the benchmarking was not 'comparing apples with apples'. As NAUSP is a volume-based method of surveillance that is calculated using the quantity of antimicrobials distributed to a ward location, hospitals usually cannot differentiate antimicrobial use in day patients from that in overnight patients. This causes bias in the *usage rate* reported.

Hypothetical example:

- Hospital A and B *both contain 100 hospital beds*. Both have an operating theatre and emergency department:
  - Hospital A: Most surgical procedures are on inpatients, with about 10% of patients going home on the day of surgery.
  - Hospital B: 50% of procedures are day surgeries with no overnight stay.
- Both hospitals only have one imprest (drug supply) for theatre. They cannot separate antimicrobials supplied for day patients from antimicrobials supplied for inpatients.
- The total quantity of antimicrobials dispensed/distributed to wards at both hospitals over one year is *exactly the same*.



- On average, Hospital A records 2,973 OBD per month.
- Hospital B averages 1,492 OBD per month.
- The calculated monthly usage rate for Hospital B is on average twice that of Hospital A.



- Both hospitals have exactly the same annual antimicrobial usage of 41,826 DDDs.
- More patients in Hospital A stay overnight after their surgeries:
  - Hospital A annual OBD = 35,673.
  - Hospital B annual OBD = 17,909.
- The annual aggregate usage rate for Hospital B is 2.0 x Hospital A.
- This causes bias in the national aggregate rate.

Annual national aggregate acute usage rates for all antibacterial classes

Hospitals are included in the national aggregated antibacterial usage rates if they contributed at least 6 months of validated data during 2021, are able to stratify their data if they have an ED or OT, and are not solely rehabilitation sites. Table 2 provides details of the hospitals included in the calculation of the national aggregated usage rates AIHW peer group. Data from 4 principal referral hospitals are not included in this report; reasons for non-inclusion in this report include non-provision of data due to lack of AMS resourcing due to COVID-19 or other reasons; or invalid data or data anomalies identified but not resolved at the time of writing this report.

Table 2: Number of hospitals by peer group included in usage rates in the 2021 NAUSP report

Hospital AIHW peer group	Registered to participate in NAUSP	Included in calculated national aggregate antibacterial rate
Principal referral	31	27
Public Acute Group A	57	54
Private Acute Group A	13	12
Public Acute Group B	39	32
Private Acute Group B	16	12
Public Acute Group C	62	44
Private Acute Group C	12	14
Public Acute Group D	13	0
Private Acute Group D	2	0
Women's hospitals / combined women's and children's hospitals	4	3
Very small hospitals	2	0
Unpeered hospitals	7	0
Public rehabilitation hospitals	1	0
Other acute specialised hospitals	2	2
Mixed sub-acute/non-acute hospitals	3	0
Mixed day procedure hospitals	1	0
Total	**265**	**200**

AIHW: Australian Institute of Health and Welfare; NAUSP: National Antimicrobial Utilisation Surveillance Program.

Aggregated usage rates are calculated by summating the total acute defined daily doses (DDDs) and dividing by the total OBD. For usage rates in the ED and OT, usage is reported relative to ED presentations and theatre cases respectively (see 'Summary of changes to NAUSP introduced in 2021'). The proportion of total antibacterial DDDs utilised in ED, theatre and other acute locations in 2021 is shown in Table 3: 78.0% of total acute hospital usage (by volume) was in acute hospital settings other than ED and theatre (Table 3). Usage rates may vary from previous reports, as the hospitals included in the report may vary from previous years. Other reasons for variations from previously reported rates include retrospective data adjustments, variation in peer group assignment by the AIHW, and changes to DDD values assigned by the World Health Organization (WHO).

Table 3: Proportion of total acute antimicrobial usage (by total DDDs) distributed by hospital location in NAUSP contributor hospitals, 2021

	Other acute	Theatre	Emergency
Alimentary antibiotics	96.4%	0.1%	3.4%
Aminoglycosides (excl streptomycin)	39.6%	14.0%	46.4%
ß-lactamase inhibitor combinations	88.3%	1.0%	10.6%
ß-lactamase resistant penicillins	84.1%	1.4%	14.5%
ß-lactamase sensitive penicillins	85.3%	0.4%	14.3%
Carbapenems	97.5%	0.4%	2.1%
Extended-spectrum penicillins	82.5%	1.9%	15.6%
First-generation cephalosporins	59.7%	30.8%	9.5%
Fluoroquinolones	92.6%	0.8%	6.5%
Fourth-generation cephalosporins	96.7%	0.2%	3.1%
Glycopeptides	85.2%	8.8%	6.0%
Lincosamides	84.1%	6.4%	9.4%
Macrolides	74.6%	0.4%	24.9%
Monobactams	98.1%	0.1%	1.9%
Nitroimidazoles	78.8%	10.0%	11.2%
Sulfamethoxazole–trimethoprim	92.8%	0.1%	7.1%
Tetracyclines	81.7%	0.2%	18.1%
Third-generation cephalosporins	76.1%	2.3%	21.7%
Trimethoprim	72.5%	2.2%	25.2%
*Other antibacterials	91.3%	5.5%	3.2%
	78.0%	**8.2%**	**13.8%**

* 'Other antibacterials': 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 dose; NAUSP: National Antimicrobial Utilisation Surveillance Program.

Table 4 provides the national aggregate usage rate for all antibacterial classes NAUSP contributor hospitals from 2017 to 2021. Note that the aggregate usage rate includes usage from all acute care settings but excludes usage in sub-acute settings, and from 2021 the aggregate usage rate does not include usage in the ED and OT for reasons provided earlier in this report. The non-inclusion of OT and ED usage has resulted in a drop in the aggregate usage rate. Not all included participating hospitals provided data for all 60 months in the 5-year period, and rates may differ from previous reports due to retrospective data adjustments, new hospitals submitting retrospective data, and changes to DDD values assigned by the WHO.

Table 4: Annual total hospital systemic antibacterial usage rates (DDDs / 1,000 OBD) in NAUSP contributor hospitals (n=200), by antibacterial class, 2017–2021

Antibacterial class	Aggregate usage rate (DDD / 1,000 OBD)					2021		
	2017	2018	2019	2020	2021¥	Median usage rate**	IQR	
Alimentary antibiotics	8.2	9.3	12.2	15.8	17.7	9.3	2.2	19.6
Aminoglycosides (excl. streptomycin)	29.1	30.6	28.1	28.1	11.7	10.7	4.8	17.1
ß-lactamase inhibitor combinations	129.8	128.2	133.0	131.5	129.1	106.4	79.3	142.0
ß-lactamase resistant penicillins	94.2	96.0	91.4	88.2	77.7	77.3	49.9	108.5
ß-lactamase sensitive penicillins	36.4	34.0	30.2	26.6	25.4	25.1	16.2	34.6
Carbapenems	12.1	13.1	13.5	14.0	14.8	8.2	3.5	13.7
Extended-spectrum penicillins	54.3	53.8	59.6	55.1	51.5	52.5	34.0	70.0
First-generation cephalosporins	151.0	153.5	161.0	167.6	113.8	107.5	82.8	131.2
Fluoroquinolones	29.8	28.8	27.1	26.3	24.8	21.5	15.4	27.4
Fourth-generation cephalosporins	5.7	5.4	4.4	4.6	5.5	1.7	0.6	4.2
Glycopeptides	25.3	25.4	25.2	24.4	22.6	14.2	7.4	23.3
Lincosamides	13.4	13.4	13.0	13.4	11.4	10.3	7.5	13.7
Macrolides	53.8	51.7	51.6	43.4	35.2	32.3	20.8	45.1
Nitroimidazoles	36.1	37.4	33.2	32.6	26.6	23.1	14.8	34.1
Sulfamethoxazole–trimethoprim	16.6	17.6	18.6	18.8	19.0	14.5	7.5	20.1
Tetracyclines	83.3	80.4	91.0	71.6	62.4	74.8	40.3	108.0
Third-generation cephalosporins	56.8	60.4	61.0	61.0	53.2	48.7	32.7	67.3
Trimethoprim	13.7	13.1	12.3	12.2	9.5	9.5	6.1	14.1
*Other	20.7	22.0	27.1	27.0	27.7	19.4	11.3	32.8
Grand total	**870.3**	**874.0**	**893.5**	**862.0**	**739.4**	**746.1**	**613.7**	**834.5**

¥ 2021 aggregate usage rates in acute inpatient setting excluding emergency and operating theatre.

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

** Median of individual hospital usage rates for each antibacterial class; IQR = interquartile range.

Note: Rates (defined daily doses (DDD) / 1,000 occupied bed days) may vary slightly from previous reports as a result of retrospective usage data adjustments, the number of hospitals contributing to aggregate data and changes to DDD values assigned by the World Health Organization.

The aggregate usage rate is calculated by pooling usage from all the hospitals, relative to the sum of the occupied bed days from all the hospitals. The median usage rate is the median of the individual hospitals, calculating the acute inpatient usage rate at each hospital relative to the activity at that hospital. In 2021, the median usage rate across the 200 hospitals was 746.1 DDD / 1,000 OBD (IQR: 613.7 – 834.5) in acute care settings (excluding emergency department and operating theatre). The aggregated usage rate for the 200 hospitals was a decrease of 14.2% from the 2020 rate from 862.0 DDD / 1,000 OBD to 739.4 DDD / 1,000 OBD. However, as noted in the section above, the 2021 usage rate does not include ED and OT. The inclusion of these 2 locations in previous reported rates have likely over-reported inpatient usage rates due to the inclusion of antimicrobial usage in day-only patients in settings where the usage cannot be separated (due to drug supplies for day patients being in the same imprest as inpatient supply). NAUSP usage rates are a surrogate for actual consumption, which is acknowledged as a limitation. However, with the exclusion of OT and ED, the calculated aggregate rate in 2021 is likely to be a closer approximation to the true acute inpatient usage rate in facilities contributing to NAUSP.

Analysis of acute hospital antibacterial use using the Priority Antibacterial List

The Priority Antibacterial List (PAL) was developed by the Australian Commission on Safety and Quality in Health Care (ACSQHC) in 2020 as a tool to support AMS.[11] The PAL categorises antibacterials available in Australia according to preferred use for containment of AMR in Australia (Table 5). The *Access* category includes antibacterials that are generally recommended as first-line treatment for infections where there is a low resistance potential. With the exception of cefazolin for surgical prophylaxis, the *Curb* and *Contain* categories include antibacterials that are not generally first-line agents. Antibacterials included in the each of the PAL categories are provided in Appendix 5.

Table 5: Classification framework for the *Access, Review, Curb* and *Contain* categories of the Priority Antibacterial List[11]

Category	Inclusion criteria
Access	Includes: • antibacterials recommended as first-line treatment for common infections with a low AMR or 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.
Review: Contain	Includes antibacterials with high AMR or HAI potential that are not recommended as first-line options for common bacterial infections.

AMR: antimicrobial resistance; HAI: healthcare-associated infection.

Previous analyses of total acute antibacterial usage using the PAL have illustrated that cefazolin was a major driver of the proportionate use of *Curb* antibacterials in NAUSP contributor hospitals.[12,13] Cefazolin is recommended as a first-line antimicrobial for surgical prophylaxis, and hospitals that predominantly provide short-stay surgical procedures consequently had a very high proportionate use of *Curb* antibacterials. From 2021, antibacterial usage in the ED and OT has been stratified from other acute hospital antibacterial usage. The following analyses of usage by PAL category by state/territory and by hospital peer group are for antibacterial usage in acute care hospital settings other than the OT and ED.

Antibacterial usage rates by state and territory by Priority Antibacterial List category

Previous NAUSP reports have highlighted substantial variation in both the usage rates and the proportionate use of antibacterial classes in the acute care setting, excluding ED and OT, across the states and territories.[14,15] Table 6 illustrates acute hospital antibacterial use for NAUSP contributors nationally and by Australian state and territory in 2021, by PAL category.

Table 6: Statewide acute hospital antibacterial usage rates by (DDD / 1,000 OBD) by Priority Antibacterial List (PAL) category and percentage use in NAUSP contributor hospitals, by state/territory

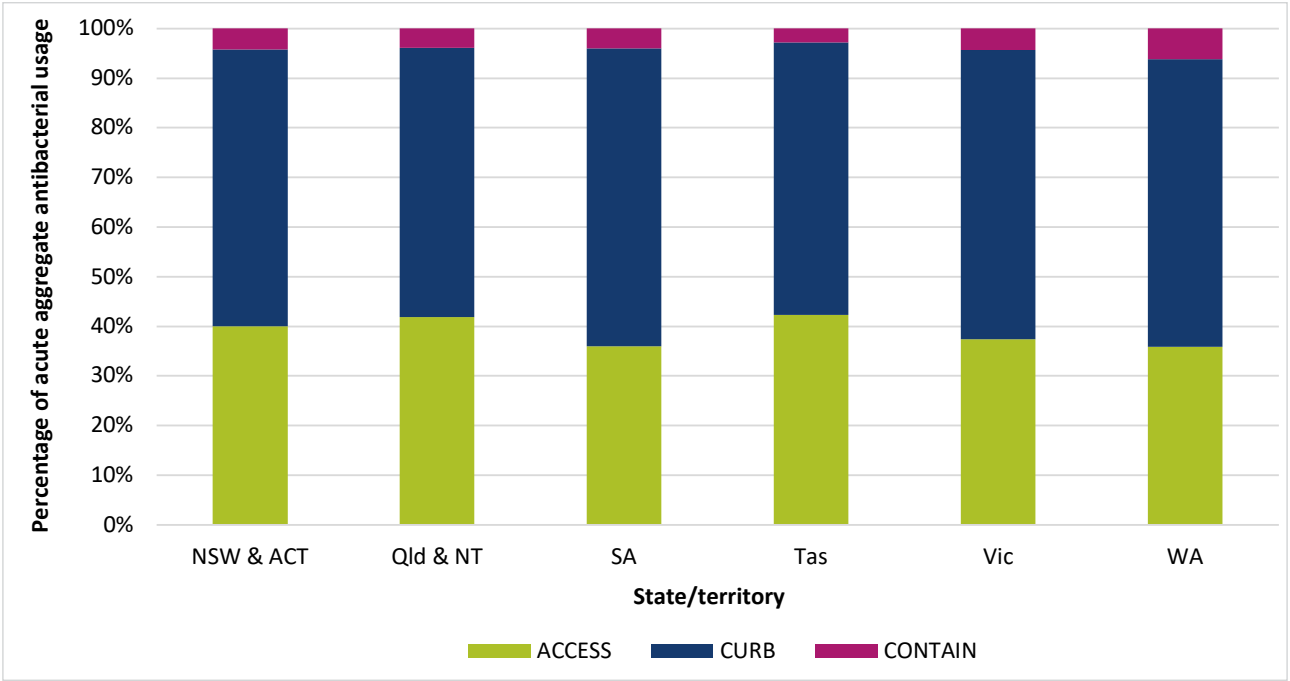
PAL category	Usage rate (DDD / 1,000 OBD) / (%)					
	NSW & ACT	Qld & NT	SA	Tas	Vic	WA
Access	311.3 (40.0%)	308.3 (41.8%)	251.9 (35.9%)	347.9 (42.3%)	261.7 (37.4%)	235.4 (35.8%)
Curb	434.6 (55.8%)	400.2 (54.3%)	420.8 (60.0%)	451.8 (54.9%)	408.8 (58.4%)	381.6 (58.1%)
Contain	32.4 (4.2%)	28.5 (3.9%)	28.2 (4.0%)	23.3 (2.8%)	30.1 (4.3%)	40.2 (6.1%)

Note: Acute usage rate excluding emergency department and operating theatre.

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

Figure 3 illustrates the proportionate use of each PAL category in the acute hospital setting, other than OT and ED, in each of the states and territories. As a proportion of total usage, South Australia uses the least amount in the *Access* category (35.9%) and as a state reported the highest proportionate use in the *Curb* category (60.0%). Western Australia reported the highest proportionate use in the *Contain* category, with 6.1% of the acute hospital usage outside of ED and OT being *Contain* antibacterials.

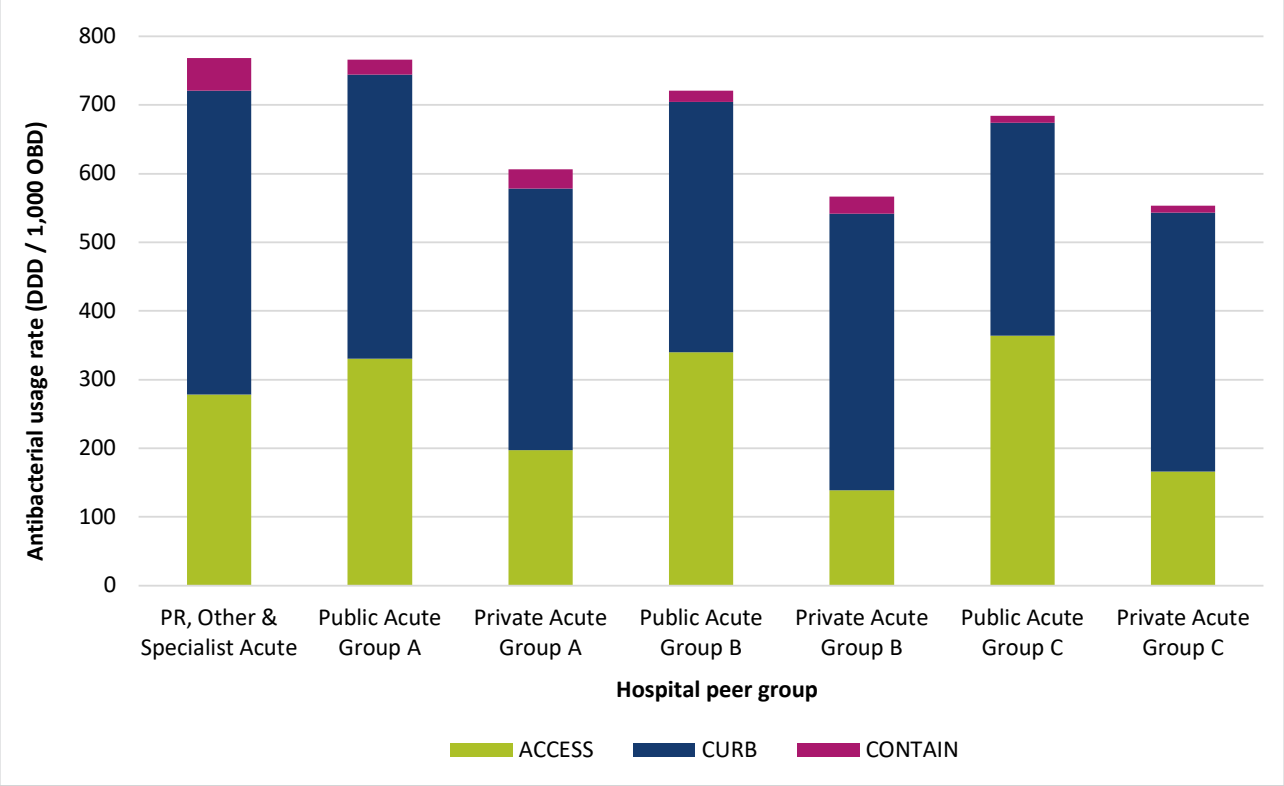
Figure 3: Percentage of acute aggregate antibacterial usage by Priority Antibacterial List (PAL) category in NAUSP contributor hospitals (excluding emergency department and operating theatre), by state/territory, 2021



Priority Antibacterial List analyses by hospital peer group

Figure 4 compares the total annual acute aggregate usage by PAL category in NAUSP contributor hospitals, excluding usage in the ED and OT, by AIHW hospital peer group. Hospital peer groupings define groups of similar hospitals based on shared characteristics, allowing benchmarking within peer groups or comparisons between different peer groups.[6]

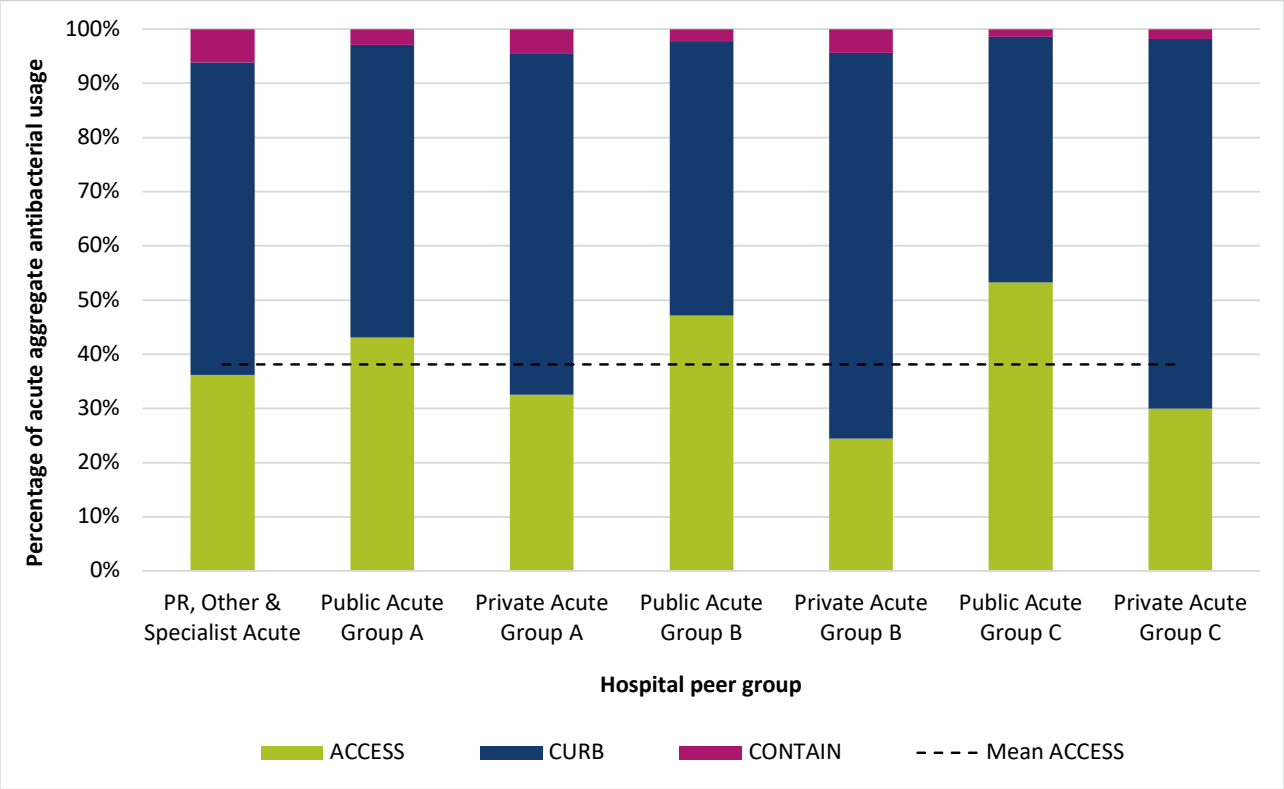
Figure 4: Aggregate acute antibacterial usage rates by Priority Antibacterial List category in NAUSP contributor hospitals (excluding emergency department and operating theatre), by hospital peer group, 2021



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

Figure 5 illustrates the proportionate use of each PAL category in NAUSP contributor hospitals by AIHW peer group. Excluding ED and OT usage, the proportionate use of *Access* antibacterials across all peer groups was just 38.1%. In principal referral and other specialist acute hospitals, 36.2% of antibacterial usage in the acute setting (excluding ED and OT) was *Access* category. In general, public hospitals have a higher proportionate use of *Access* antimicrobials than private hospitals. In 2021, only 32.6% of acute antibacterial use, outside of the ED and OT settings, in large private hospitals (Private Acute Group A hospitals) was *Access* category antibacterials. For Private Acute Group B and C hospitals the proportionate use of *Access* antimicrobials was even lower, at 24.4% and 30.0% respectively.

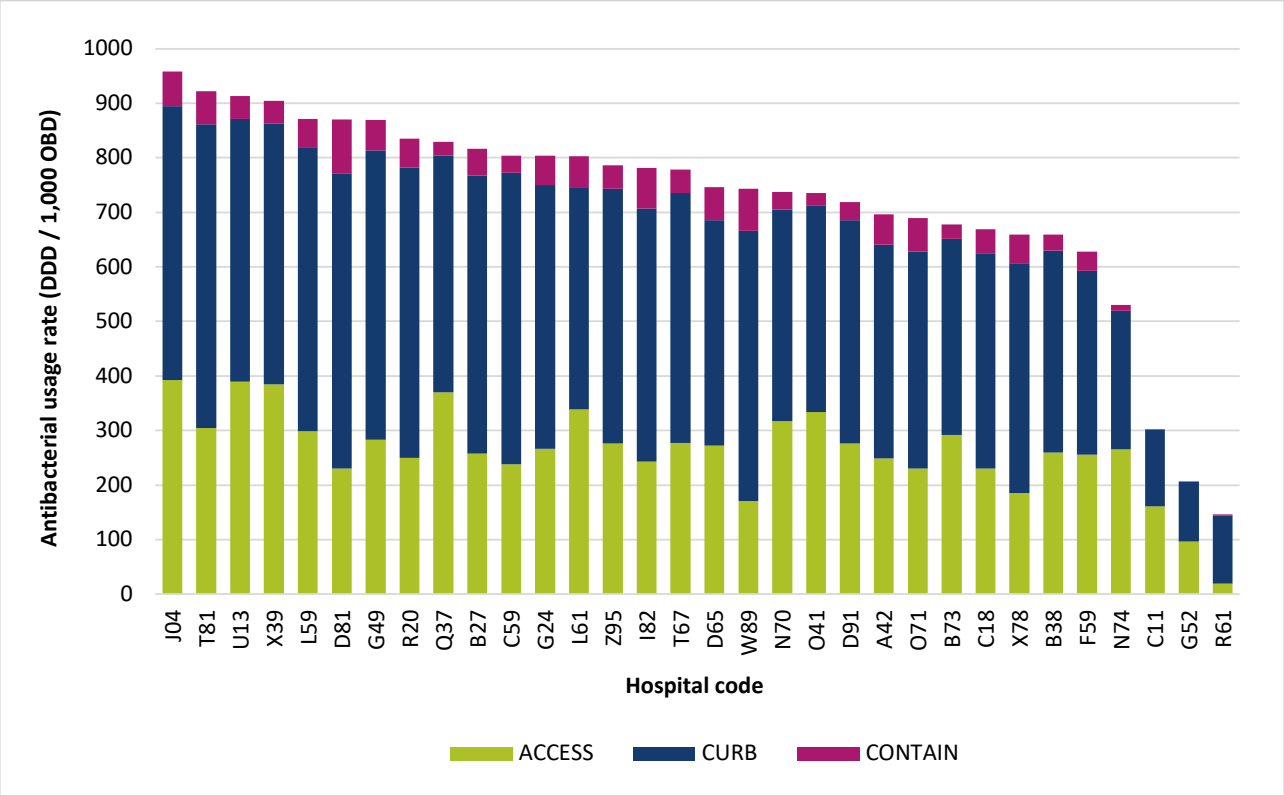
Figure 5: Percentage of acute aggregate antibacterial usage by Priority Antibacterial List category in NAUSP contributor hospitals (excluding emergency department and operating theatre), by hospital peer group, 2021



NAUSP: National Antimicrobial Utilisation Surveillance Program; PR: principal referral.

Figures 6 to 19 show the annual aggregate usage (excluding ED and OT) by PAL category, for each peer group, with usage benchmarked as both a rate (DDD / 1,000 OBD) and as a percentage of antimicrobial usage.

Figure 6: Aggregate acute antibacterial usage (excluding emergency department and operating theatre) by Priority Antibacterial List category in principal referral, specialist women's and other specialist acute hospitals, 2021



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

Figure 7 illustrates the proportionate annual use of antibacterials by PAL category in principal referral hospitals and specialist women's hospitals in 2021 in acute settings other than ED or OT. While it is expected that *Contain* antibacterials would be used in large referral hospitals, there was a wide range in the proportionate use of *Contain* antibacterials in this peer group, ranging from 0.2% to 11.4%.

Figure 7: Percentage of acute aggregate antibacterial usage (excluding emergency department and operating theatre) by Priority Antibacterial List category in principal referral and specialist women's hospitals, 2021

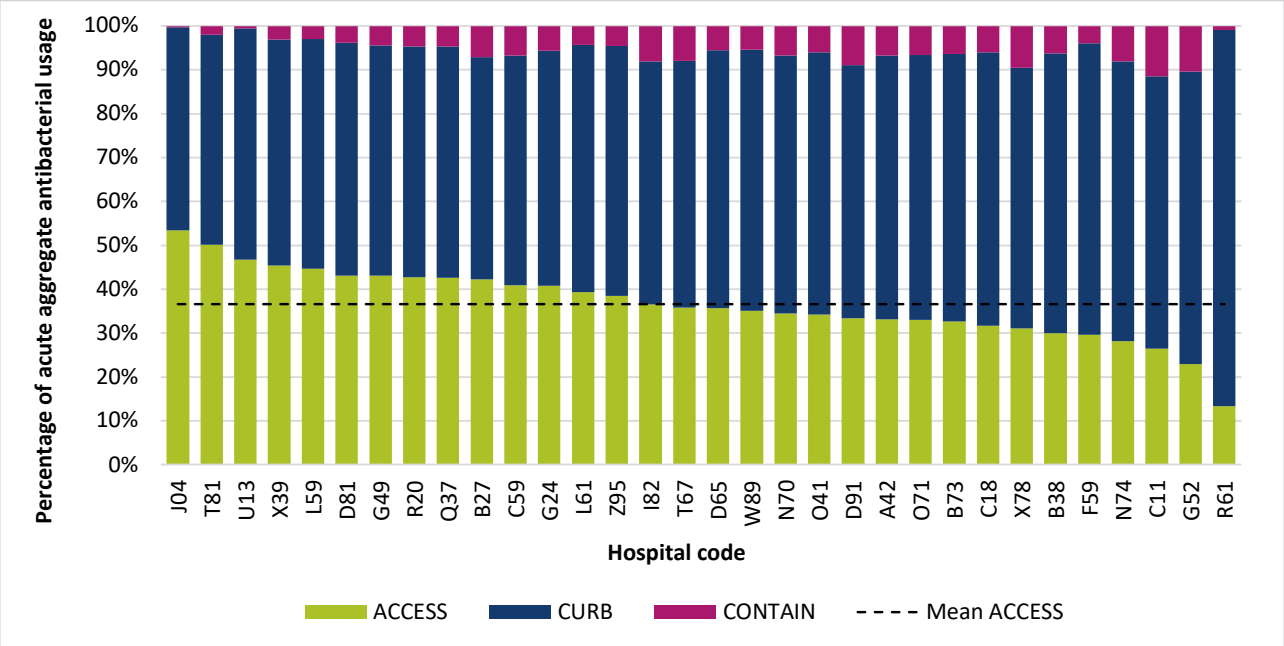
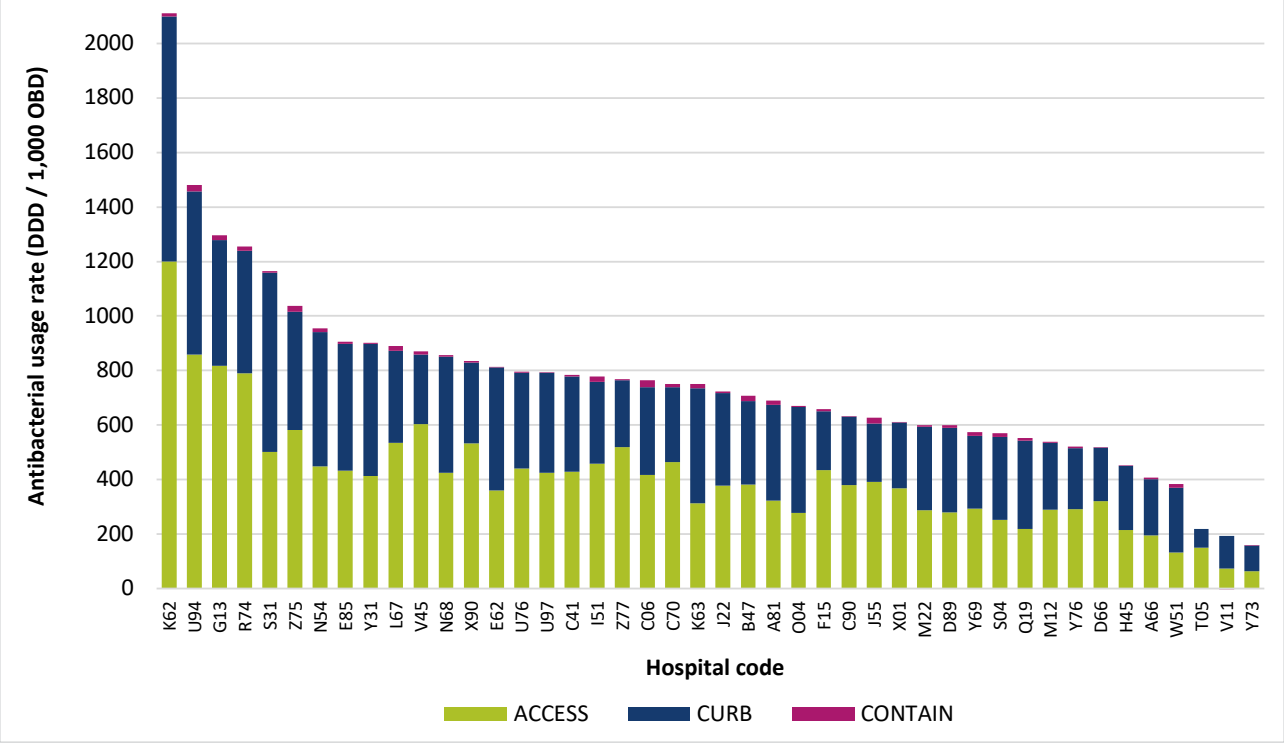


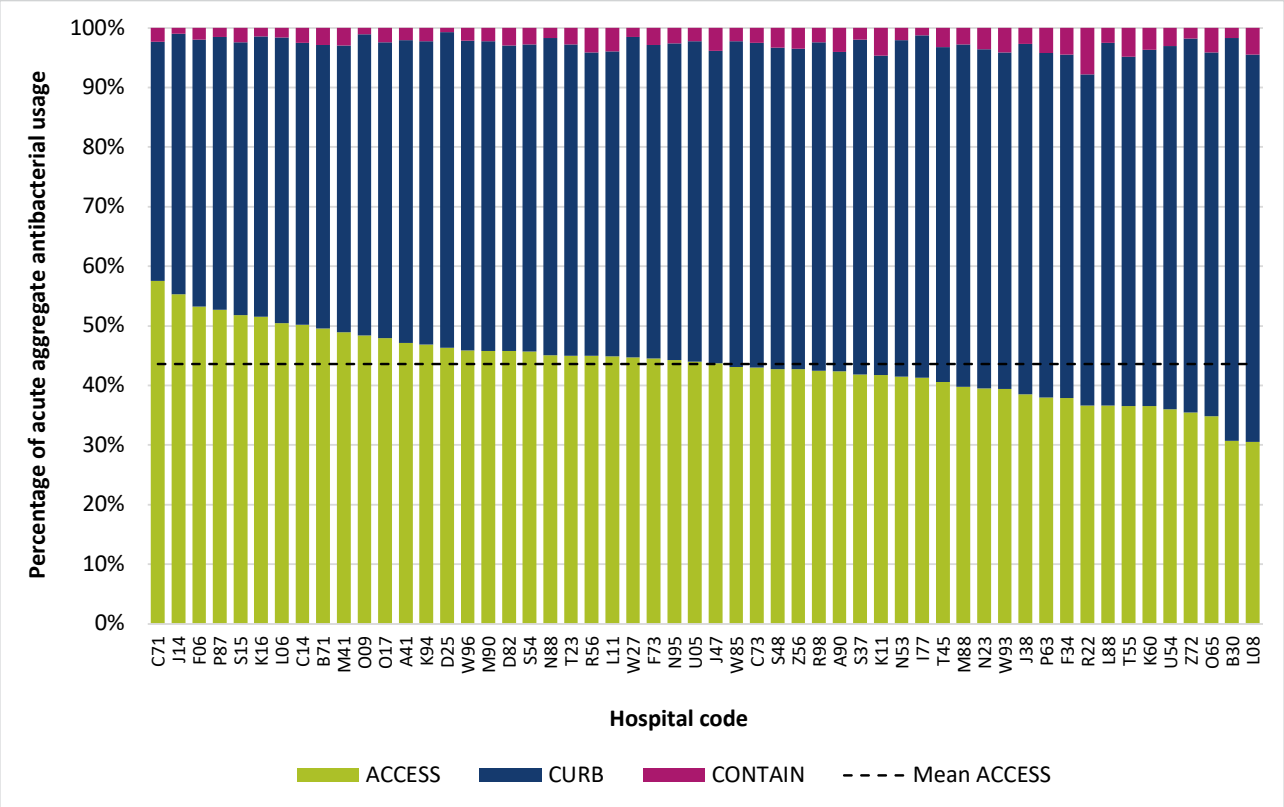
Figure 8 shows antibacterial usage by PAL category for Public Acute Group A hospitals in the acute setting, excluding ED and OT. Across hospitals in this peer group, proportionate annual *Access* usage averaged 43.6%, *Curb* 53.6% and *Contain* 2.8% (Figure 8).

Figure 8: Aggregate acute antibacterial usage (excluding emergency department and operating theatre) by Priority Antibacterial List category in Public Acute Group A hospitals, 2021



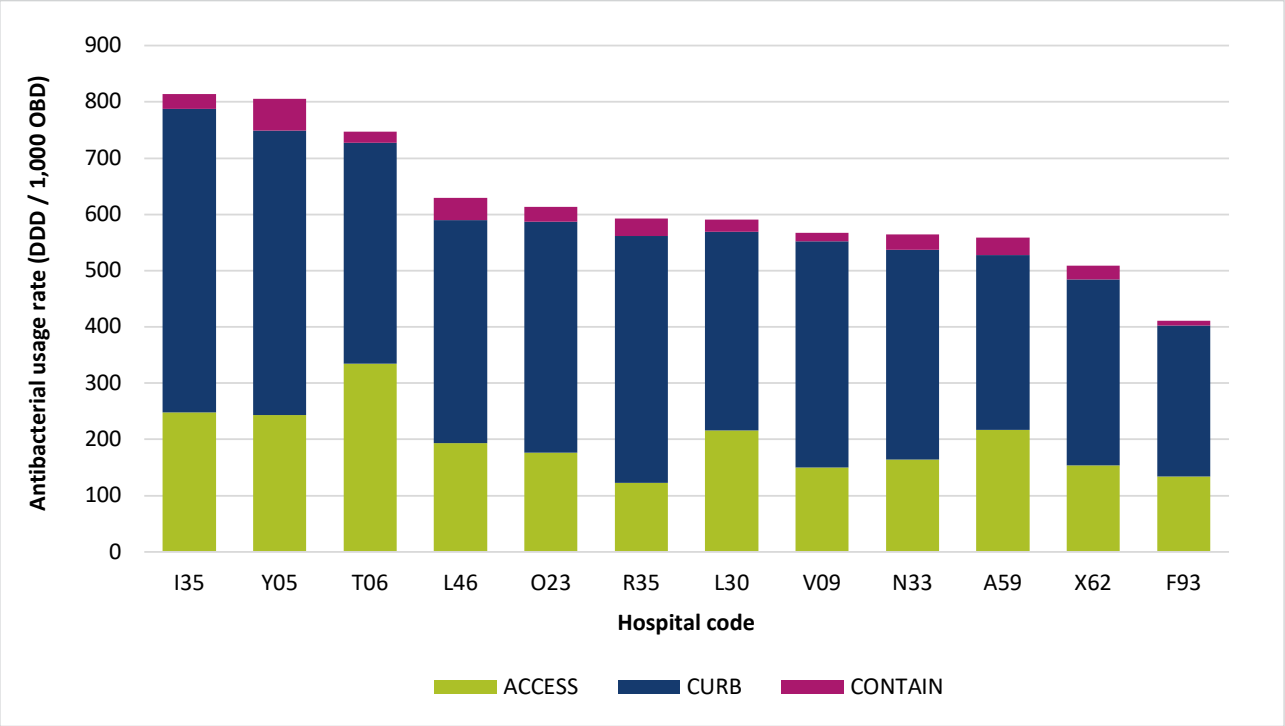
DDD: defined daily dose; OBD: occupied bed days.

Figure 9: Percentage of acute aggregate antibacterial usage (excluding emergency department and operating theatre) by Priority Antibacterial List category in Public Acute Group A hospitals, 2021



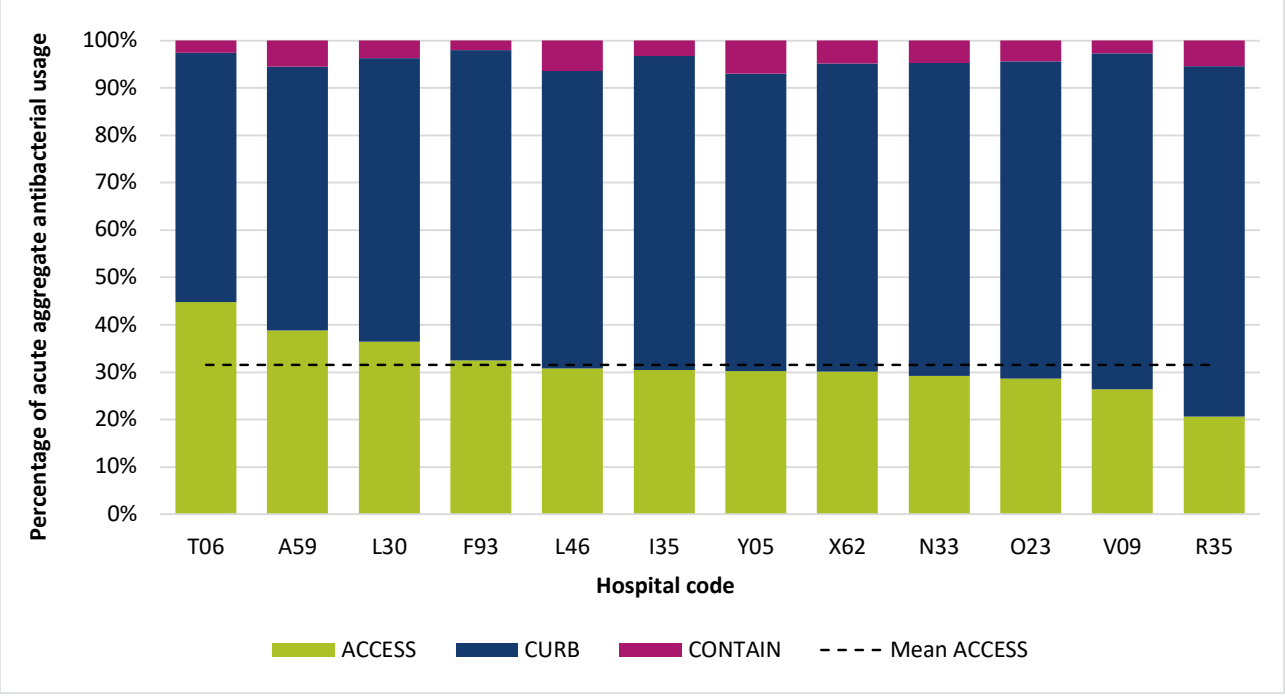
In Private Acute Group A hospitals, the proportionate use of *Curb* antibacterials was higher in 2021 than in Public Acute Group A hospitals. Across NAUSP contributor hospitals in this peer group, on average 64.0% of acute usage (excluding ED and OT usage) was in the *Curb* category, compared with Public Acute Group A, where the proportionate use of *Curb* category antibacterials averaged 53.6%. Figure 10 shows the annual aggregate usage rate for Private Acute Group A hospitals, and Figure 11 shows the proportionate use by PAL category in this peer group.

Figure 10: Aggregate acute antibacterial usage (excluding emergency department and operating theatre) by Priority Antibacterial List category in Private Acute Group A hospitals, 2021



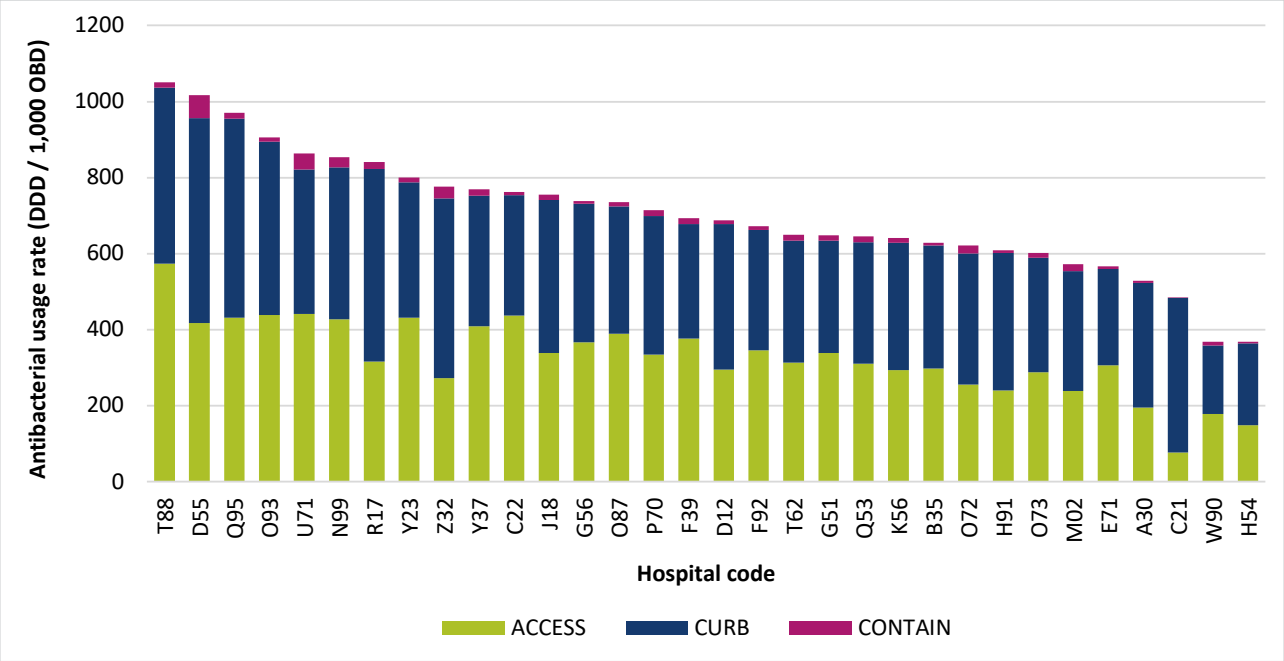
DDD: defined daily dose; OBD: occupied bed days.

Figure 11: Percentage of acute aggregate antibacterial usage (excluding emergency department and operating theatre) by Priority Antibacterial List category in Private Acute Group A hospitals, 2021



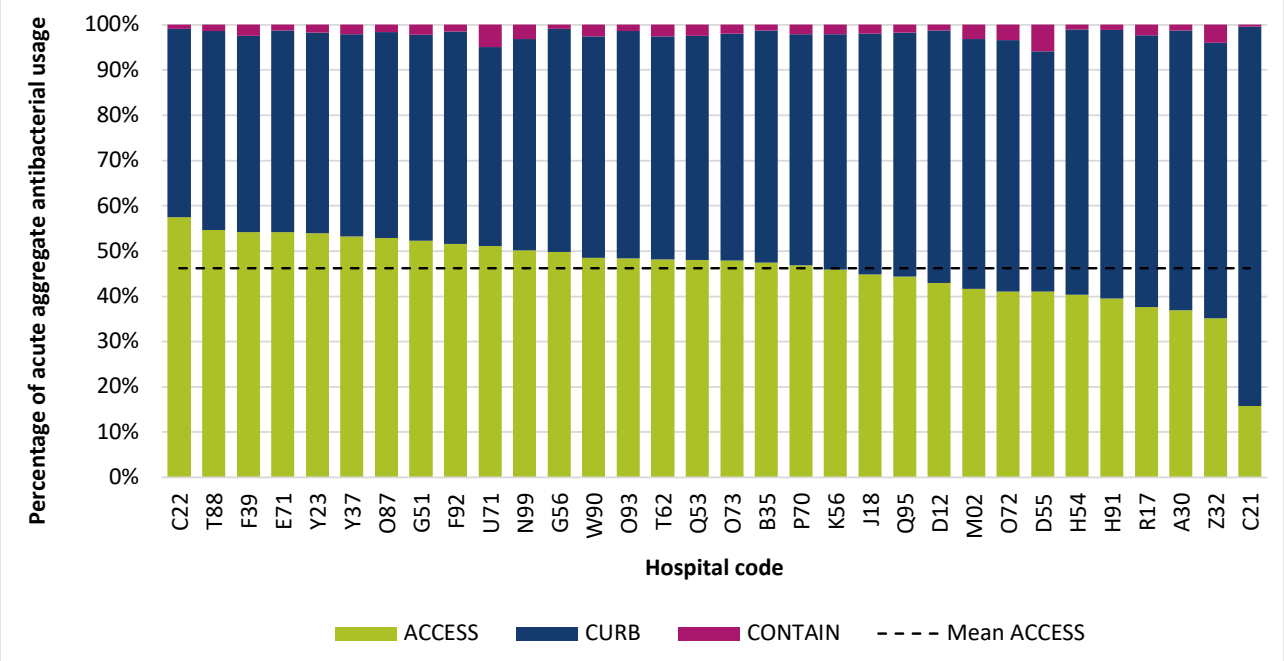
On average, Public Acute Group B hospitals use proportionately more *Access* antibacterials than Private Acute Group B hospitals. Figure 12 shows 2021 annual usage rates (excluding ED and OT usage) by PAL category for Public Acute Group B contributor hospitals and Figure 14 shows the rates for private hospitals with similar acuity and casemix.

Figure 12: Aggregate acute antibacterial usage (excluding emergency department and operating theatre) by Priority Antibacterial List category in Public Acute Group B hospitals, 2021



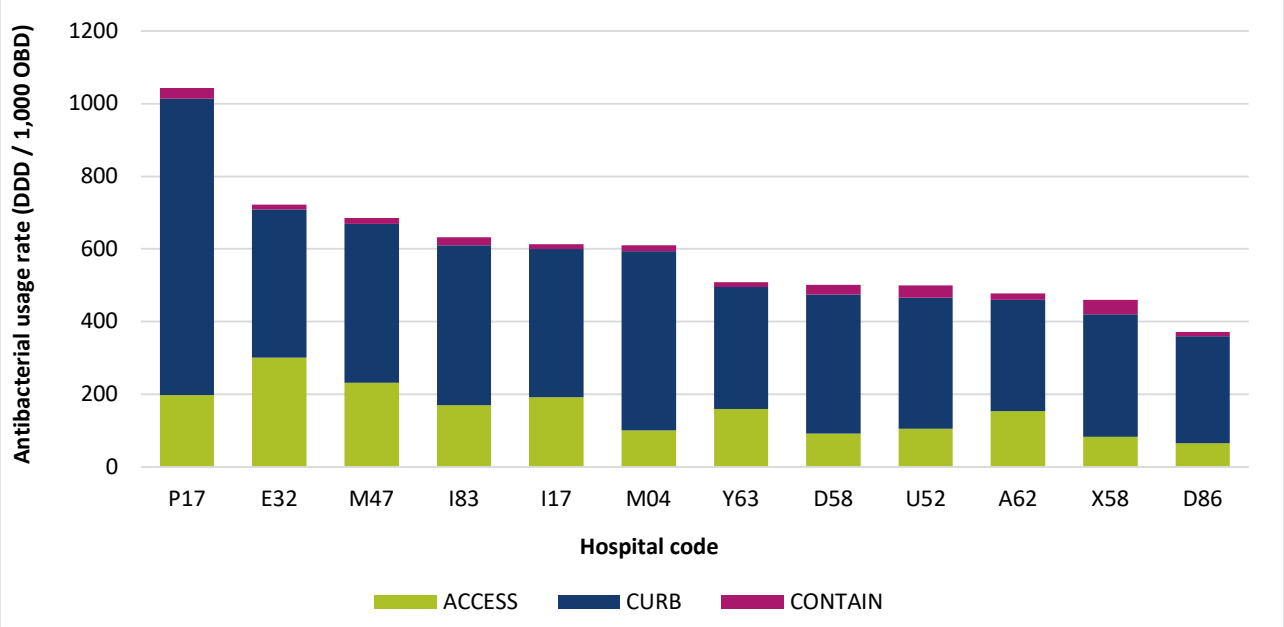
DDD: defined daily dose; OBD: occupied bed days.

Figure 13: Percentage of acute aggregate antibacterial usage (excluding emergency department and operating theatre) by Priority Antibacterial List category in Public Acute Group B hospitals, 2021



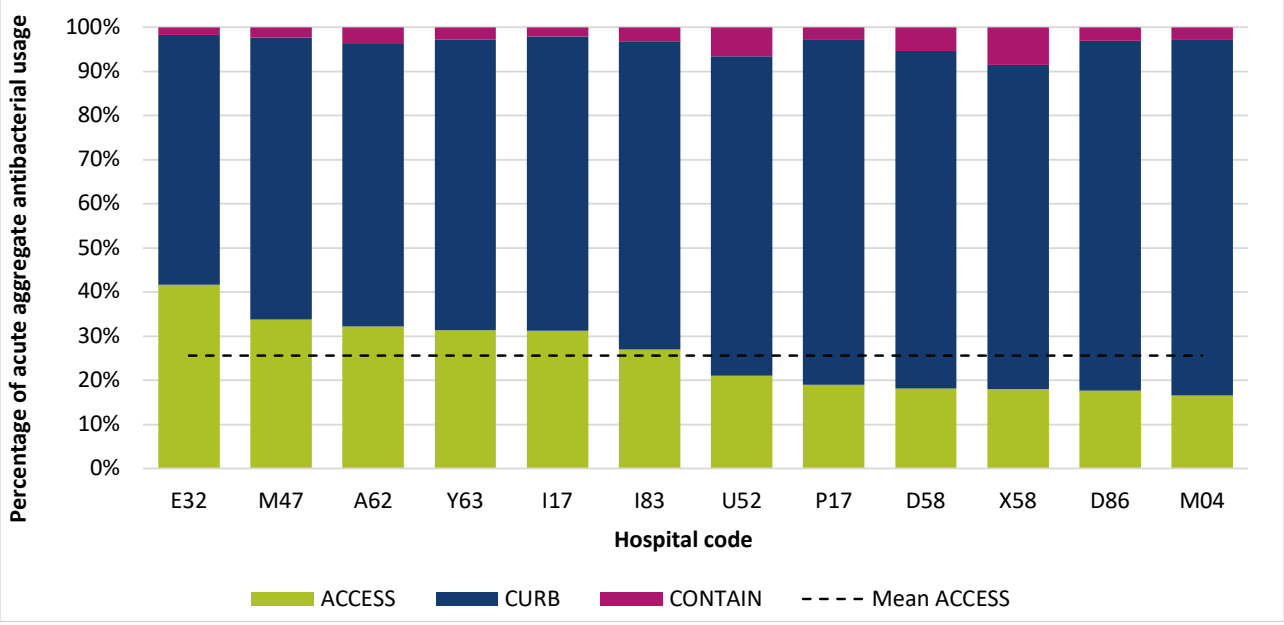
Private Acute Group B hospitals on average use proportionately the highest amount of *Curb* antimicrobials in the acute hospital setting (excluding usage in ED and OT) of all the peer groups. Figure 14 shows antibacterial usage rates by PAL category for hospitals in this peer group, and Figure 15 shows the proportionate annual usage. Across the 12 hospitals in this peer group, the average proportionate usage of *Curb* antibacterials was 71.2%. Access usage in this peer group was just 24.4% of annual use, which is approximately half the proportionate Access use in similarly peered public sites (47.1%).

Figure 14: Aggregate acute antibacterial usage (excluding emergency department and operating theatre) by Priority Antibacterial List category in Private Acute Group B hospitals, 2021



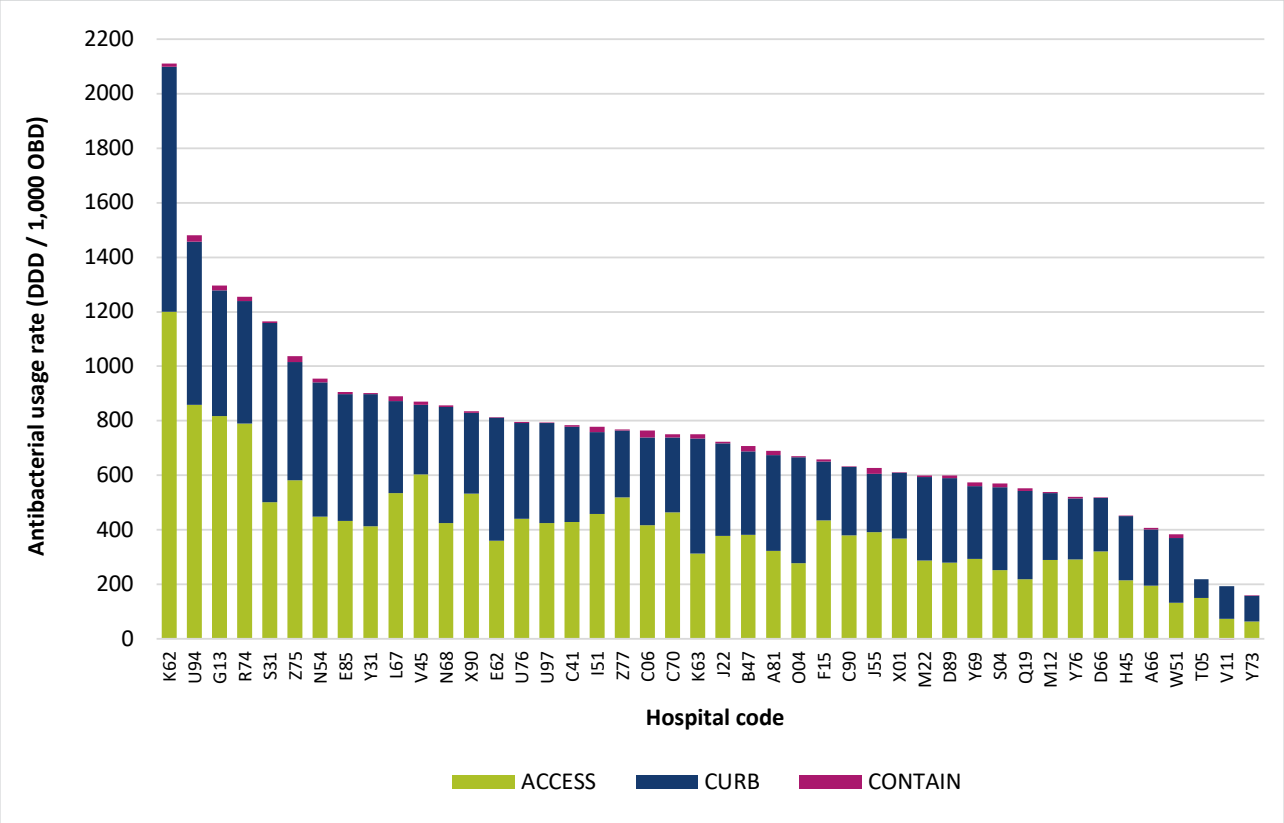
DDD: defined daily dose; OBD: occupied bed days.

Figure 15: Percentage of acute aggregate antibacterial usage (excluding emergency department and operating theatre) by Priority Antibacterial List category in Private Acute Group B hospitals, 2021



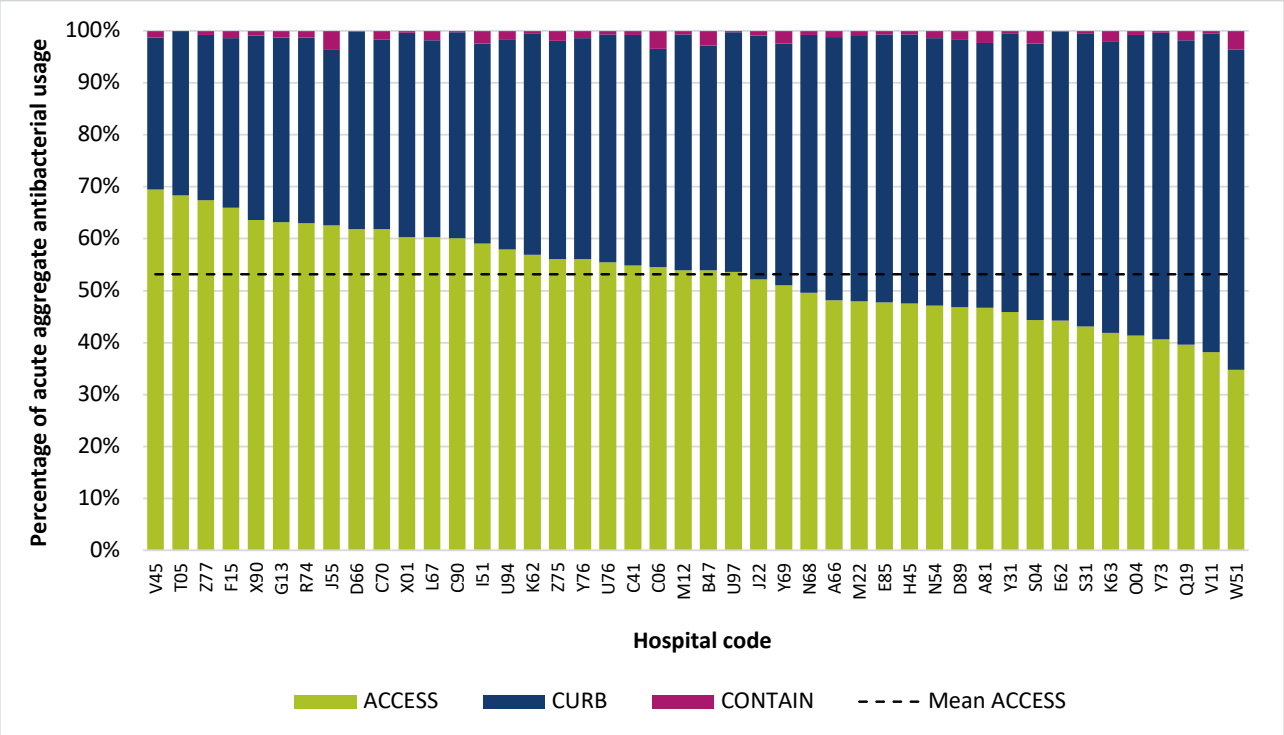
In Public Acute Group C hospitals, *Access* antibacterials account for 53.2% of all antibacterial use on average, with this peer group using proportionately more *Access* antibacterials than all other peer groups. Figure 16 shows 2021 usage rates by PAL category for hospitals in this peer group, and Figure 17 shows the proportionate usage.

Figure 16: Aggregate acute antibacterial usage (excluding emergency department and operating theatre) by Priority Antibacterial List category in Public Acute Group C hospitals, 2021



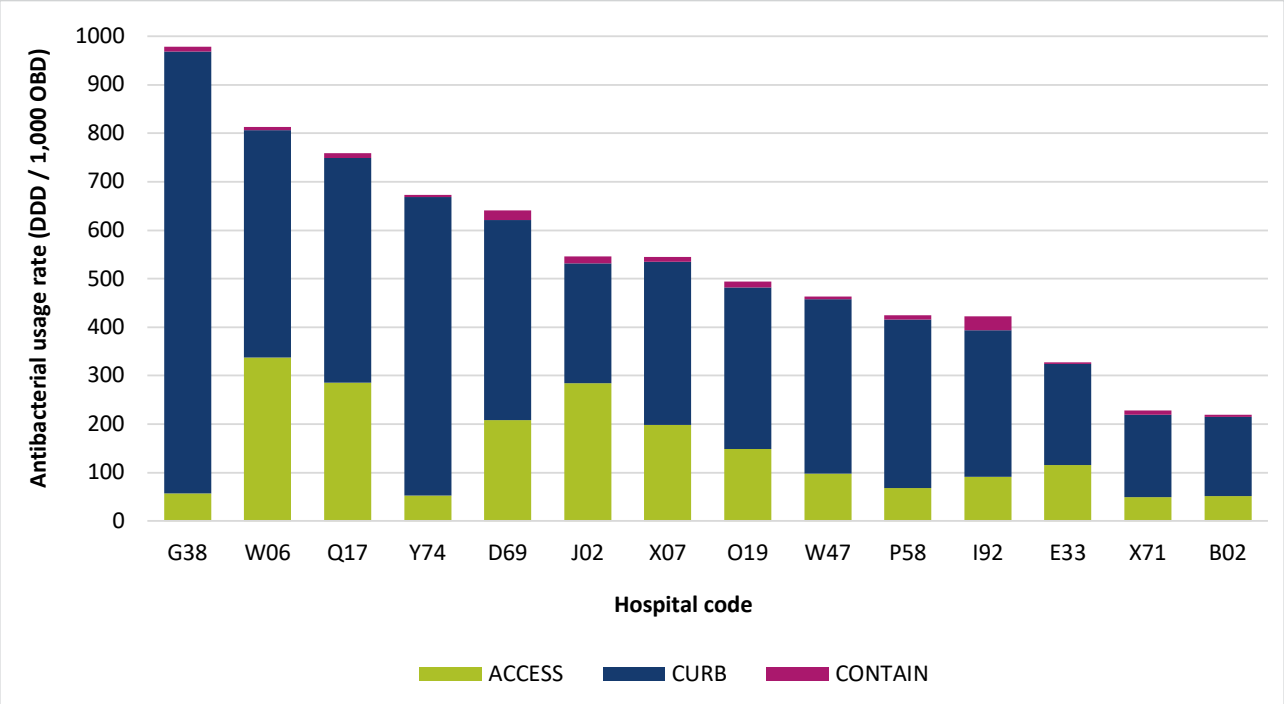
DDD: defined daily dose; OBD: occupied bed days.

Figure 17: Percentage of acute aggregate antibacterial usage (excluding emergency department and operating theatre) by Priority Antibacterial List category in Public Acute Group C hospitals, 2021



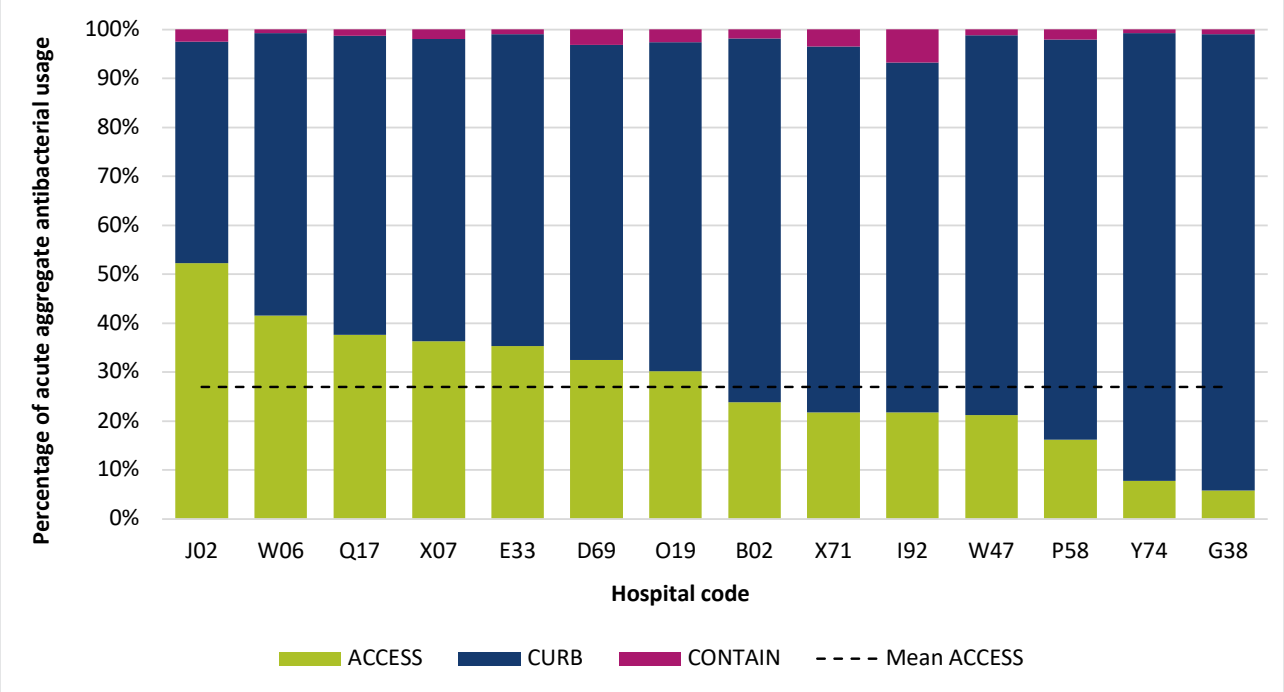
Private Acute Group C hospitals' use of *Curb* antibacterials was more than double that of the *Access* group on a proportionate basis (68.2% and 27.4% respectively). On average, *Curb* antibacterial use comprised 68.2% of antibacterial usage in these sites, excluding ED and OT usage (Figure 18). For 2 private hospitals in this peer group, *Curb* antibacterial usage comprised more than 90% of the total annual usage in the acute setting, outside of ED and OT (Figure 19).

Figure 18: Aggregate acute antibacterial usage (excluding emergency department and operating theatre) by Priority Antibacterial List category in Private Acute Group C hospitals, 2021



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

Figure 19: Percentage of acute aggregate antibacterial usage (excluding emergency department and operating theatre) by Priority Antibacterial List category in Private Acute Group C hospitals, 2021



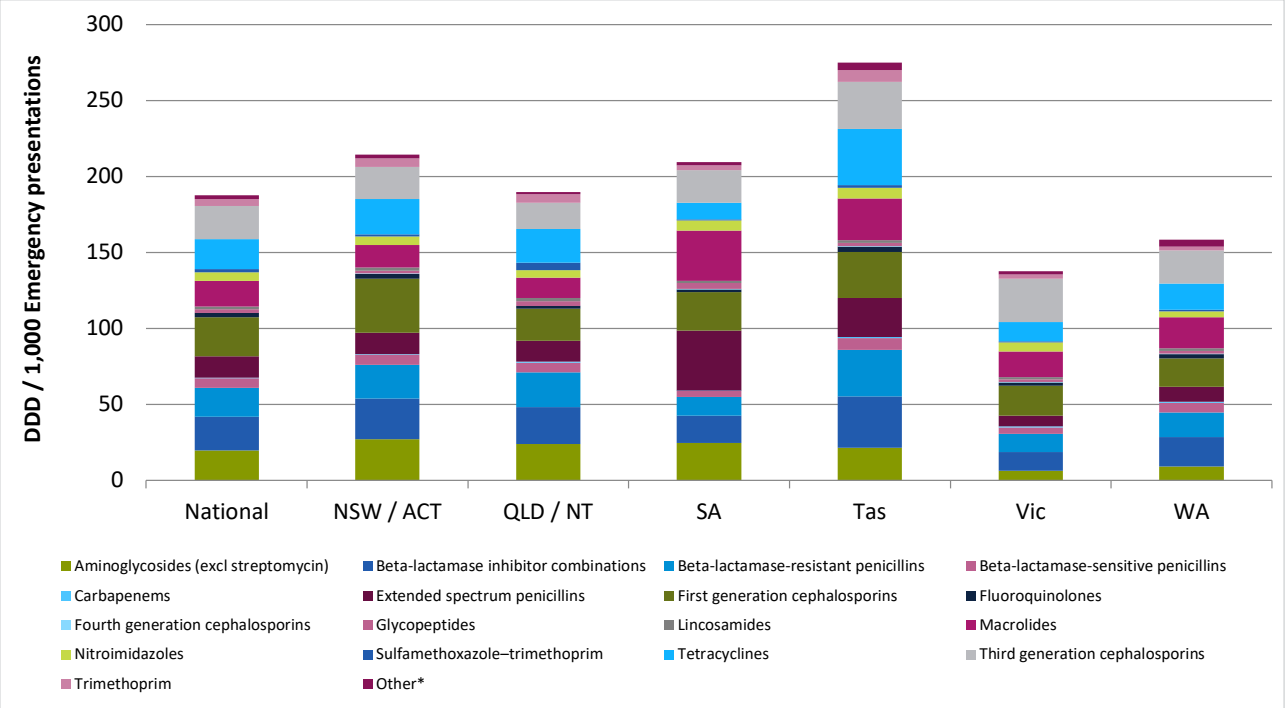
Antibacterial usage in the emergency department setting, 2021

From January 2021, ED antimicrobial usage is submitted and reported separately from other acute hospital usage. Benchmarking of antimicrobial usage in the ED is reported relative to emergency presentations (DDD / 1,000 ED presentations), to overcome the limitations of OBD as a metric of activity in this setting. Many patients admitted to ED are treated and discharged or transferred within the same day, meaning that bed occupancy at midnight does not accurately represent patient activity in this setting. An 'emergency presentation' (EP) is defined by the AIHW as 'the arrival of a patient at the emergency department and is the earliest occasion of being registered clerically or triaged'.

Emergency department antibacterial usage by state and territory, 2021

Figure 20 illustrates annual ED antibacterial usage rates for 2021 by antibacterial class, by state and territory. The aggregate national usage rate of all antibacterials in the ED in 2021 was 187.5 DDD / 1,000 EPs. There is substantial variation in both the usage rates and the classes of antibacterials used in the ED setting between the states and territories. Variation in distribution practices in this setting may account for some of this variation between jurisdictions - for example, ED stock may be used as an after-hours supply when the pharmacy is closed, some sites do not label prepacks for outpatient use and therefore cannot distinguish inpatient from outpatient use, and some sites distribute stock for HITH from ED.

Figure 20: Aggregate emergency department antibacterial usage rates (DDD / 1,000 emergency presentations) by class in NAUSP contributor hospitals, by state and territory, 2021

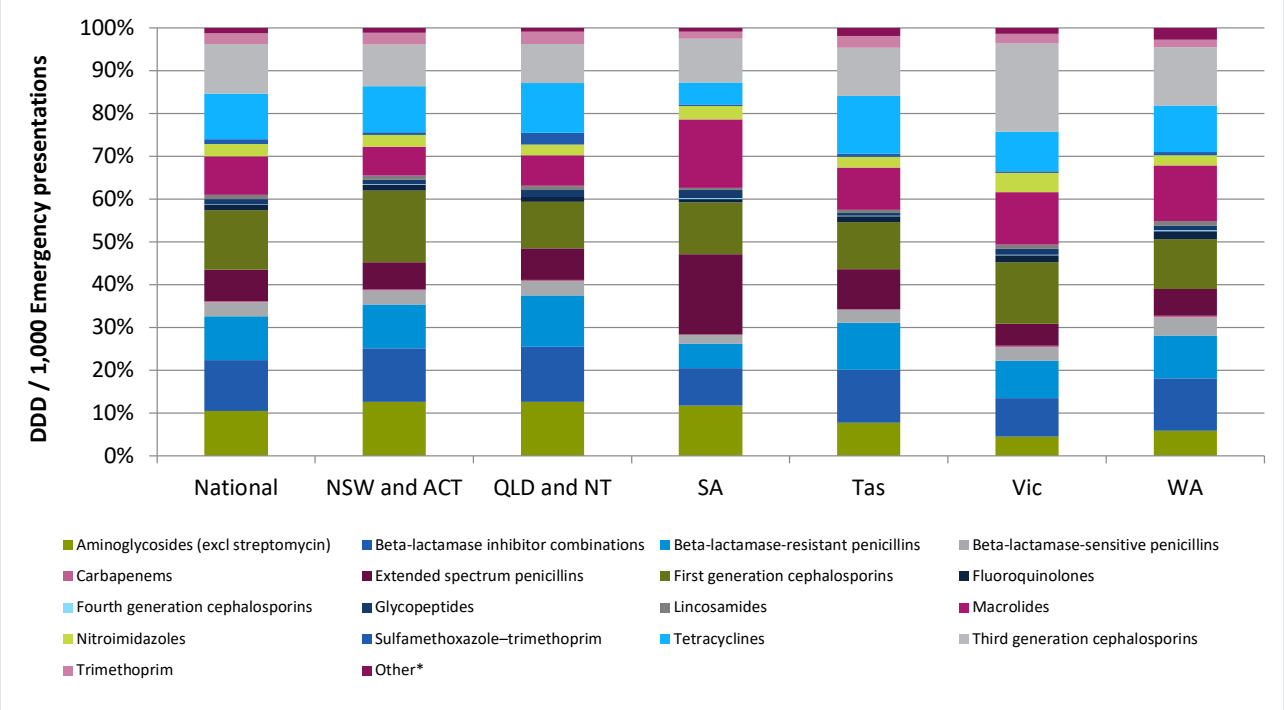


* 'Other': Combination products for the eradication of *Helicobacter pylori*, cycloserine, rifampicin, rifabutin, monobactams, nitrofurans, polymyxins, sodium fusidate, streptogramins, other cephalosporins, fosfomycin, linezolid, daptomycin, tedizolid.

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

Figure 21 provides the proportionate annual antibacterial usage in the ED, by state and territory, in 2021. Victoria uses proportionately more third-generation cephalosporins in ED than other states and territories (20.6% of total ED usage relative to the number of presentations). In New South Wales / Australian Capital Territory, 16.7% of ED usage comprises first-generation cephalosporins (cefalexin and cefazolin). South Australia reported the highest proportionate rates of ED usage of extended-spectrum penicillins (amoxicillin/ampicillin) (18.8%) and macrolides (15.9%).

Figure 21: Proportionate emergency department antibacterial usage rates (DDD / 1,000 emergency presentations) by class in NAUSP contributor hospitals, by state and territory, 2021



* 'Other': 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 dose; NAUSP: National Antimicrobial Utilisation Surveillance Program.

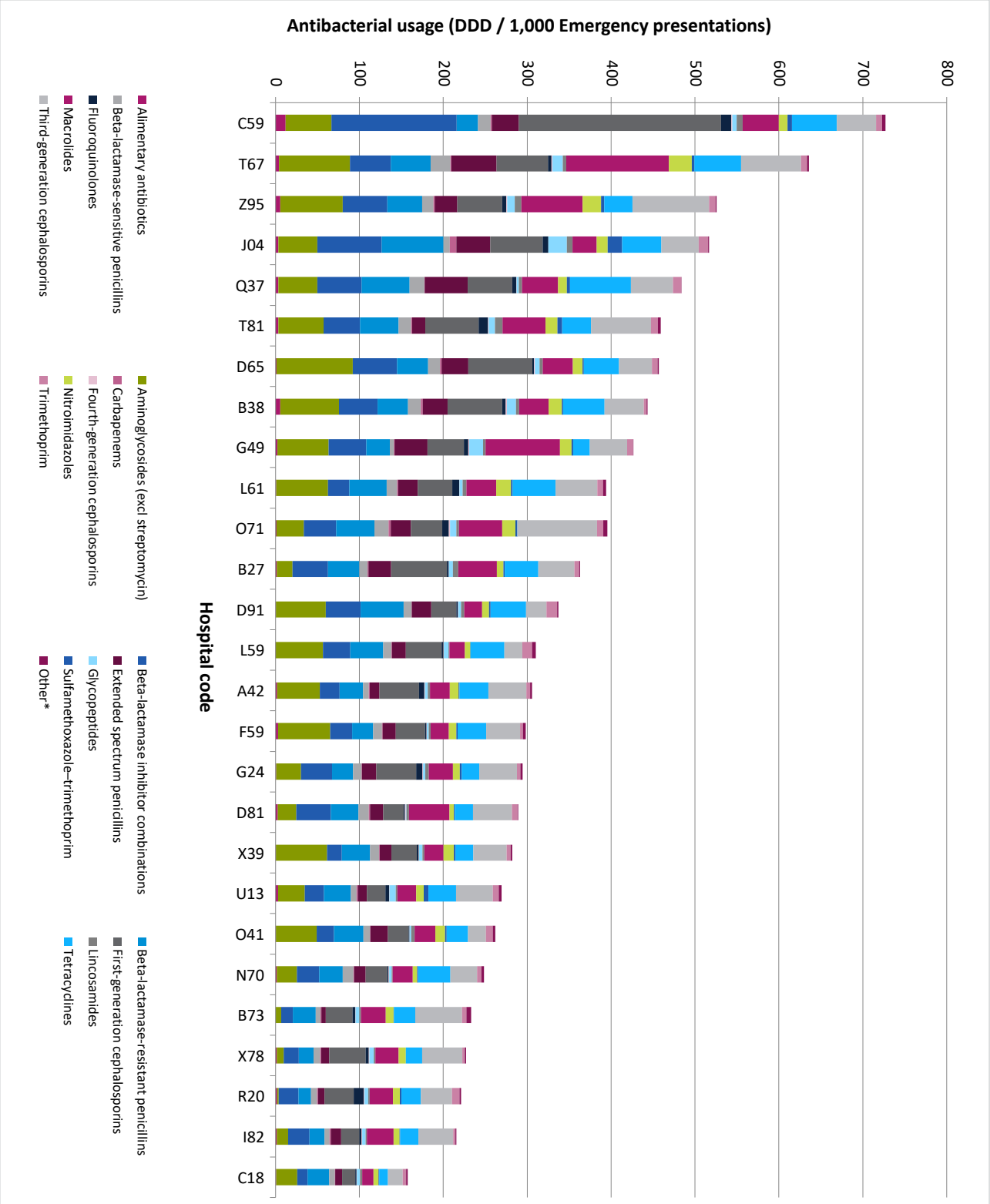
Emergency department antibacterial usage by hospital peer group, 2021

Figures 22 to 25 show the aggregated usage rates for all antibacterials in 2021 for NAUSP contributor hospitals, by AIHW peer group. Hospital peer groups are categorised based on similar characteristics (services provided, hospital size, and the case mix and acuity of patient population) allowing benchmarking within or between different peer groups.

There are 198 hospitals registered to contribute data for the ED location, of which 185 contributed at least one month of data for 2021. Only hospitals that contributed at least 6 months of data are included in the following benchmarking graphs.

Principal referral hospitals

Figure 22: Emergency department antibacterial usage rates (DDD / 1,000 emergency presentations) by class in principal referral hospitals, 2021

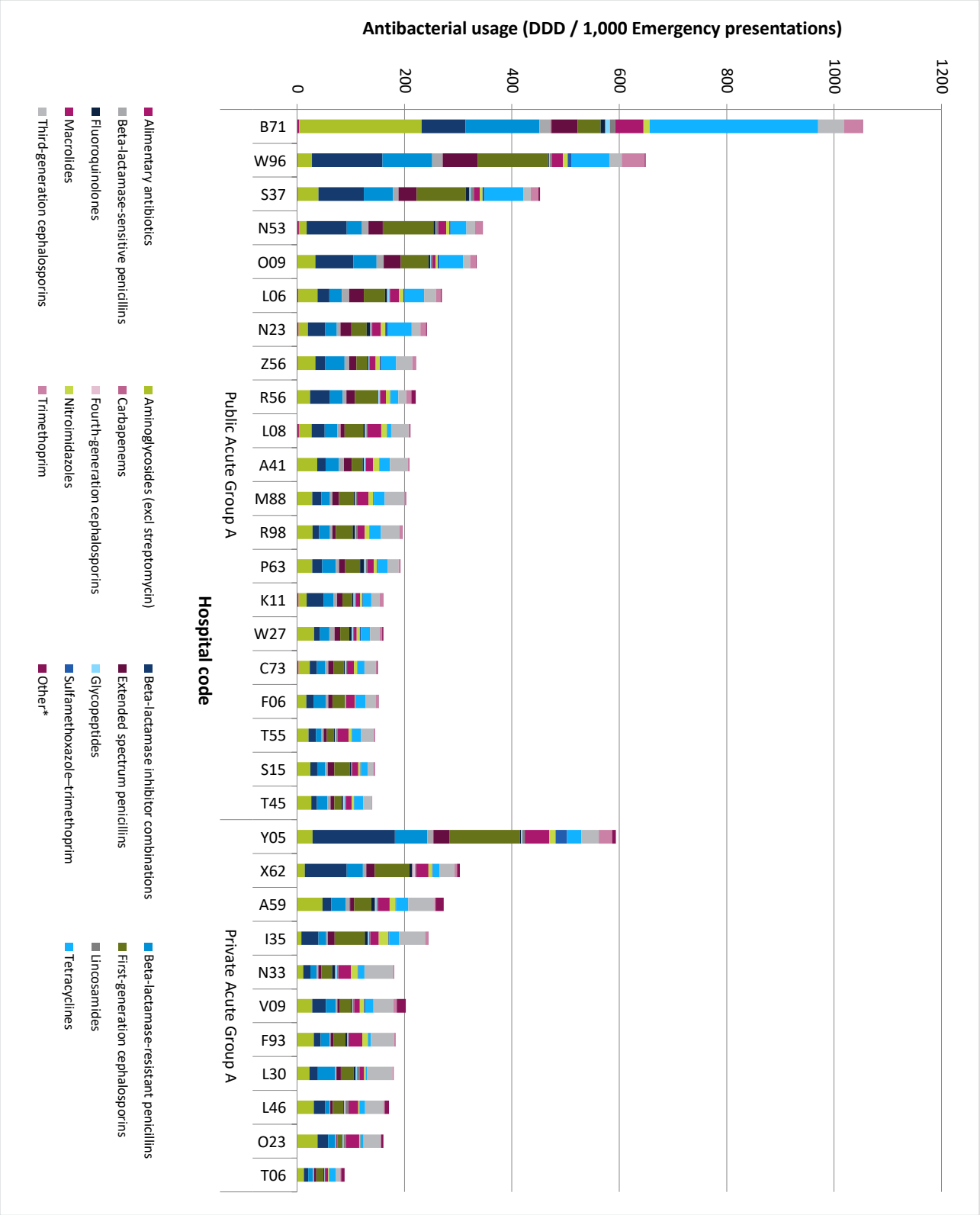


* 'Other': Combination products for the eradication of *Helicobacter pylori*, cycloserine, rifampicin, rifabutin, monobactams, nitrofurans, polymyxins, sodium fusidate, streptogramins, other cephalosporins, fosfomycin, linezolid, daptomycin, tedizolid.

DDD: defined daily dose.

Public and Private Acute Group A hospitals

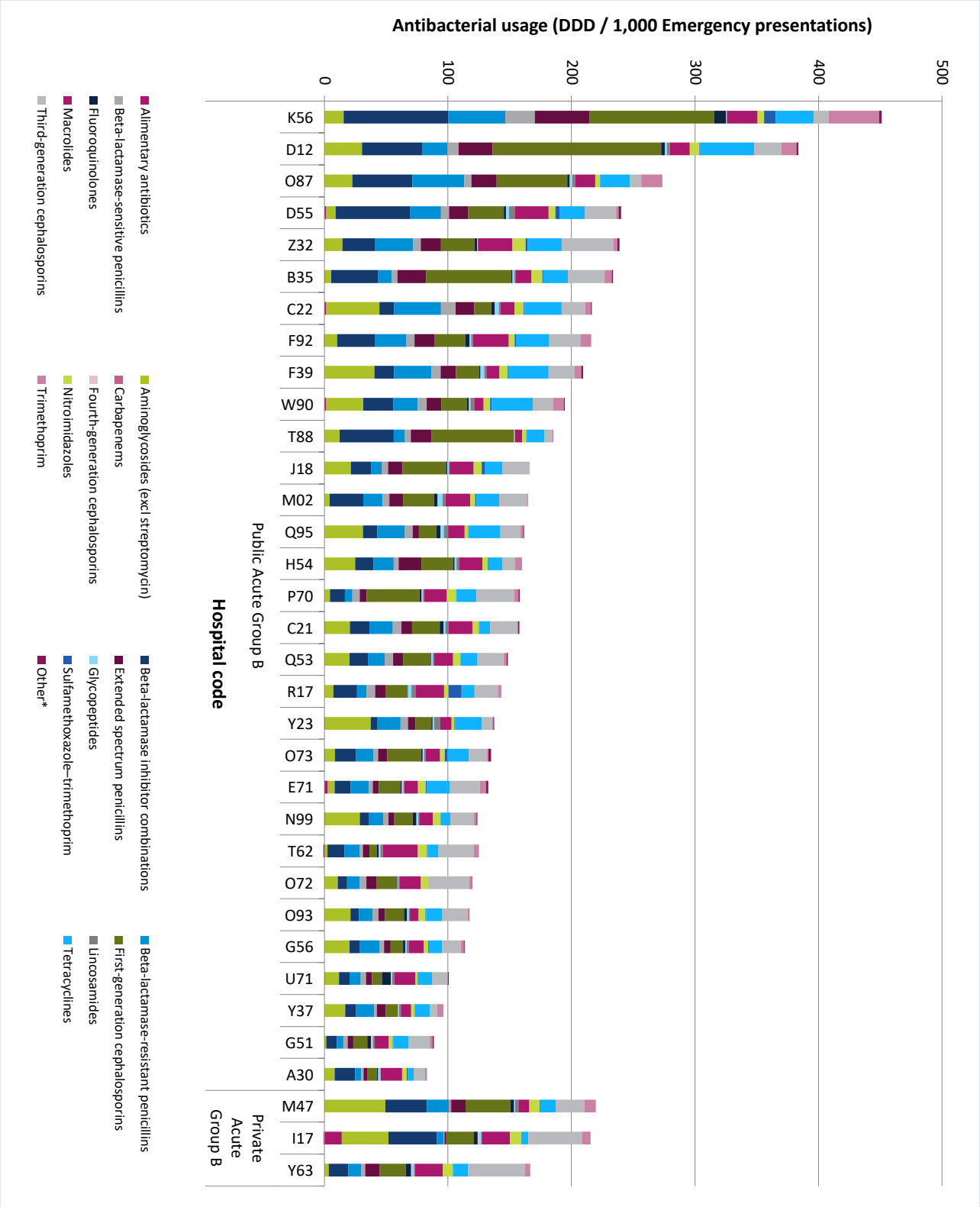
Figure 23: Emergency department antibacterial usage rates (DDD / 1,000 emergency presentations) by class in Public and Private Acute Group A hospitals, 2021



* 'Other': 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 dose.

Public and Private Acute Group B hospitals

Figure 24: Emergency department antibacterial usage rates (DDD / 1,000 emergency presentations) by class in Public and Private Acute Group B hospitals, 2021

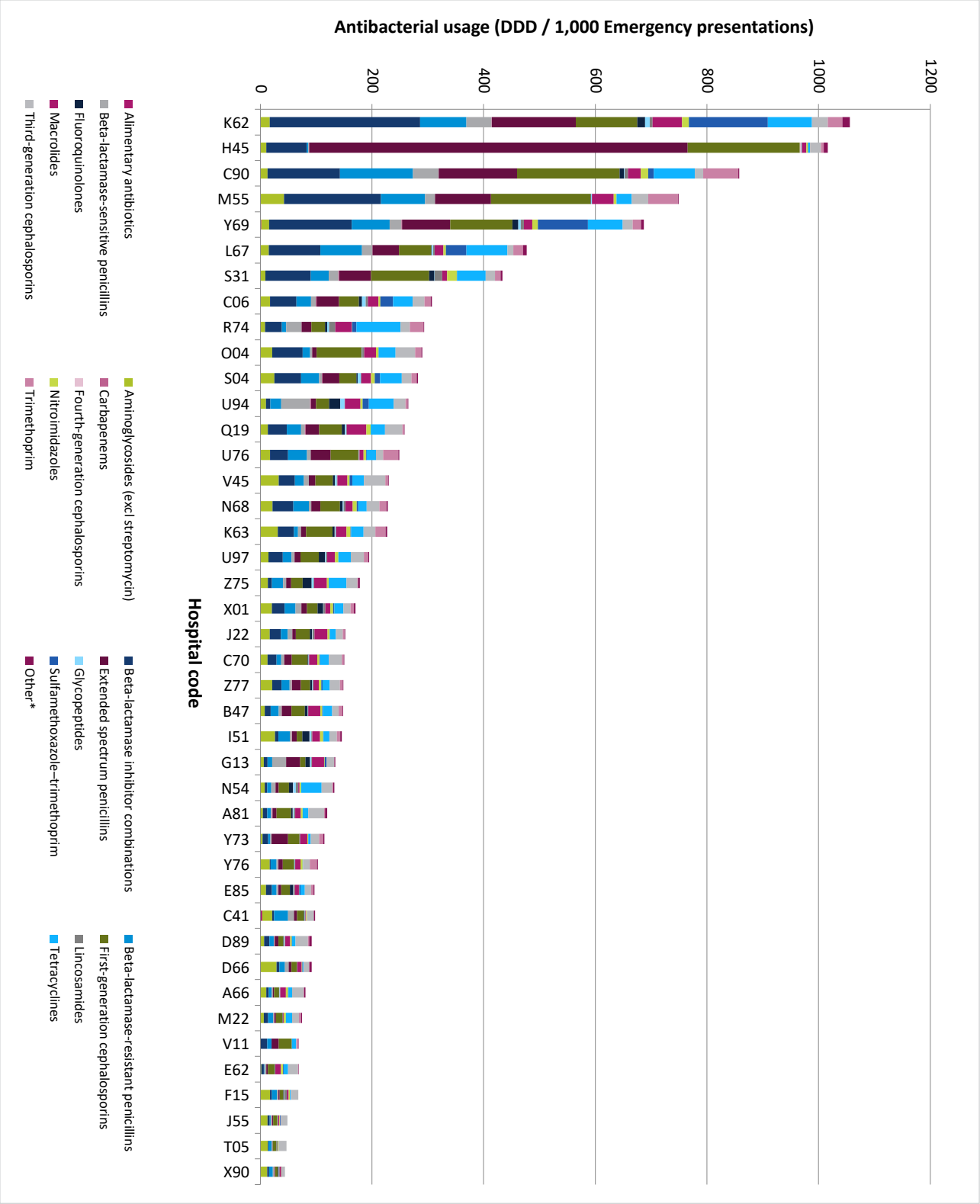


* 'Other': Combination products for the eradication of *Helicobacter pylori*, cycloserine, rifampicin, rifabutin, monobactams, nitrofurans, polymyxins, sodium fusidate, streptogramins, other cephalosporins, fosfomycin, linezolid, daptomycin, tedizolid.

DDD: defined daily dose.

Public Acute Group C hospitals

Figure 25: Emergency department antibacterial usage rates (DDD / 1,000 emergency presentations) by class in Public Acute Group C hospitals, 2021



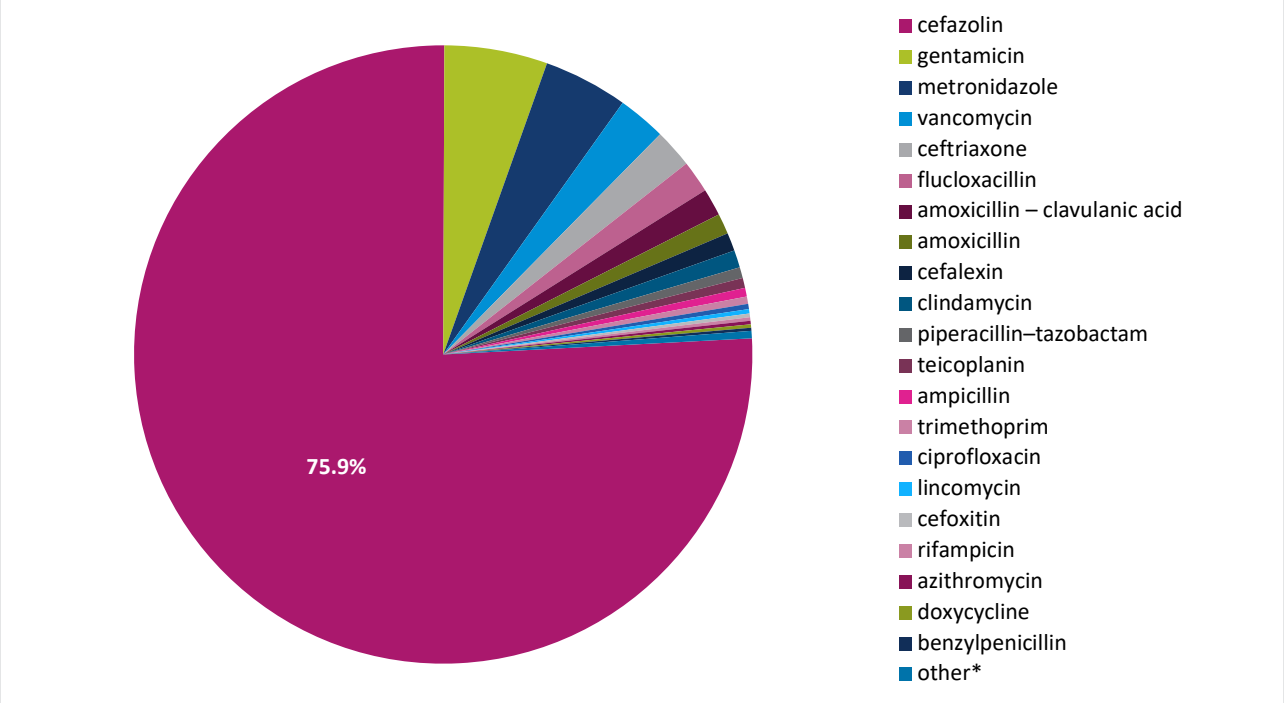
* 'Other': Combination products for the eradication of *Helicobacter pylori*, cycloserine, rifampicin, rifabutin, monobactams, nitrofurans, polymyxins, sodium fusidate, streptogramins, other cephalosporins, fosfomycin, linezolid, daptomycin, tedizolid.

DDD: defined daily dose.

Operating theatre antimicrobial usage, 2021

One hundred and eighty-seven contributors provided stratified theatre data included in this report. Cefazolin comprised 75.9% of all antimicrobial usage (as a proportion of total DDDs) in the OT across 187 participating hospitals nationally that were able to stratify their OT usage from other acute antimicrobial use (Figure 26). A high rate of cefazolin use is expected in theatre given it is a first-line antimicrobial for surgical prophylaxis.[16]

Figure 26: Proportionate antimicrobial usage (DDDs) in the operating theatre and recovery setting, National (n=187), 2021



* 'Other': meropenem, erythromycin, cefotaxime.

DDD: defined daily dose.

The above proportionate usage represents the total volume (total DDDs) of antimicrobials dispensed and distributed to the OT and recovery setting in 2021 in NAUSP contributor hospitals. As preoperative prophylactic infusions (e.g. vancomycin) may be commenced on the ward, not all antimicrobials used for surgical prophylaxis may be captured in this data. Conversely, some antimicrobial agents used in the theatre and recovery setting may be for the treatment of a proven infection rather than for surgical prophylaxis. It is important to interpret these data noting usage is not entirely attributable to prophylaxis; patients undergoing emergency/trauma procedures or undergoing treatment for an existing infection will also account for some non-prophylactic antimicrobial use.

The total quantities (in DDDs) distributed to the theatre/recovery setting per antimicrobial agent (and the proportional percentage) are provided in Table 7 below.

Table 7: National antimicrobial use (DDD) in theatre/recovery by antimicrobial agent, NAUSP contributor hospitals, 2021

Antimicrobial	Sum of DDD	%	Antimicrobial	Sum of DDD	%
Cefazolin	606,480	75.9	Ceftazidime	107	0.0
Gentamicin	43,085	5.4	Norfloxacin	107	0.0
Metronidazole	35,232	4.4	Cefaclor	83	0.0
Vancomycin	20,143	2.5	Tobramycin	80	0.0
Ceftriaxone	16,204	2.0	Clarithromycin	75	0.0
Flucloxacillin	13,430	1.7	Daptomycin	71	0.0
Amoxicillin – clavulanic acid	11,430	1.4	Methenamine hippurate	71	0.0
Amoxicillin	8,577	1.1	Amikacin	52	0.0
Cefalexin	7,565	0.9	Dicloxacillin	50	0.0
Clindamycin	7,278	0.9	Moxifloxacin	49	0.0
Piperacillin–tazobactam	4,537	0.6	Phenoxymethylpenicillin	40	0.0
Teicoplanin	4,187	0.5	Nitrofurantoin	37	0.0
Ampicillin	3,636	0.5	Ertapenem	37	0.0
Trimethoprim	3,055	0.4	Fosfomycin	29	0.0
Ciprofloxacin	2,190	0.3	Vancomycin oral	24	0.0
Lincomycin	1,827	0.2	Cefuroxime	14	0.0
Cefoxitin	1,545	0.2	Linezolid	12	0.0
Rifampicin	1,471	0.2	Tigecycline	8	0.0
Azithromycin	1,470	0.2	Imipenem–cilastatin	8	0.0
Doxycycline	1,416	0.2	Colistin	7	0.0
Benzylpenicillin	1,287	0.2	Minocycline	7	0.0
Meropenem	552	0.1	Levofloxacin	6	0.0
Erythromycin	402	0.1	Neomycin	3	0.0
Cefotaxime	297	0.0	Benzathine benzylpenicillin	3	0.0
Sulfamethoxazole–trimethoprim	258	0.0	Cycloserine	2	0.0
Rifaximin	232	0.0	Pristinamycin	2	0.0
Roxithromycin	211	0.0	Aztreonam	1	0.0
Cefepime	147	0.0	Ceftaroline	1	0.0

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

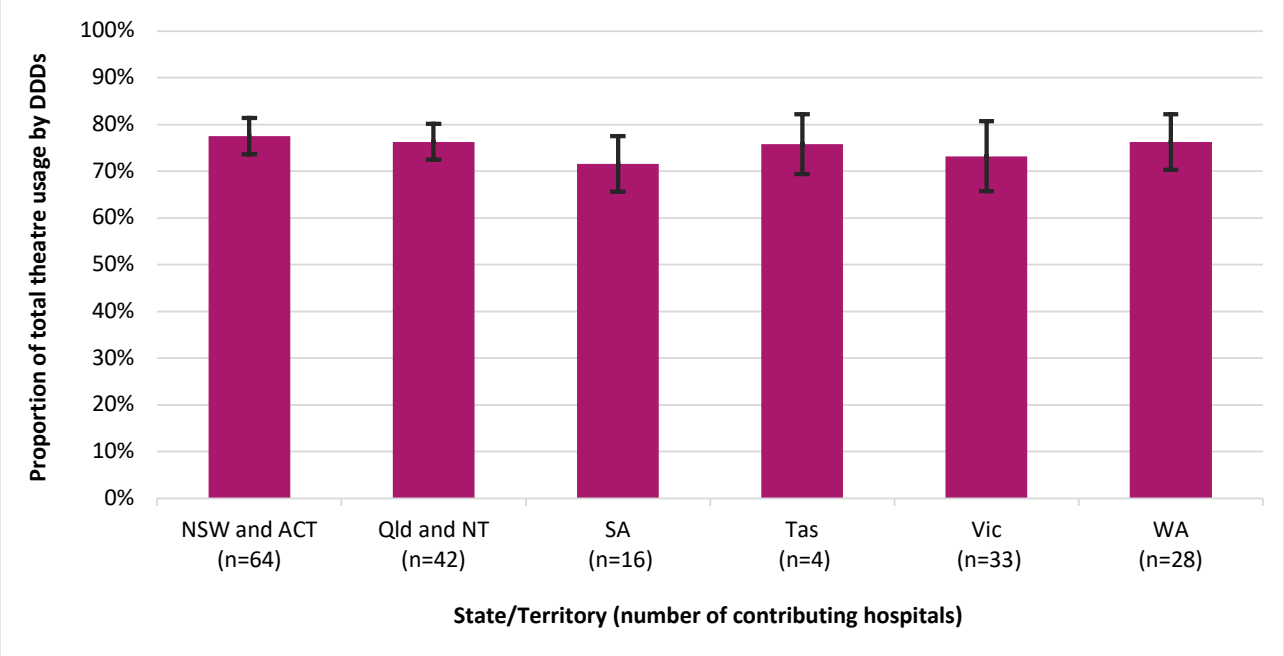
Cefazolin comprised 75.9% of total antimicrobial DDDs used in the OT across all 187 hospitals reporting stratified theatre data. This high proportionate usage is expected given that cefazolin is recommended as a first-line prophylactic agent for most surgical procedures.[16] When comparing the proportionate use of cefazolin across the states and territories, there is some variability (Table 8 and Figure 27).

Table 8: Proportionate use of cefazolin (as a proportion of total antibacterial DDDs distributed) in theatre and recovery, NAUSP contributor hospitals, 2021

State	Mean proportionate cefazolin use	95% Confidence interval
New South Wales and Australian Capital Territory	77.5%	73.7-81.4
Queensland and Northern Territory	76.3%	72.4-80.0
South Australia	71.6%	65.7-77.6
Tasmania	75.8%	69.4-82.1
Victoria	73.2%	65.7-80.7
Western Australia	76.3%	70.3-82.2

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

Figure 27: Cefazolin usage (total DDDs) in theatre and recovery as a proportion of total annual usage, 2021

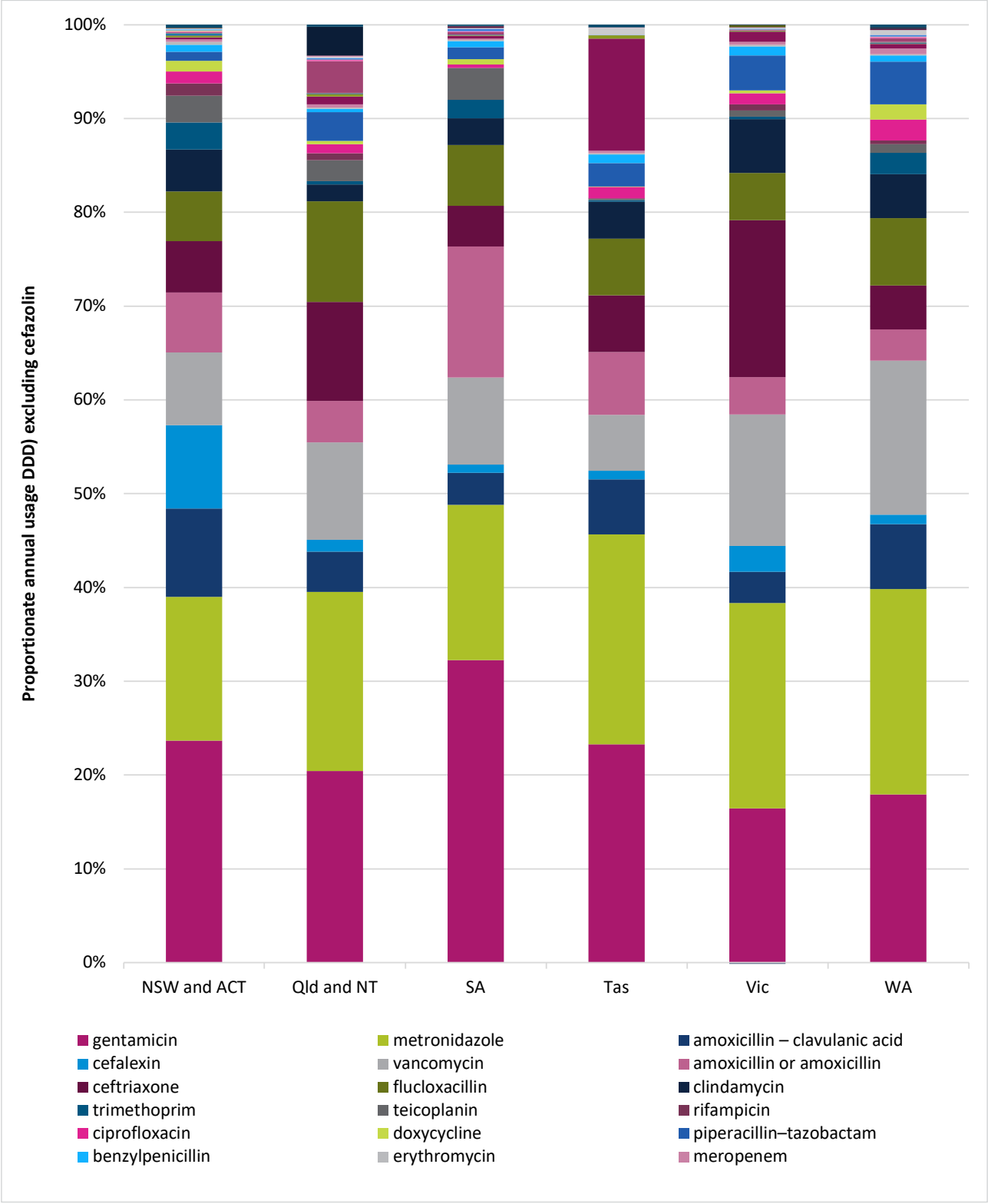


DDD: defined daily dose.

Excluding cefazolin, gentamicin and metronidazole are the next most used antimicrobials in the theatre setting, comprising 5.4 and 4.4% of theatre use by volume (DDDs). Vancomycin is also in the top 5 most used antimicrobials in theatre and recovery. As mentioned above, vancomycin is likely to be under-reported in this theatre data, as prophylactic infusions of vancomycin may be commenced on the ward in some hospitals.

The proportionate usage of antimicrobials other than cefazolin in theatre and recovery are shown by jurisdiction in Figure 28.

Figure 28: Proportionate annual usage (proportion of total DDDs) of antibacterials other than cefazolin, 2021



* 'Other': annual usage <50 DDD in theatre in all states (includes amikacin, clarithromycin, phenoxymethylpenicillin, fosfomycin, vancomycin oral, dicloxacillin, colistin, levofloxacin, linezolid, moxifloxacin, tigecycline, ertapenem, cycloserine, cefuroxime, ceftaroline, benzathine benylpenicillin, aztreonam, imipenem–cilastatin, minocycline, neomycin, pristinomycin).

DDD: defined daily dose.

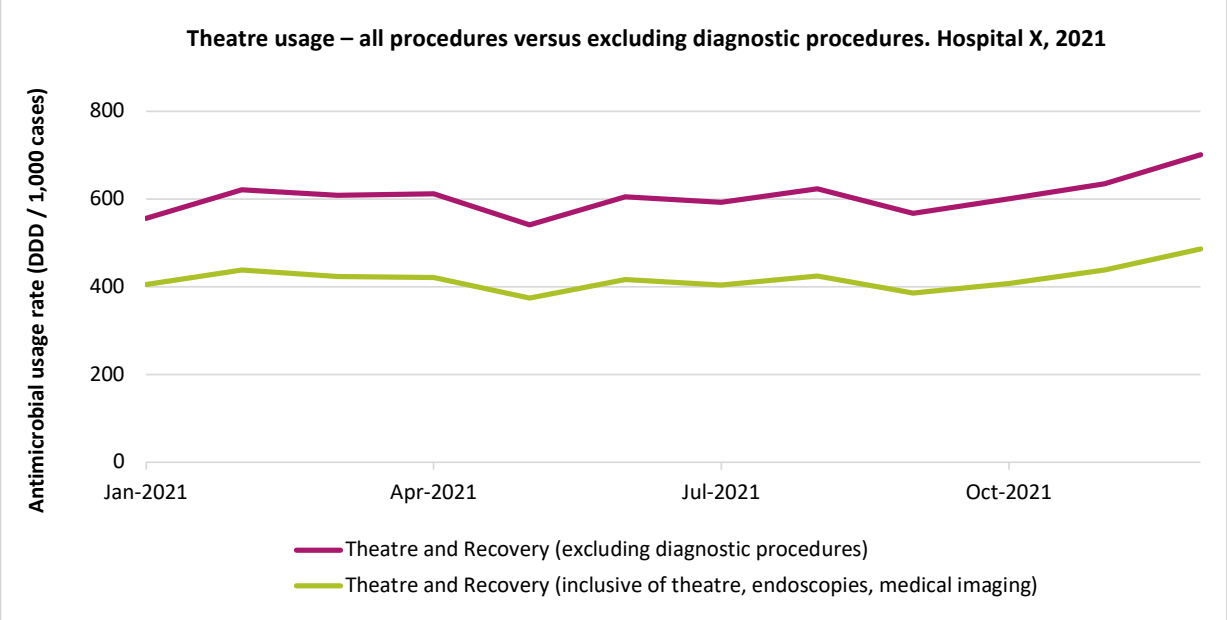
Challenges with benchmarking antimicrobial use in the perioperative setting

Benchmarking antimicrobial usage between hospitals in the peri-operative setting is not yet achievable using NAUSP data. Hospitals undertaking diagnostic procedures (such as investigative scopes, cardiac catheterisation and other medical imaging procedures) in theatre have inflated denominator values (theatre case numbers) due to the inclusion of procedures where antimicrobials are not routinely required. Where there is shared theatre space with only one imprest for distribution of antimicrobials, it may not be possible stratify usage or activity to determine antimicrobial usage rates for invasive procedures.

Conversely, other sites (generally larger or private facilities) may be able to stratify usage and activity for non-invasive and invasive procedures. This enables them to monitor their usage rates for invasive surgical procedures.

Illustration using data from Hospital X

Hospital X is an inner regional hospital, classified by the Australian Institute of Health and Welfare as a Public Acute Group A facility, offering specialist surgical services along with day procedures. Its theatre setting includes endoscopy suites and medical imaging. However, they do have the ability to stratify the data for these distinct locations, as they have a separate imprest for each.



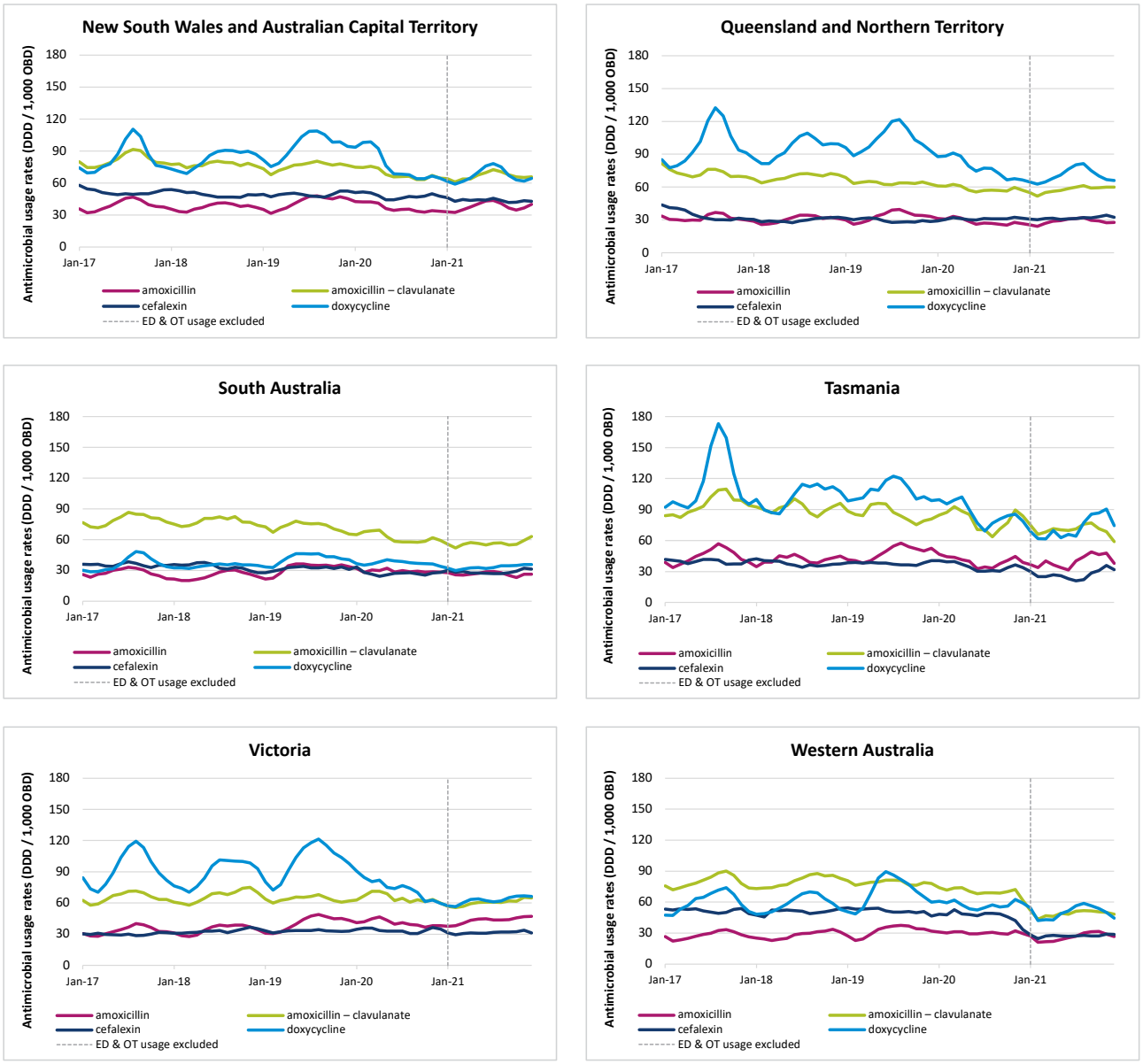
As evidenced in the example above, including the small amount of antimicrobial usage and substantial case numbers coming from endoscopy and medical imaging, the difference in usage rates is notable. Therefore, benchmarking usage between sites with a widely differing procedure types included in the denominator value would not provide a meaningful comparison.

Currently, hospitals can monitor their usage over time to identify concerning trends or unexpected usage. However, the provision of a comparator rate would enable greater opportunity to identify excessive use to target stewardship activities. Possible solutions include modifying the NAUSP portal to enable 2 distinct cohorts to more accurately provide benchmarking in the perioperative setting; one group including sites that cannot stratify theatre from ancillary areas and a second that could.

Usage rates for high-volume oral antibacterials, 2017–2021

In Australian acute care hospitals, the most prescribed oral antibacterials are amoxicillin – clavulanic acid, doxycycline, cefalexin, and amoxicillin. Figure 29 shows longitudinal usage rates for these 4 oral antibacterials in NAUSP contributor hospitals over the 5-year period from January 2017 to December 2021. (Note: From January 2021, usage rates in the ED and OT settings are reported separately and are not included with other acute usage rates). Seasonal variation was observed for doxycycline and amoxicillin, with usage typically higher in the winter months, for the years prior to the onset of the COVID-19 pandemic. During 2020, the usual seasonal variation was not seen. In 2021, the average monthly usage rate for doxycycline in the acute inpatient setting was highest in Tasmania and Queensland (72.4 and 70.5 DDD / 1,000 OBD respectively), which was more than double the average monthly usage rate in South Australia (33.2 DDD / 1,000 OBD). Oral amoxicillin – clavulanic acid usage is highest in Tasmania and New South Wales / Australian Capital Territory, with the average monthly acute usage rate in 2021 in Tasmania being 70.3 DDD / 1,000 OBD and in New South Wales / Australian Capital Territory 66.5 DDD / 1,000 OBD.

Figure 29: High-volume oral antibacterial usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals by state and territory, 2017–2021 (3-month moving average)



DDD: defined daily dose; ED: emergency department; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days; OT: operating theatre.

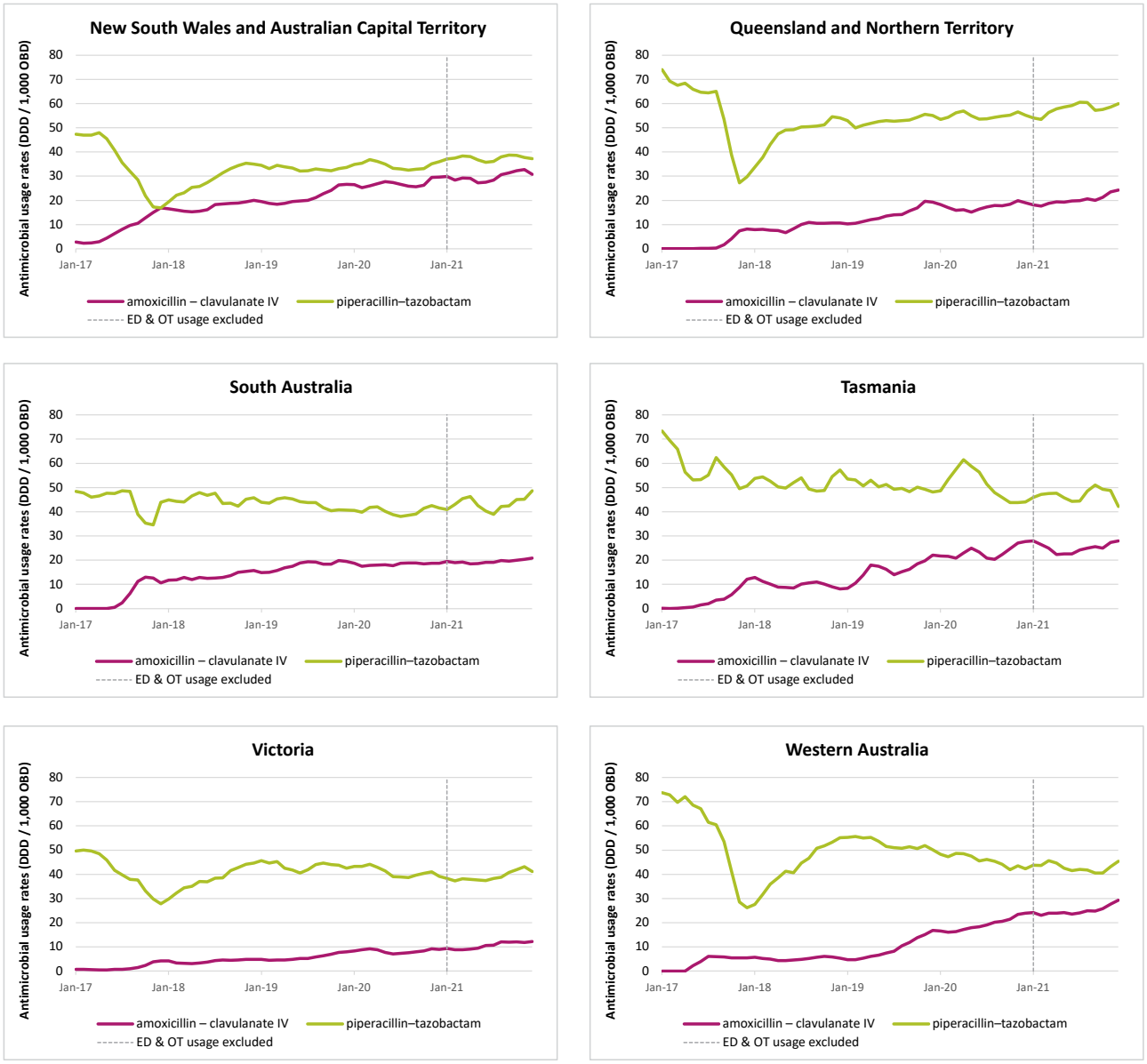
Usage rates for intravenous broad-spectrum antimicrobials, 2017–2021

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

In the second half of 2017 until April 2018 there was a shortage of piperacillin–tazobactam in Australia, which is evident in Figure 30. Intravenous amoxicillin – clavulanic acid was registered for use in Australia at the beginning of 2017 and since then usage has increased. However, the concurrent reduction in piperacillin–tazobactam usage has not been of the same magnitude. There is some evidence that using IV amoxicillin – clavulanic acid in preference to piperacillin–tazobactam may decrease the rate of hospital-acquired vancomycin-resistant enterococcus (VRE).[17]

(Note: From January 2021, usage rates in the ED and OT settings are reported separately and are not included with other acute usage rates).

Figure 30: Penicillin-ß-lactamase inhibitor combination usage rates in NAUSP contributor hospitals by state and territory, 2017–2021 (3-month moving average)



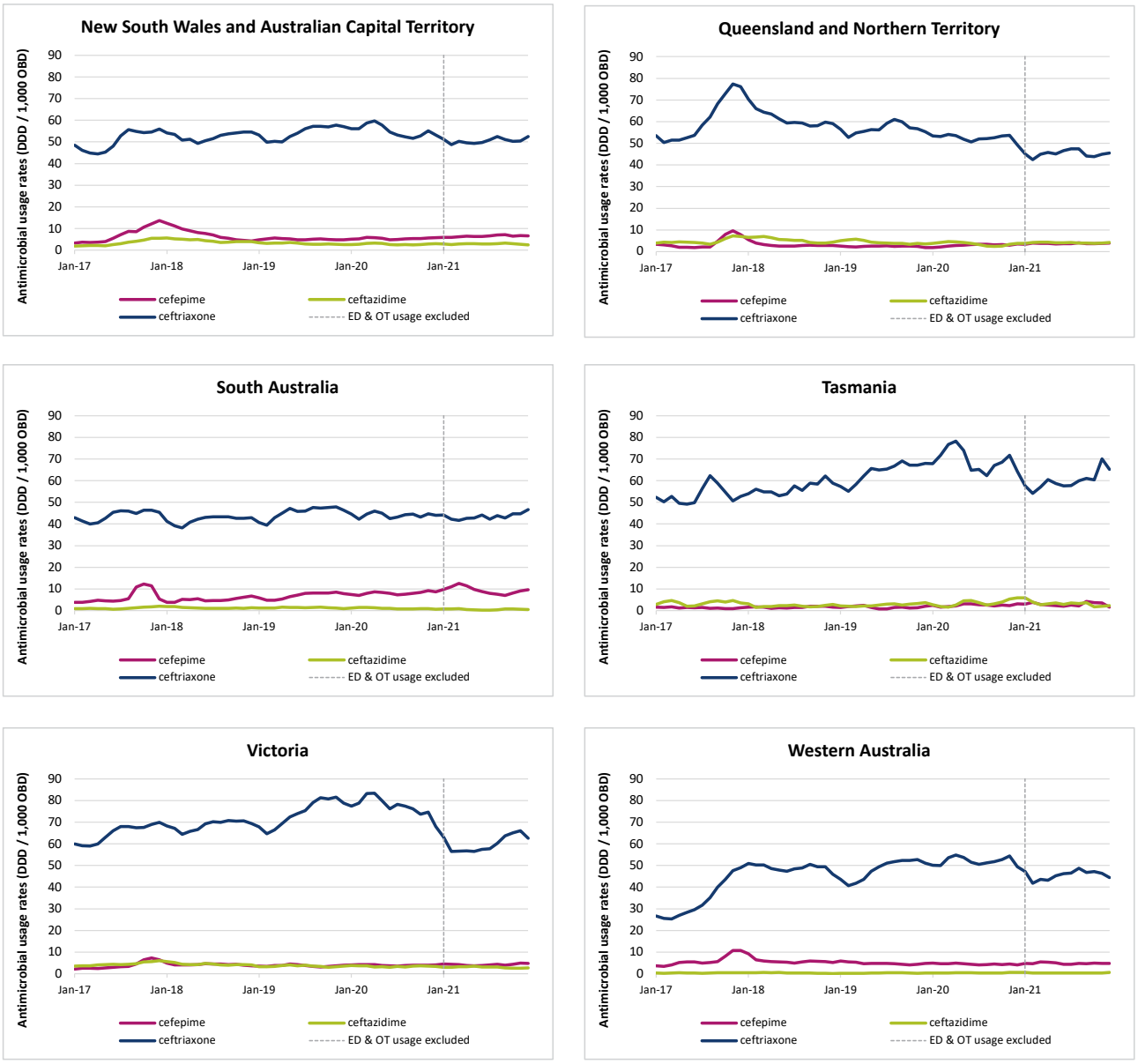
Note: Intravenous amoxicillin – clavulanic acid was registered in Australia in January 2017.[18]

DDD: defined daily dose; ED: emergency department; IV: intravenous; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days; OT: operating theatre.

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

Usage rates for the broad-spectrum third- and fourth-generation cephalosporins are shown in Figure 31. Ceftriaxone is the most commonly used of these agents. However, the stratification of ED usage from the usage rate in other acute settings has illustrated a drop in the reported usage rates outside of emergency. From January 2021, hospitals can download usage reports specific to the ED so that they can monitor usage of this high-volume antibacterial in the emergency setting.

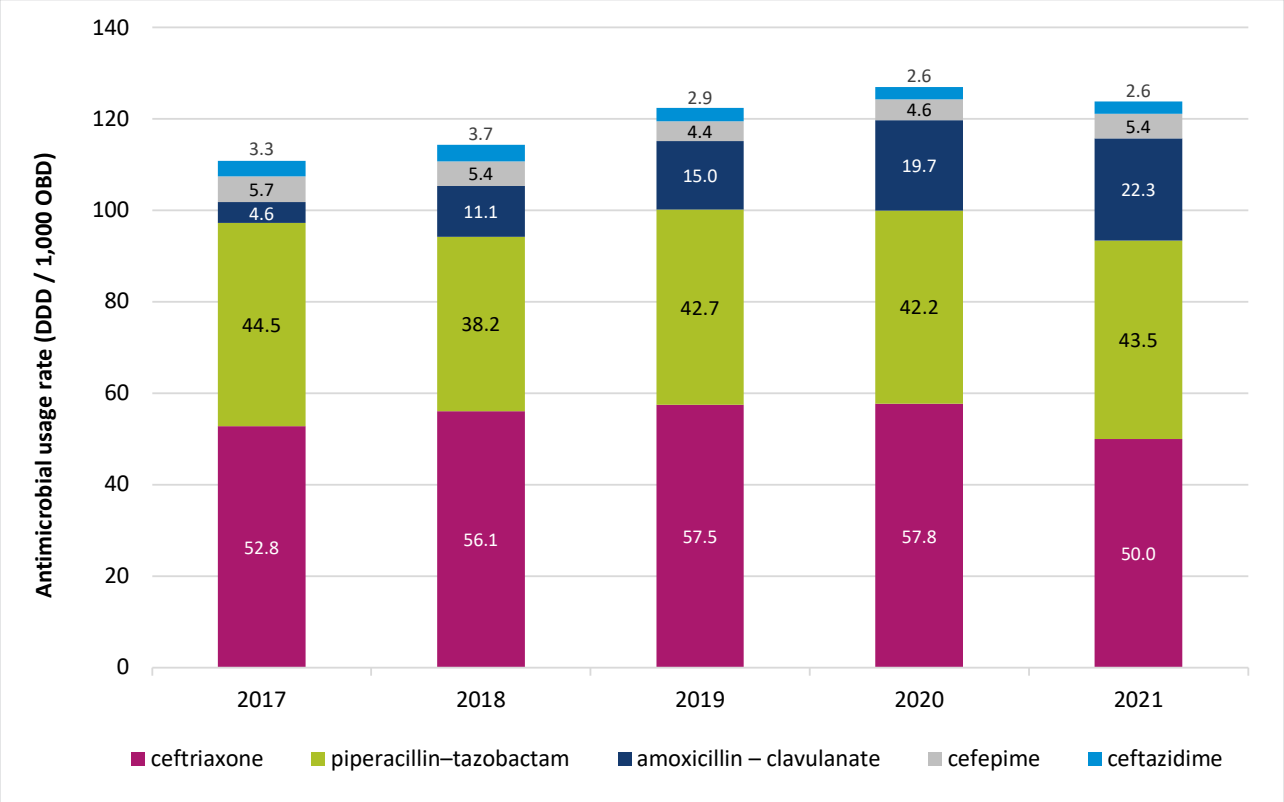
Figure 31: Cephalosporin usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals by state and territory, 2017–2021 (3-month moving average)



DDD: defined daily dose; ED: emergency department; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days; OT: operating theatre.

National proportional annual use of penicillin-ß-lactamase inhibitor combinations and third- and fourth-generation cephalosporins, 2017–2021

Figure 32: National aggregate acute hospital usage rates (excluding emergency department and operating theatre) for intravenous penicillin-ß-lactamase inhibitor combinations and third- and fourth-generation cephalosporins in NAUSP contributor hospitals, 2017–2021



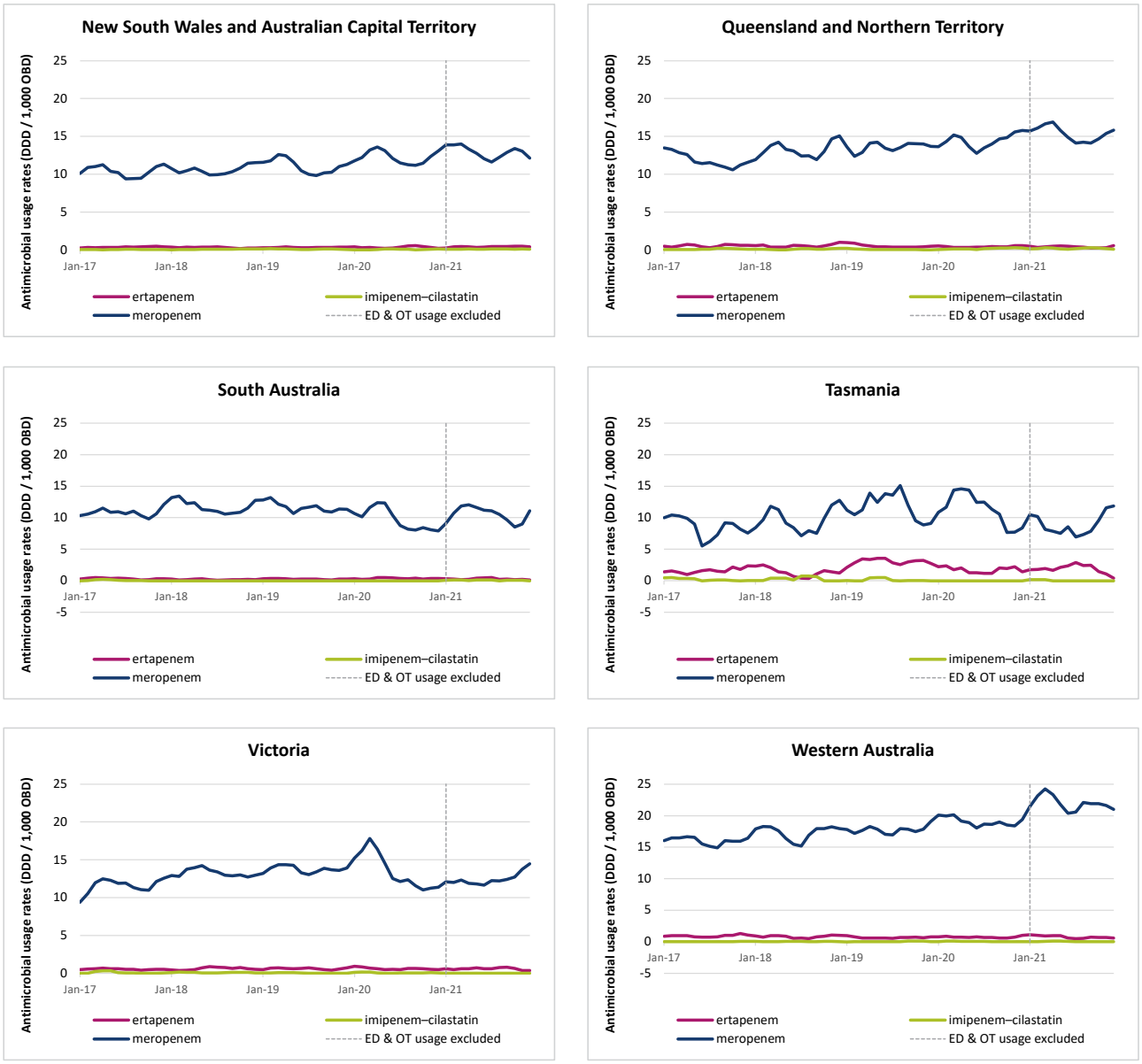
Note: Intravenous amoxicillin – clavulanic acid was registered in Australia in January 2017.[18]

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

Carbapenems – meropenem and ertapenem

Carbapenems have a very broad spectrum of activity and are reserved for treatment of serious or life-threatening infections. Carbapenem usage is increasing globally due to the spread of extended-spectrum ß-lactamase-producing bacteria which are resistant to most other antibacterials. The average monthly meropenem usage in 2021 ranged from 9.0 DDD / 1,000 OBD in Tasmania to 22.0 DDD / 1,000 OBD in Western Australia. Ertapenem and imipenem–cilastatin usage are negligible in NAUSP contributor hospitals. However, Tasmanian hospitals do use ertapenem with the average monthly inpatient use in 2021, being 1.9 DDD / 1,000 OBD (Figure 33).

Figure 33: Carbapenem usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2017–2021 (3-month moving average)



Note: Usage of doripenem and meropenem-vaborbactam are negligible and not shown.

DDD: defined daily dose; ED: emergency department; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days; OT: operating theatre.

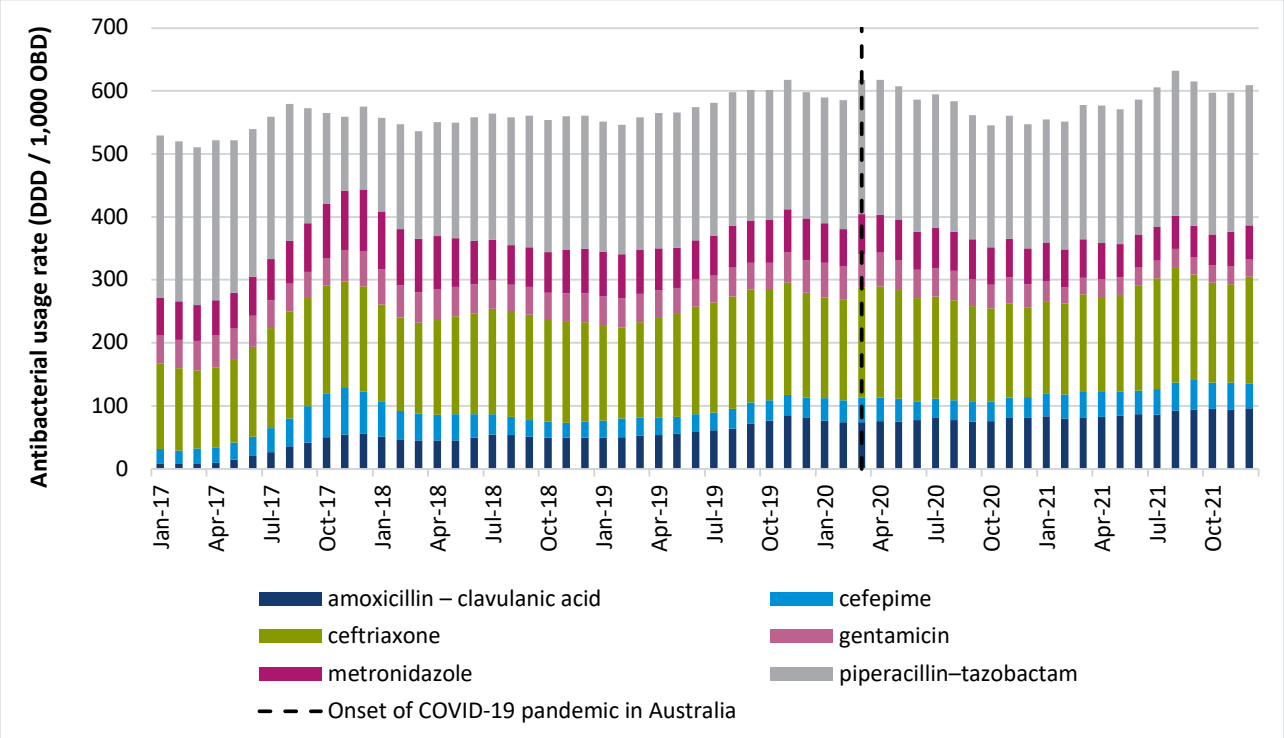
Impact of COVID-19

Despite international concerns regarding possible increased antimicrobial use during the COVID-19 pandemic, the AURA 2021 report showed a dramatic reduction in 2020 in community-dispensed Pharmaceutical Benefits Scheme listed antibiotics commonly used for upper respiratory tract infections.[19] In the hospital setting, there were initial market changes in antimicrobial usage observed in the initial stages of the pandemic (March-April, 2020), which was at least to some extent attributed to the establishment and stocking of new wards to accommodate COVID-19 patients, repurposing of some wards as additional emergency wards, and closure of some wards due to the suspension of elective surgery.

Large principal referral hospitals were the main custodians of care for COVID-19 patients requiring hospitalisation, and most patients requiring intensive care are treated in these large tertiary hospitals. A systematic review of antibacterial prescribing in the intensive care setting across 16 countries in the era of COVID-19 reported that an estimate of 30.8% of patients had a bacterial co-infection. However, many more received broad-spectrum antibacterial treatment, increasing the risk of adverse events and multi-drug resistant infections.[20]

Figure 34 illustrates the monthly usage of intravenous broad-spectrum antibacterials in the intensive care setting over the last 5 years in Australian principal referral hospitals. The onset of the COVID-19 pandemic in Australia at the beginning of March 2020 is illustrated by the dotted line.

Figure 34: Critical care use of intravenous broad-spectrum antibacterials used to treat bacterial pneumonia, Australian principal referral hospitals, 2017-2021



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

As seen in Figure 34, aggregate use of these broad-spectrum agents in the critical care setting has increased in 2020 and 2021. The average monthly usage rates for intravenous cefepime in 2019 was 29.7 DDD / 1,000 OBD in critical care, increasing by 37.0% to 40.6 DDD / 1,000 OBD in 2021. The average monthly piperacillin–tazobactam usage rate in critical care increased by 4% from 209.1 DDD / 1,000 OBD to 217.4 DDD / 1,000 OBD.

Usage rates for reserve-line antibacterials, 2017-2021

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, levofloxacin

Fluoroquinolone antibacterials have a broad-spectrum of activity and they are considered last-line antimicrobials given that, as a class, they are amongst the most likely to drive AMR. Resistance to fluoroquinolones is increasing rapidly, and in 2017 the percentage of fluoroquinolone non-susceptible *E. coli* included in AURA surveillance was 12.5%.[21] Ciprofloxacin is the most commonly used fluoroquinolone in Australian hospitals. Moxifloxacin is classified as a *Contain* antimicrobial in the Australian PAL[11] and usage is predominantly confined to large tertiary hospitals. Usage of levofloxacin, which is not registered for use in Australia, is negligible. Figure 35 shows fluoroquinolone usage rates in NAUSP contributor hospitals over the last 5 years.

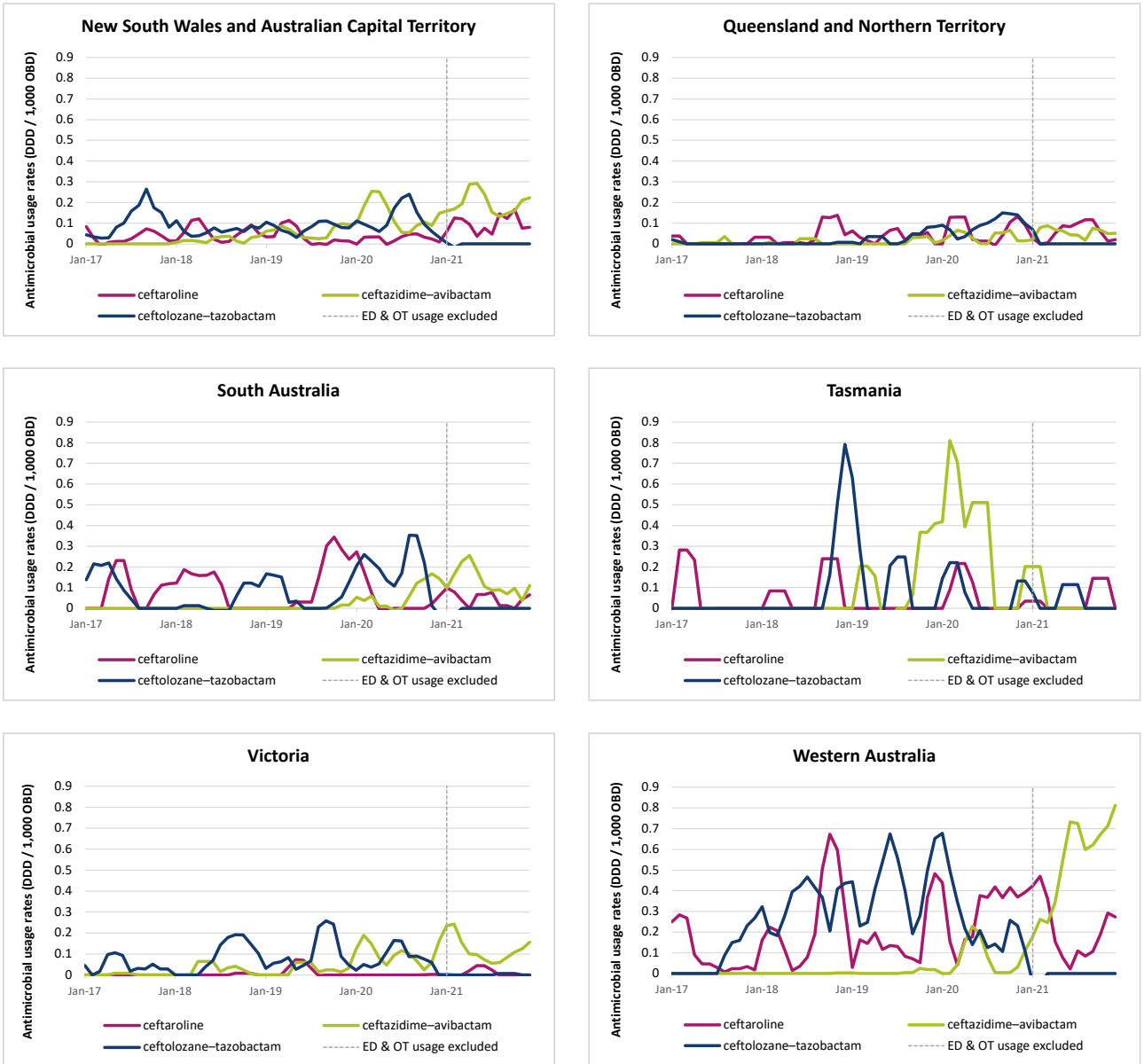
Figure 35: Fluoroquinolone usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2017–2021 (3-month moving average)

DDD: defined daily dose; ED: emergency department; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days; OT: operating theatre.

Ceftaroline, ceftazidime–avibactam, ceftolozane–tazobactam

Figure 36 shows the usage of reserve-line, newly introduced cephalosporins for each of the jurisdictions. Due to a product recall there was an Australia-wide (and global) shortage of ceftolozane–tazobactam from December 2020 to March 2022.[22] Although usage of these agents is generally low (<1.0 DDD / 1,000 OBD), prior to the shortage, usage of ceftolozane–tazobactam was increasing, particularly in Western Australia. Ceftazidime–avibactam was registered in Australia in February 2019, and usage remains low in NAUSP contributor hospitals. However, a substantial increase in usage was seen in Western Australia in 2021.

Figure 36: Reserve-line cephalosporin usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2017–2021 (5-month moving average)*



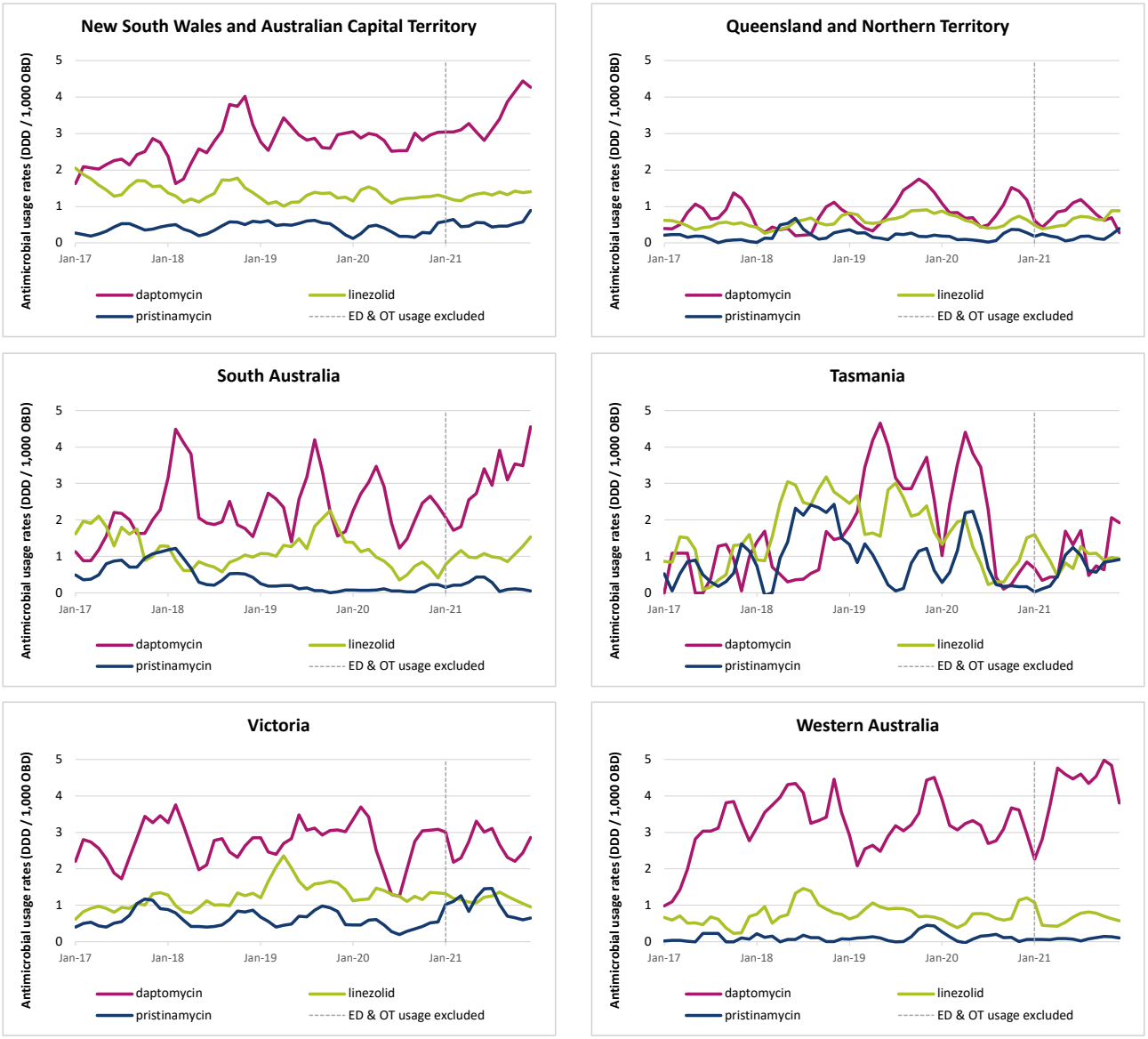
DDD: defined daily dose; ED: emergency department; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days; OT: operating theatre.

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

Daptomycin, linezolid, pristinamycin

Daptomycin, linezolid and pristinamycin should be reserved for the treatment of multi-drug resistant bacterial infections. Usage of pristinamycin, an oral streptogramin antimicrobial used for treatment of methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant enterococci (VRE), remains very low, with the average monthly usage rate in 2021 ranging from 0.08 DDD / 1,000 OBD in Western Australia to 1.0 DDD / 1,000 OBD in Victoria. Usage of daptomycin, a lipopeptide antibacterial with bactericidal activity against VRE and MRSA, is increasing, particularly in New South Wales / Australian Capital Territory, Western Australia and South Australia (Figure 37). In 2021 the average monthly usage rate for linezolid, a bacteriostatic antibacterial used to treat multi-drug resistant Gram-positive infections, including VRE and MRSA, was highest in New South Wales / Australian Capital Territory at 1.32 DDD / 1,000 OBD. Tedizolid is a new oxazolidinone with a similar spectrum of activity to linezolid and is available in both oral and parenteral form, but it is not registered for use in Australia and usage is negligible (and not shown here).

Figure 37: Daptomycin, linezolid and pristinamycin usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2017–2021 (5-month moving average)*



DDD: defined daily dose; ED: emergency department; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days; OT: operating theatre.

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

Colistin, fosfomycin, tigecycline

Colistin is a reserve-line polymyxin antibacterial, available as colistimethate sodium for intravenous usage. Usage is restricted to multi-drug resistant infections, treated under infectious disease / clinical microbiology oversight. In NAUSP contributor hospitals, usage of colistin is minimal, with average monthly usage in 2021 being below 0.1 DDD / 1,000 OBD across all states and territories. Fosfomycin is active against many multi-drug resistant Gram-negative bacteria, including extended spectrum ß-lactamase-producing isolates, and is reserved for treatment of multi-drug resistant urinary tract infections.[16] Usage of fosfomycin is highest in Western Australia, with the average monthly usage in 2021 being 0.21 DDD / 1,000 OBD. Tigecycline usage is very low in Australian hospitals; usage was 2-3 times higher in Tasmania than other jurisdictions. However, in 2021 usage dropped substantially, with the average monthly usage falling almost fivefold from 0.88 DDD / 1,000 OBD in 2020 to 0.18 DDD / 1,000 OBD in 2021 (Figure 38).

Figure 38: Colistin, fosfomycin and tigecycline usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2017–2021 (5-month moving average)*

Note: Colistin for nebulisation/inhalation is not included in the above rate calculations.
DDD: defined daily dose; ED: emergency department; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days; OT: operating theatre.

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

Topical antimicrobial usage in Australian hospitals

NAUSP data definitions were expanded in 2019 to include topical antimicrobials. Very few clinical situations require treatment with topical antibacterials.[23] Inappropriate topical antibacterial use is common postoperatively and is a focus of AMS. Topical antibacterials should not be used routinely on surgical wounds postoperatively, as their use contributes to the antimicrobial burden and increases the risk of AMR.[24] Inappropriate topical antimicrobial use is not uncommon in aged care, particularly for patients in residential aged care homes where topical antifungals are frequently overused for skin conditions, many of which may be incorrectly assumed to be candidiasis.

There are no DDDs for topical antimicrobials; topical usage is reported in this report as the number of grams of active ingredient per 1,000 OBD.

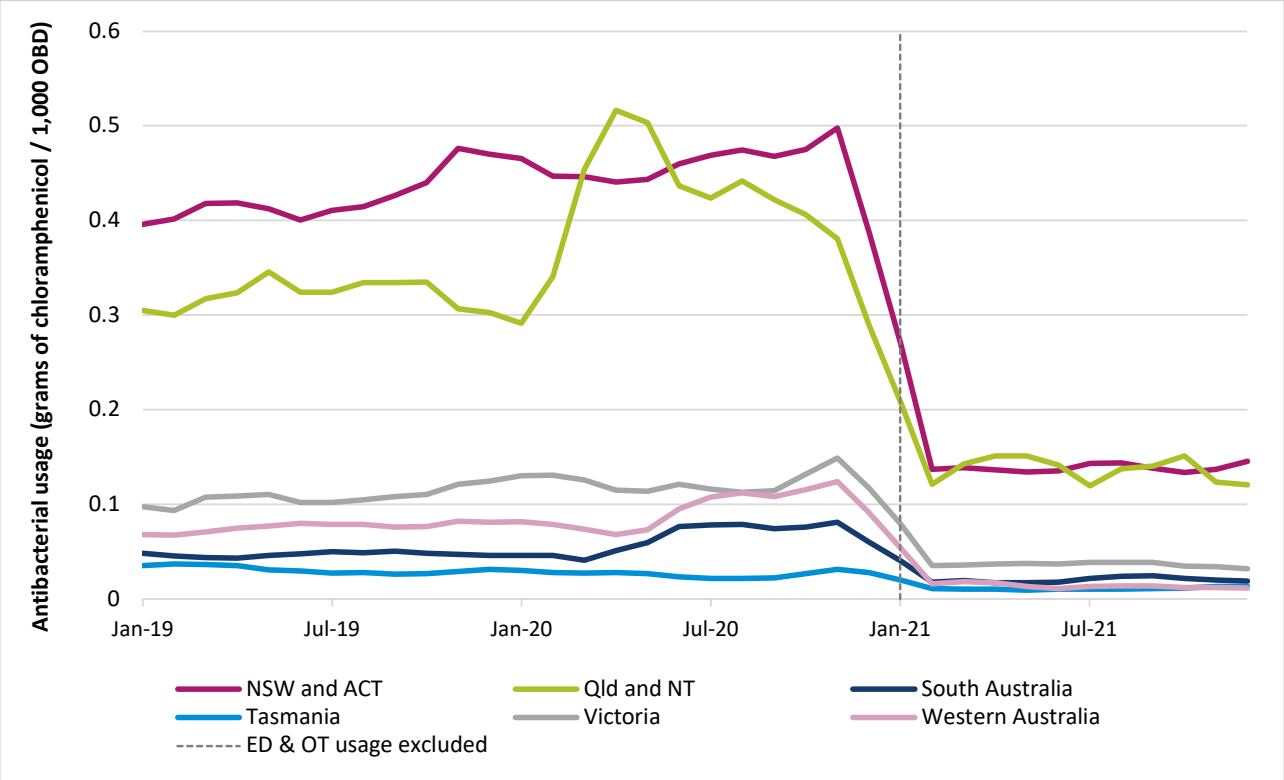
High-volume topical antimicrobials

This section provides the usage rates for some of the high-volume topical antimicrobials used in Australian hospitals for the 3-year period 2019 to 2021. From January 2021, ED and OT usage is reported separately from usage rates in other acute settings.

Chloramphenicol eye ointment

Topical chloramphenicol ointment is frequently used on surgical wounds despite this practice not being recommended in most circumstances. The exclusion of OT usage from other acute usage from January 2021 has illustrated the high proportionate use of this product in the theatre and recovery location (Figure 39). Outside of theatre, usage of chloramphenicol ointment is relatively low. (Note: One 4 g tube of 1% chloramphenicol ointment contains 0.04 g chloramphenicol).

Figure 39: Inpatient use of chloramphenicol 1% ointment (grams of active ingredient* / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2019-2021 (3-month moving average)

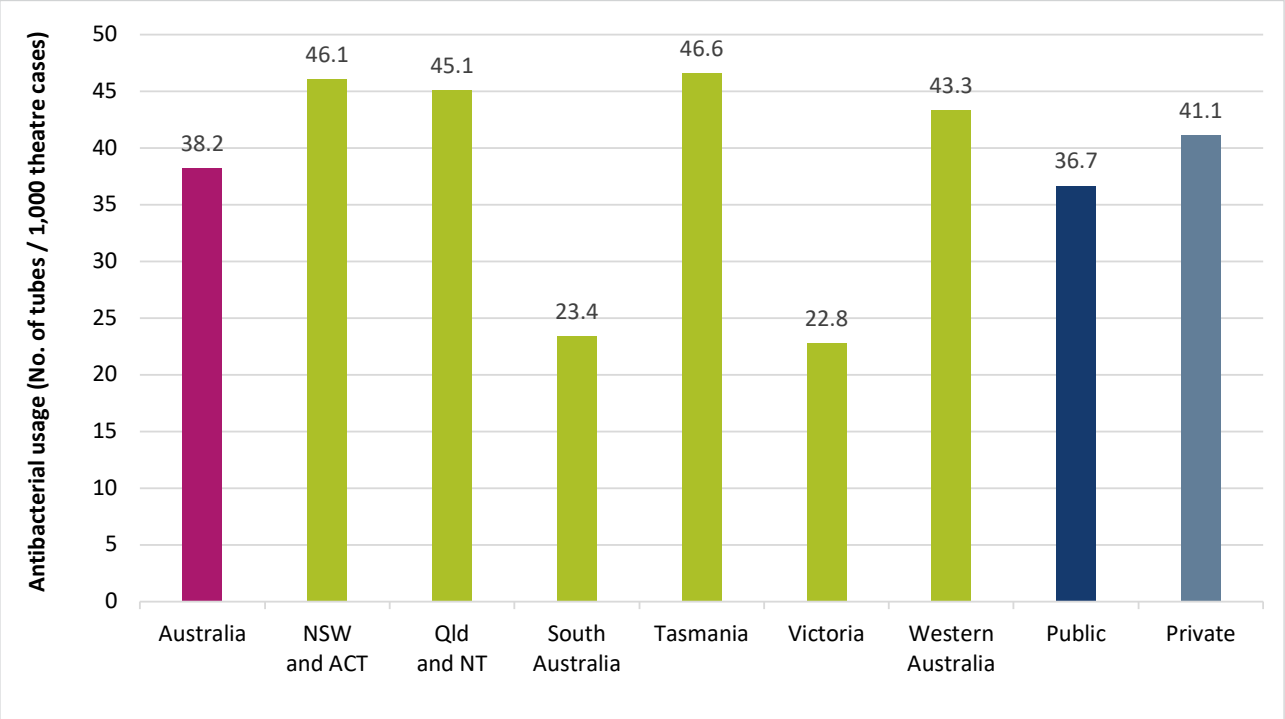


* 1 g of chloramphenicol is contained in 25 tubes of 4 g ointment 1%.

ED: emergency department; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days; OT: operating theatre.

Figure 40 illustrates the comparative rate of use of chloramphenicol 1% ointment (4 g tubes) in the OT and recovery setting between the states and territories. Nationally, the usage rate was 38 tubes of 1% ointment per 1,000 theatre cases. In New South Wales / Australian Capital Territory, Queensland / Northern Territory and Tasmania, the usage rate was over 45 tubes per 1,000 theatre cases. Usage was higher in private hospitals than public hospitals (41 versus 37 tubes per 1,000 theatre cases respectively).

Figure 40: Inpatient use of chloramphenicol 1% eye ointment (number of 4 g tubes / 1,000 theatre cases) in theatre and recovery, nationally, by state and territory and by public and private hospitals, 2021

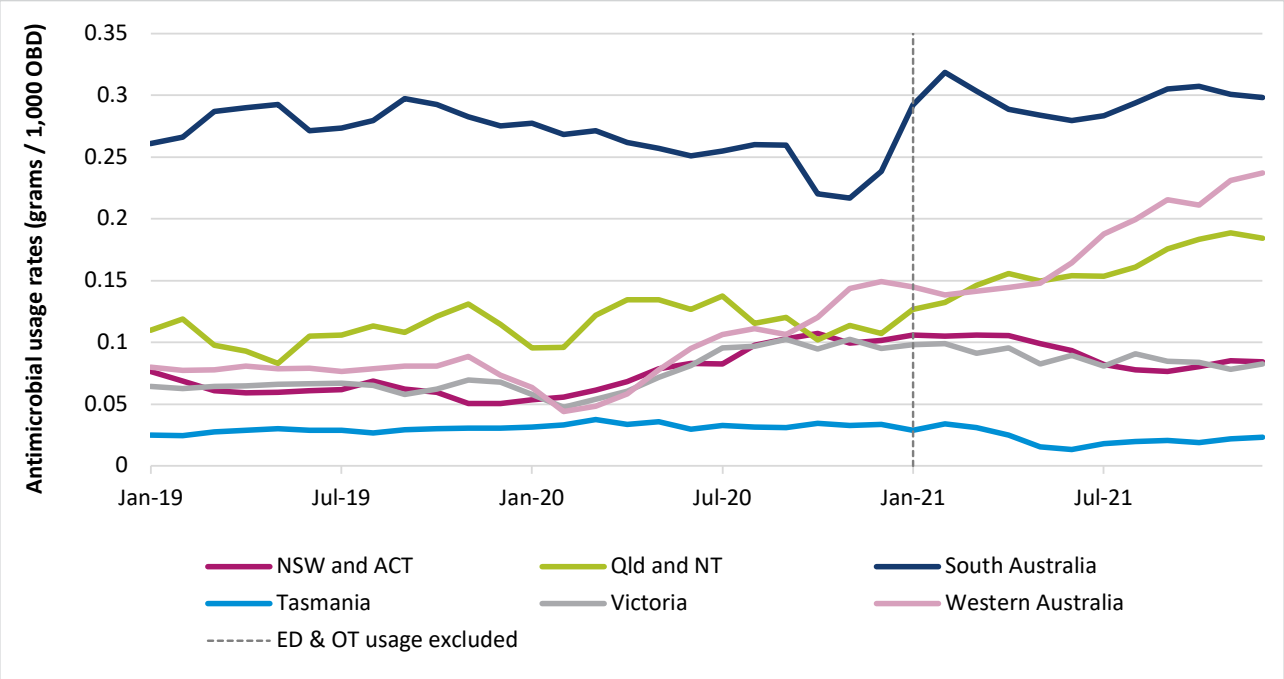


g = grams

Mupirocin

South Australia has the highest usage rate of topical mupirocin in the acute inpatient setting (Figure 41). With the exclusion of usage in the OT and ED locations from the acute aggregate rate in January 2021, a noticeable increase in the other acute usage was seen in Queensland / Northern Territory and Western Australia, illustrating that their proportionate use is higher in settings outside of OT and ED.

Figure 41: Annual usage of topical mupirocin (grams of active ingredient* / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2019-2021: total acute hospital usage rate¥



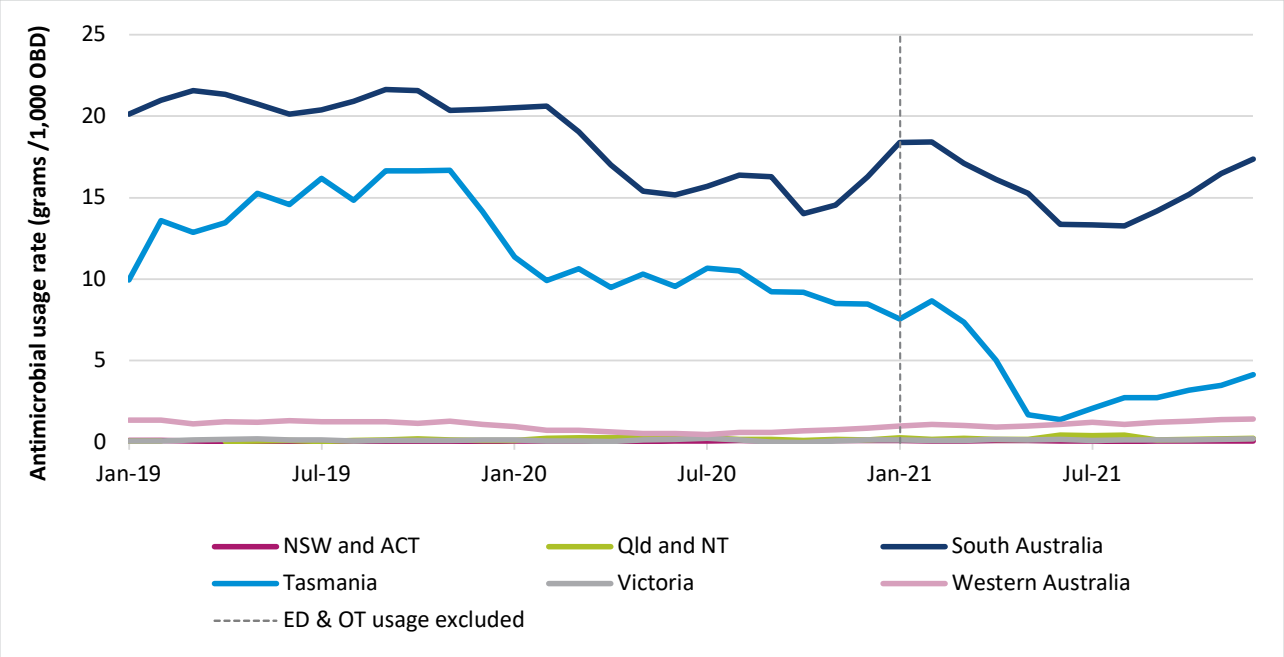
¥ Excludes emergency and operating theatre usage from January 2021, as indicated by dotted line.

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

ED: emergency department; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days; OT: operating theatre.

The monthly average use in critical care in 2021 was highest in South Australia (15.7 g of active ingredient / 1,000 OBD), equating to 785 g of 2% ointment (262 x 3 g tubes) per 1,000 OBD (Figure 42). This is almost 4 times the rate of usage in critical care in Tasmanian hospitals and over 100 times the monthly average usage in New South Wales / Australian Capital Territory and Victorian critical care units.

Figure 42: Annual usage of topical mupirocin (grams of active ingredient*/1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2019-2021: critical care



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

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

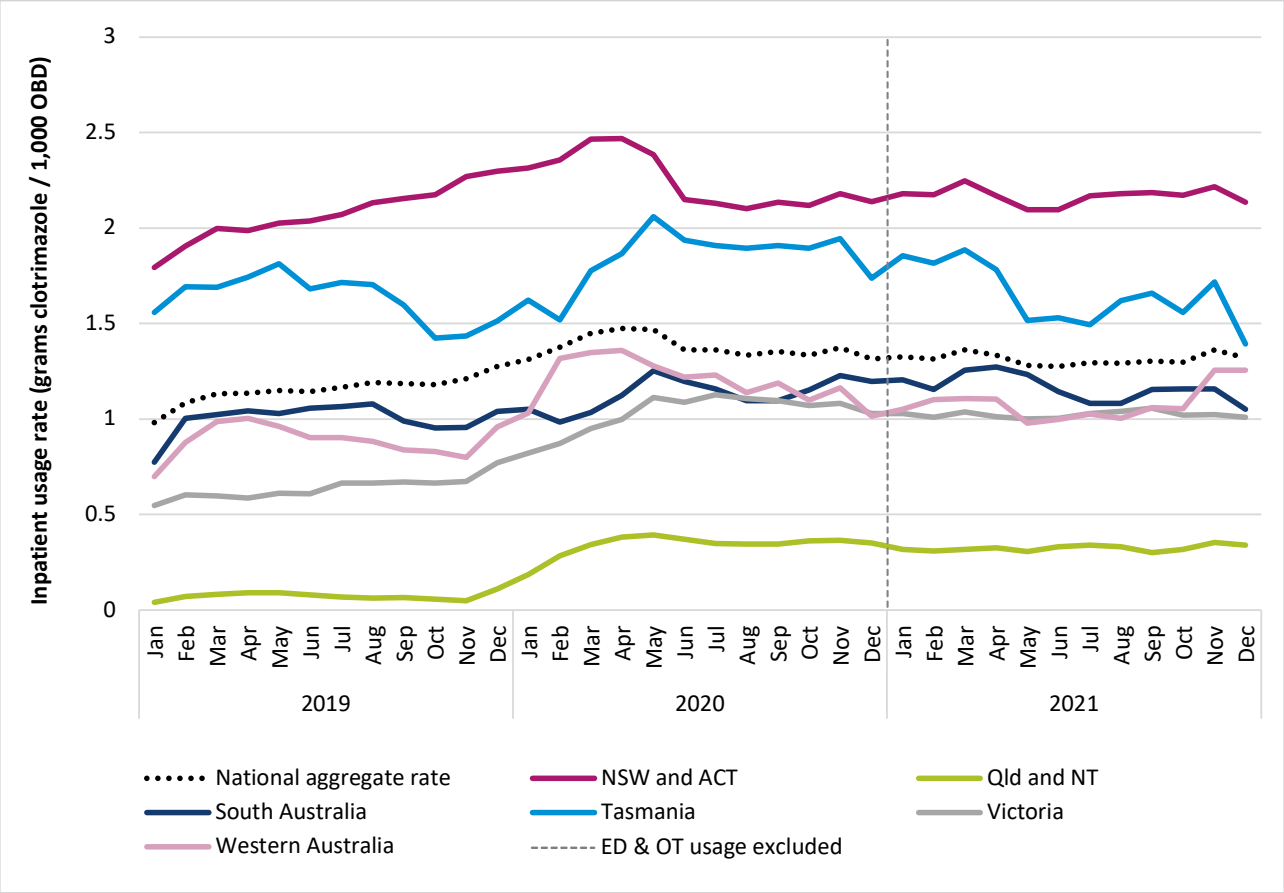
OT: Operating theatre

ED & OT usage excluded from Jan 2021

Clotrimazole and miconazole

The national aggregate inpatient monthly usage rate for topical clotrimazole lies between 1 g and 1.5 g / 1,000 OBD for clotrimazole, and just under 0.5 g / 1,000 OBD for miconazole. There is notable variation in the usage rates of these topical antifungals between the states and territories (Figure 43 and Figure 44). Queensland / Northern Territory has the highest usage rate for topical miconazole (threefold higher than national aggregate usage rate) and lower use of clotrimazole compared with other states. Differences in formulary listings in public hospitals may account for some of the variation between states. Clotrimazole usage is highest in New South Wales / Australian Capital Territory, closely followed by Tasmania.

Figure 43: Dermatological usage# of clotrimazole (grams of active ingredient* / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2019-2021 (3-month moving average)



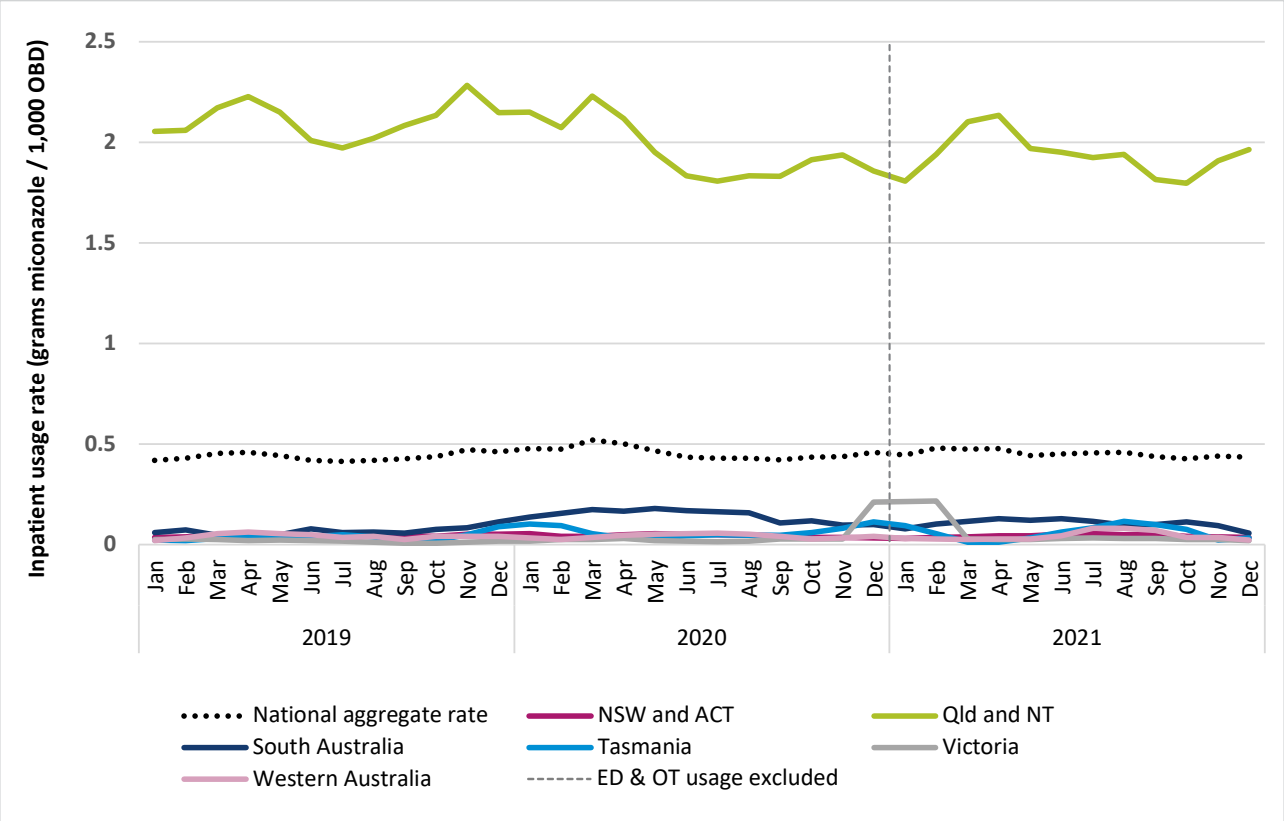
Excludes vaginal usage.

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

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

ED & OT usage excluded from Jan 2021.

Figure 44: Dermatological usage# of miconazole (grams of active ingredient* / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2019-2021 (3-month moving average)



Excludes vaginal usage. * 1 g of miconazole is contained in 50 g of 2% cream/ointment.
ED: emergency department; OBD: occupied bed days; NAUSP: National Antimicrobial Utilisation Surveillance Program.

Systemic antifungal use

Systemic antifungals are used for treatment and prophylaxis of invasive fungal infections, and the risk of invasive fungal infections is higher in immunocompromised individuals. The prevalence of immunosuppressed patients at risk of invasive fungal disease is increasing, resulting in increased use of antifungals.[25] Overuse and inappropriate use of antifungals in both humans and the environment is increasing the risk of resistant fungi emerging globally, particularly resistance to the azole class of antifungals.[26] This is associated with increased treatment costs and higher risk of mortality for patients with resistant fungal infections.[25]

National antifungal usage

In NAUSP contributor hospitals, inpatient systemic antifungal usage is predominantly in the critical care and haematology/oncology wards. In 2021, only 1.0% of antifungal use (by proportion of total DDDs used) was in the ED and 0.27% in the OT. The aggregate antifungal usage rate in acute hospital settings is shown in Table 9. For 2021, usage in the ED and OT is not included.

In 2021, the annual aggregate antifungal usage rate in all acute settings other than ED and OT in NAUSP contributor hospitals was 35.0 DDD / 1,000 OBD (Table 9). This aggregate rate was a marginal increase from 2020 (34.6 DDD / 1,000 OBD), although it is noted that the 2020 aggregate rate included ED and OT.

Table 9: Annual antifungal usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, 2017–2021

Antifungal	Aggregate usage rate (DDD / 1,000 OBD)					2021 Mean usage rate¥	95% CI (2021)	
	2017	2018	2019	2020	2021¥			
Amphotericin B	0.11	0.12	0.14	0.18	0.13	0.07	-0.05	0.19
Amphotericin, lipid complex	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Amphotericin, liposomal*	0.85	0.97	1.01	0.87	1.00	0.44	0.32	0.57
Anidulafungin	1.14	1.56	1.58	1.46	1.60	0.78	0.54	1.02
Caspofungin	0.43	0.34	0.25	0.61	0.77	0.46	0.32	0.60
Fluconazole	17.37	17.95	17.97	18.45	18.72	12.48	10.32	14.64
Flucytosine	0.14	0.14	0.15	0.15	0.14	0.07	0.04	0.09
Griseofulvin	0.03	0.14	0.14	0.11	0.12	0.29	-0.04	0.62
Isavuconazole	0.01	0.01	0.01	0.02	0.04	0.02	0.00	0.03
Itraconazole	2.92	2.42	2.43	2.91	2.58	1.40	0.11	2.69
Ketoconazole	0.10	0.07	0.05	0.06	0.08	0.03	0.01	0.06
Micafungin	0.09	0.15	0.20	0.21	0.26	0.11	0.04	0.19
Posaconazole	4.73	5.23	5.63	5.85	6.04	2.55	1.72	3.39
Terbinafine	0.82	0.84	0.83	0.97	0.98	0.95	0.65	1.25
Voriconazole	2.57	2.64	2.68	2.74	2.58	1.35	0.97	1.73
Total	**31.34**	**32.58**	**33.06**	**34.59**	**35.02**	**21.00**	**17.03**	**24.98**

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

¥ Usage rates in 2021 exclude emergency department and operating theatre.

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

Triazole antifungals (fluconazole, itraconazole, isavuconazole, ketoconazole, posaconazole and voriconazole) accounted for 85.6% of systemic antifungal use in NAUSP contributor hospitals in 2021. Fluconazole remains the most used systemic antifungal in NAUSP contributor hospitals, comprising more than half the total aggregate antifungal usage. Posaconazole use has increased annually over the last 5 years; in 2021 posaconazole usage comprised 17.2% of the systemic antifungal inpatient use in NAUSP contributor hospitals.

Usage of echinocandins (anidulafungin, caspofungin and micafungin) and liposomal amphotericin has trended upwards nationally over the last 5 years.

Antifungal usage in Australian hospitals by state and territory

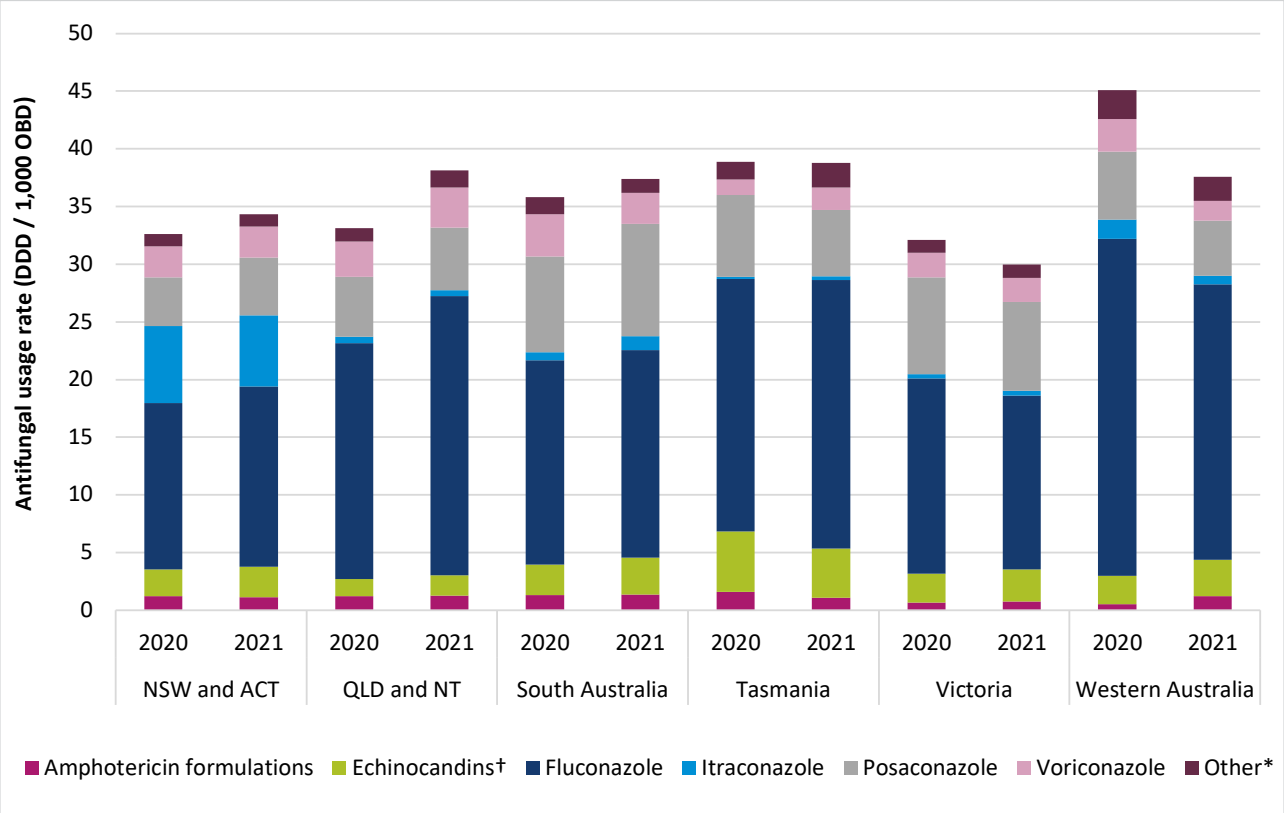
Excluding usage in the ED and OT (where antifungal use is minimal), systemic antifungal usage rates increased in 2021 compared to 2020 in New South Wales / Australian Capital Territory, Queensland / Northern Territory, and South Australia by 5.0%, 13.2%, and 4.3%, respectively (Figure 45).

Fluconazole is the predominant driver of the change in annual antifungal usage rates, as seen in these states and territories. The exclusion of ED usage from the reported total hospital antifungal usage rates in 2021 may have accounted for some of this change. Excluding usage in ED and OT, Tasmania reported the highest total systemic antifungal usage rate in 2021 at 38.8 DDD / 1,000 OBD.

There continues to be notable differences between states and territories in the antifungal agents used. Analysis of acute usage rates in 2021, excluding the small proportion of usage in ED and OT, found:

- The inpatient usage rate for itraconazole remained high in New South Wales / Australian Capital Territory; the aggregate annual usage rate was 6.2 DDD / 1,000 OBD, which was nearly ninefold higher than the average usage rate in other states (0.64 DDD / 1,000 OBD).
- Fluconazole use in 2021 was highest in Queensland / Northern Territory at 24.2 DDD / 1,000 OBD, closely followed by Western Australia at 23.9 DDD / 1,000 OBD and Tasmania at 23.3 DDD / 1,000 OBD. The exclusion of ED usage from total acute aggregate rates in 2021 may account for the substantial decrease in fluconazole usage rates in other acute inpatient settings in Victoria and Western Australia.
- Posaconazole is the second highest systemic antifungal used in the acute inpatient setting after fluconazole, with South Australia reporting the highest usage rate in 2021 at 9.7 DDD / 1,000 OBD.
- The relative annual usage of voriconazole also decreased substantially by (38.2%) in Western Australia, as compared with 2020. Some of this decrease in the acute aggregate inpatient usage rate may be accounted for with the stratification of ED and OT usage from January 2021. However, usage of voriconazole in ED and OT in general is low, accounting for only 1.1% of total hospital usage by total volume (DDDs). A similar decrease was observed in South Australia, where the annual voriconazole usage rate was 2.7 DDD / 1,000 OBD - a decrease of 27.5% compared with 2020.
- Tasmanian contributors reported the highest aggregate usage rate for echinocandins in 2021 (4.25 DDD / 1,000 OBD), although this was a decrease compared to the reported usage rate in 2020 (5.2 DDD / 1,000 OBD). Annual usage rates for echinocandins trended upwards in 2021 compared with 2020 in all the other states and territories.

Figure 45: Antifungal usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, 2020–2021



† 'Echinocandins' includes anidulafungin, caspofungin and micafungin.

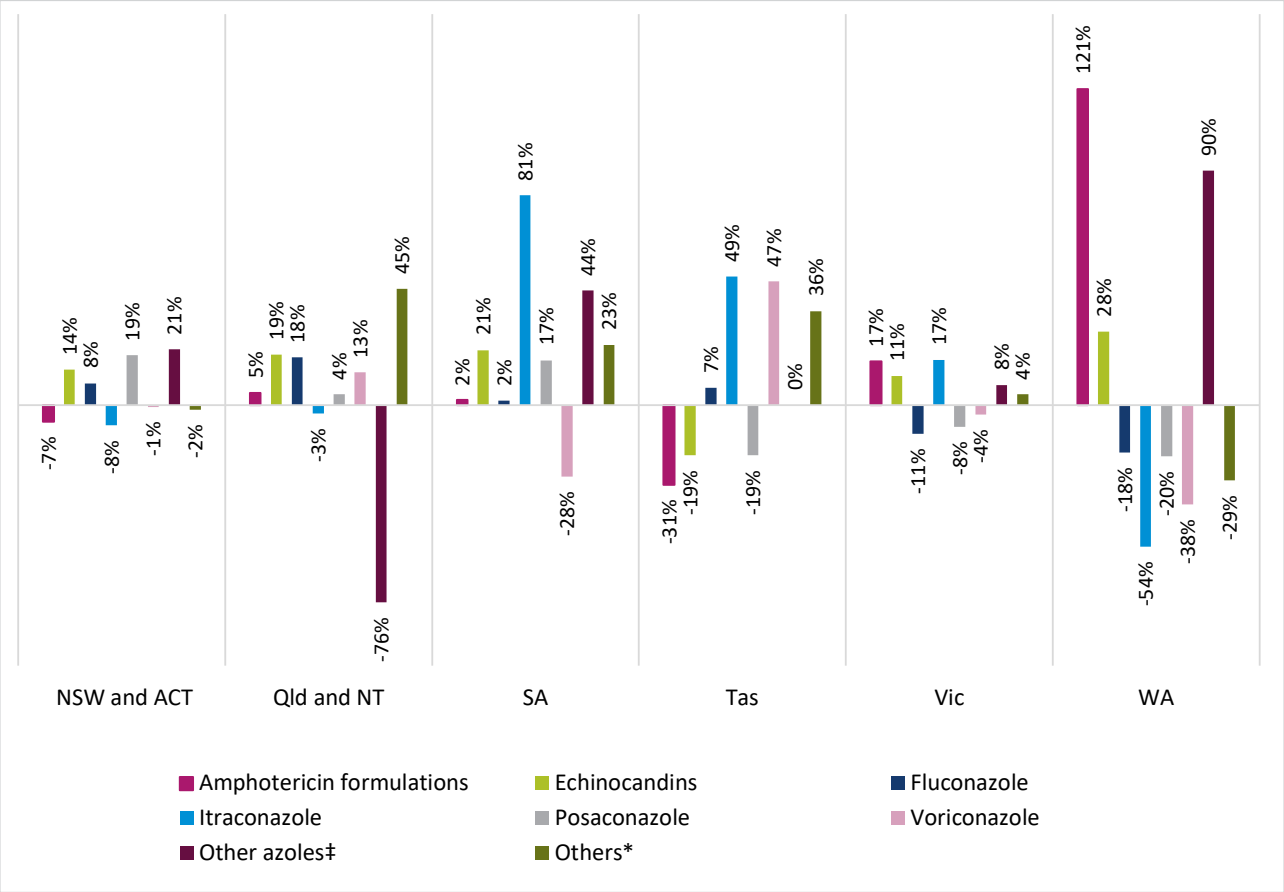
* 'Other' comprises flucytosine, griseofulvin, isavuconazole, ketoconazole and terbinafine.

Note: Usage rates in 2021 exclude emergency department and operating theatre.

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

Figure 46 shows the relative change observed in annual antifungal use in 2021 compared with 2020, by antifungal agent or class, across the states and territories. The exclusion of ED and OT from 2021 rates may account for some of the change; however, systemic antifungal usage in ED and OT is minimal.

Figure 46: Percent change in annual antifungal usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals, by state and territory, in 2021 compared with 2020



† 'Echinocandins' includes anidulafungin, caspofungin and micafungin.

‡ 'Other azoles' include isavuconazole and ketoconazole.

* 'Others' comprises flucytosine, griseofulvin and terbinafine.

Note: Usage rates in 2021 exclude emergency department and operating theatre.

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

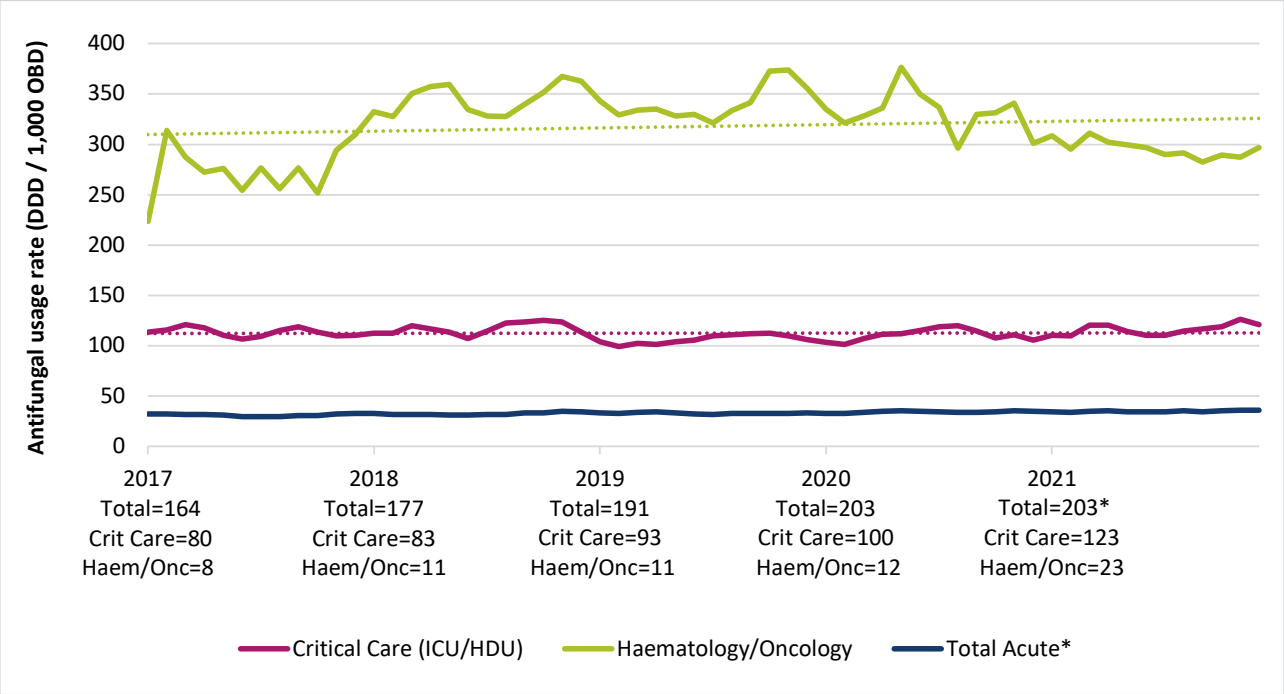
Antifungal usage in critical care, haematology/oncology, and total hospital

Figure 47 shows the use of antifungal agents in the inpatient haematology/oncology and critical care settings compared with usage in other acute settings, excluding ED and OT. The number of hospitals contributing stratified data for these locations is shown in Table 10.

Specialist oncology wards use antifungals both prophylactically for immunocompromised patients and for treatment of invasive fungal disease. Monthly usage rates for the 5-year period 2017-2021 were on average almost 10 times higher in haematology/oncology units compared with overall hospital usage.

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 47: Antifungal usage rates (DDD / 1,000 OBD) in NAUSP contributor hospitals (total hospital, critical care and haematology/oncology), 2017–2021 (3-month moving average)



* Includes all other acute care locations, excluding emergency department and theatre from 2021.
Note: Dotted lines included to indicate linear trends.

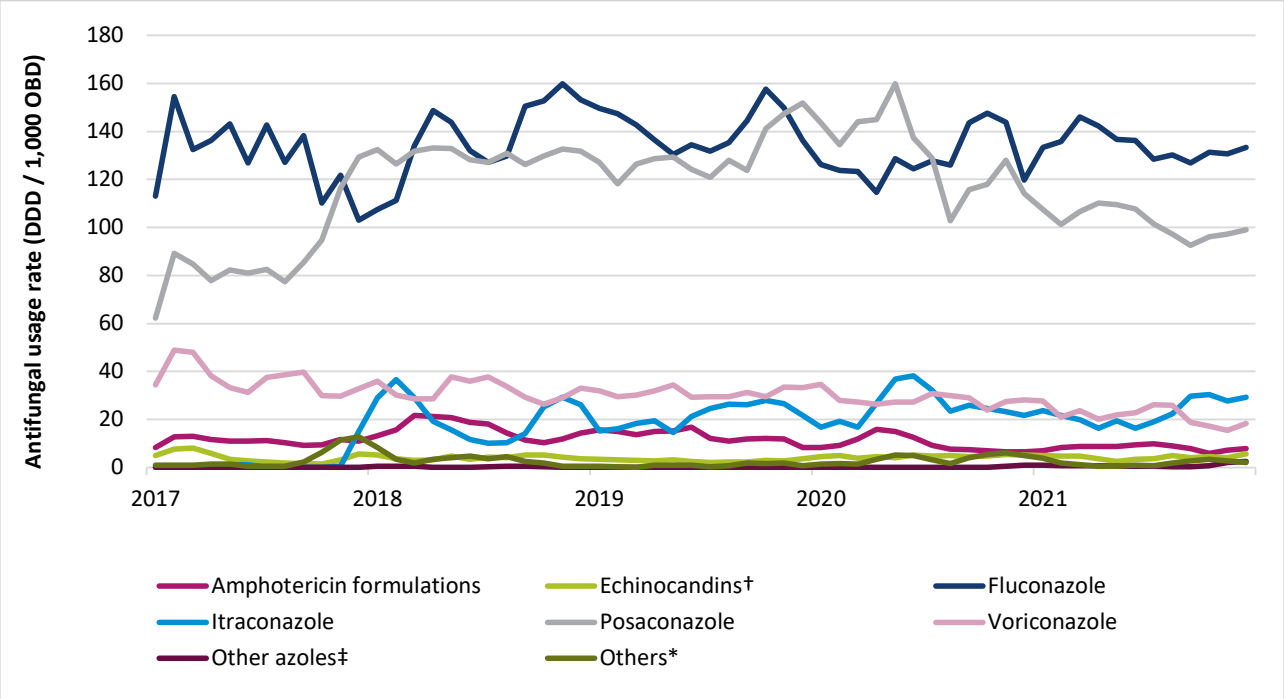
DDD: defined daily dose; ICU: intensive care unit; HDU: high dependency unit; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

Table 10: Number of contributors submitting location-specific data for critical care and haematology/oncology, 2017-2021

	Contributors for critical care					Contributors for haematology/oncology				
Peer group	**2017**	**2018**	**2019**	**2020**	**2021**	**2017**	**2018**	**2019**	**2020**	**2021**
Principal referral	26	27	27	27	27	5	7	7	7	11
Public Acute Group A	37	36	39	41	52	2	2	2	2	6
Public Acute Group B	4	7	8	9	16	0	0	0	0	0
Public Acute Group C	0	0	1	0	1	0	0	0	1	0
Private Acute Group A	4	5	8	11	13	2	2	2	2	6
Private Acute Group B	5	6	7	9	11	0	0	0	0	0
Private Acute Group C	1	1	2	2	3	0	0	0	0	0
National	**77**	**82**	**92**	**99**	**123**	**9**	**11**	**11**	**12**	**23**

Figure 48 illustrates the antifungal usage in haematology/oncology inpatient units, by class or agent. Fluconazole and posaconazole remain the predominant antifungal agents used in this setting, comprising 80% (combined) of the total antifungal usage rate in 2021.

Figure 48: Aggregate antifungal usage rates (DDD / 1,000 OBD) in haematology/oncology specialty units in NAUSP contributor hospitals, by agent or class, 2017–2021 (3-month moving average)



† 'Echinocandins' includes anidulafungin, caspofungin and micafungin.

‡ 'Other azoles' comprises isavuconazole and ketoconazole.

* 'Others' comprises flucytosine, griseofulvin and terbinafine.

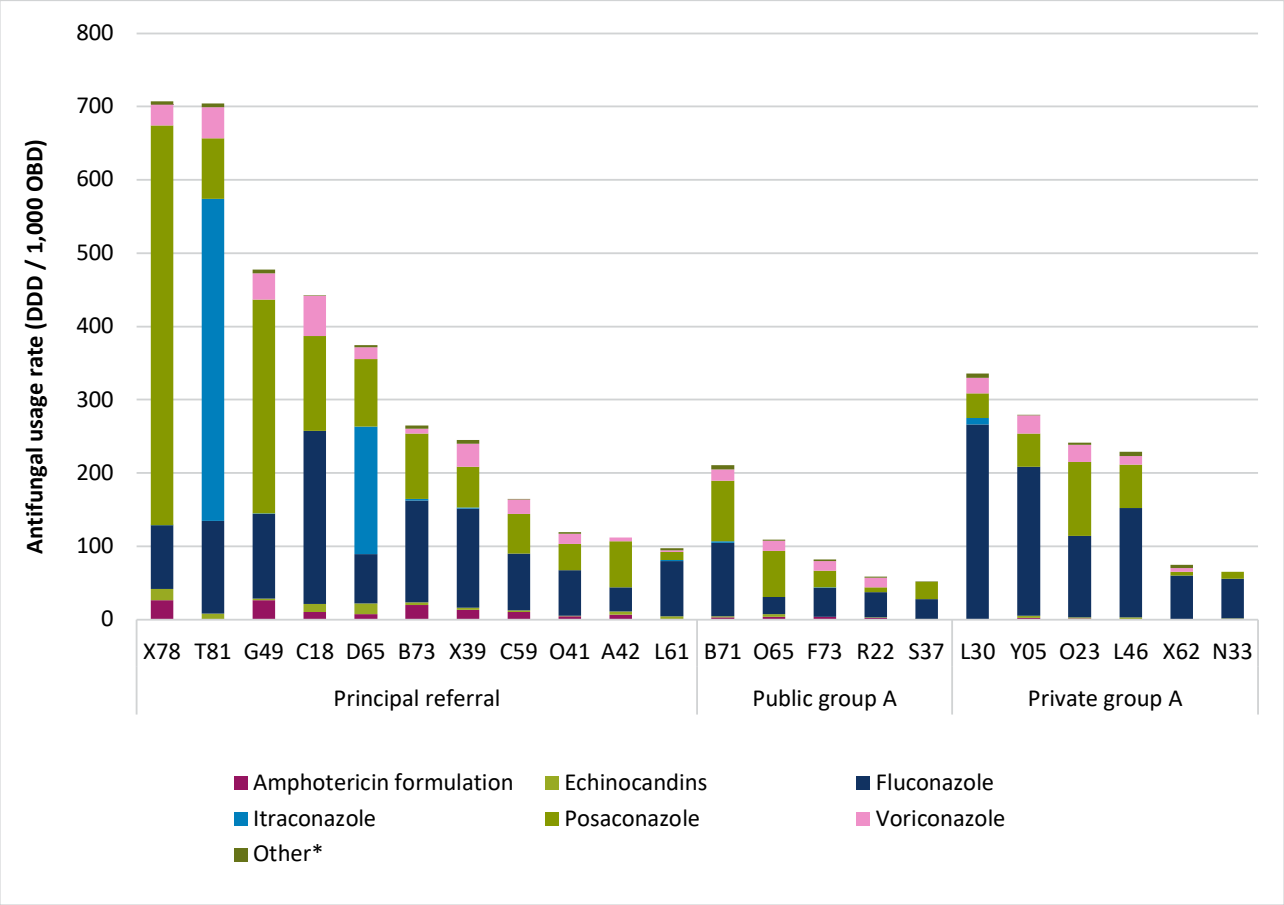
DDD: defined daily dose; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days.

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 49 shows the variation in the usage rates for different antifungal agents between hospitals submitting data for haematology/oncology wards, by AIHW peer group. A high variability in usage rate for posaconazole and itraconazole was driven by a few contributors in certain states. Itraconazole is predominantly used by hospitals performing organ transplants for antifungal prophylaxis in transplant patients.

Figure 49: Annual antifungal usage rate (percent of total) in haematology/oncology specialty units in NAUSP contributor hospitals, by agent or class, 2021



† 'Echinocandins' include anidulafungin, caspofungin and micafungin.

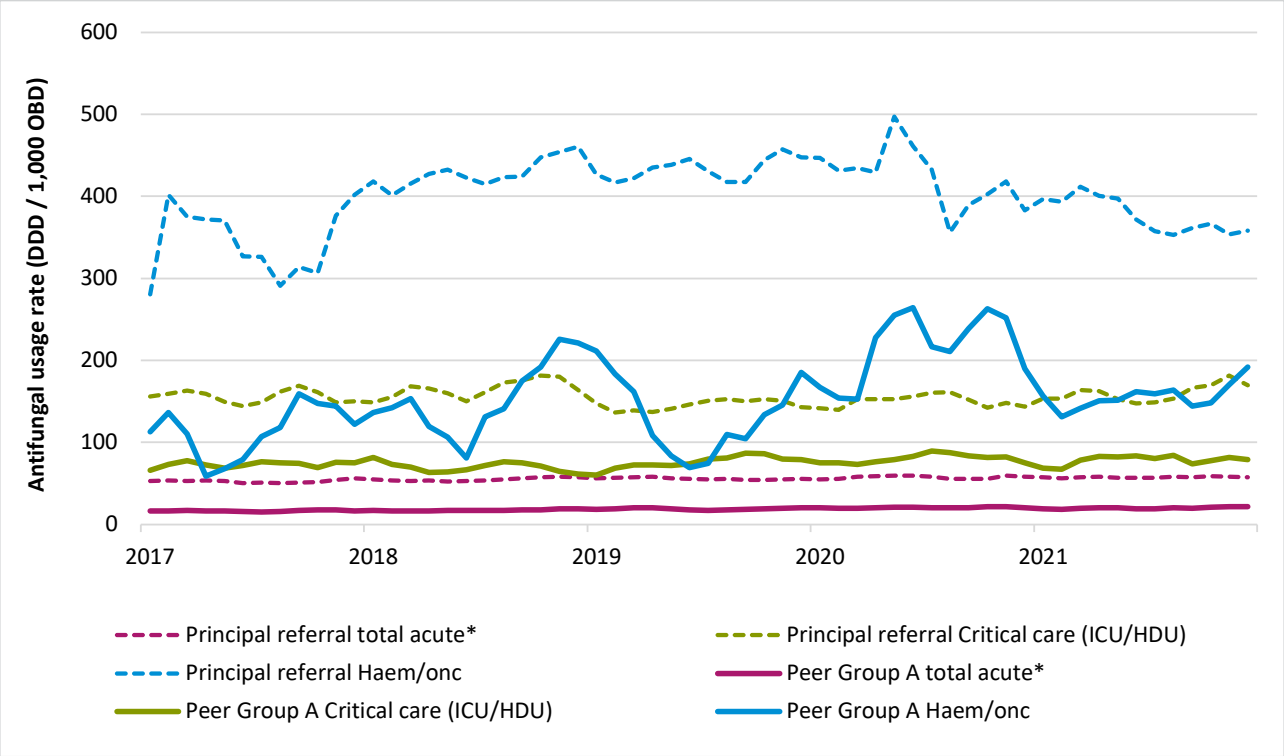
‡ 'Other azoles' comprises isavuconazole and ketoconazole.

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

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

Figure 50 illustrates systemic antifungal usage rates in principal referral and Acute Group A hospitals, showing the usage in critical care (ICU/HDU) and haematology/oncology units compared with 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 peer Group A (public and private combined) hospitals, which is to be expected given the higher acuity patients in the principal referral sites.

Figure 50: Antifungal usage rates (DDD / 1,000 OBD) in principal referral hospitals and Peer Group A hospitals contributing to NAUSP (total hospital, critical care (ICU/HDU) and haematology/oncology), 2017–2021 (3-month moving average)



DDD: defined daily dose; haem/onc: haematology/oncology; NAUSP: National Antimicrobial Utilisation Surveillance Program; OBD: occupied bed days; ICU: intensive care unit; HDU: high dependency unit

*Emergency Department and Operating Theatre use not included from January 2021

Discussion and conclusions

Hospital AMS programs require an accurate measure of antimicrobial use across a variety of clinical settings, including inpatient and day-only patient. In addition, for accurate benchmarking between hospitals, an appropriate denominator representing hospital activity in a particular setting is required. The changes implemented to NAUSP at the beginning of 2021 were aimed at increasing the participation of hospitals in the program and enabling previously excluded sites (such as sub-acute healthcare facilities and day-only surgical centres) to monitor their antimicrobial use. Although antimicrobial usage from sub-acute settings is not included in public reporting, expansion of NAUSP at the beginning of 2021 has allowed many hospitals to submit sub-acute data to allow them to run usage reports to support their AMS initiatives in expanded settings. In 2021, 84 hospitals were registered to submit data for rehabilitation - 30 in palliative care, 79 in mental health and 15 for sub-acute aged care wards. In addition, 72 hospitals registered to submit usage data for HITH. The rapid uptake of this expansion of surveillance has illustrated the desire of healthcare facilities to measure their antimicrobial usage in settings that were previously considered less of a stewardship focus. However, publications in recent years have demonstrated substantial inappropriate antimicrobial use in aged care settings outside of hospital. It is hoped that enabling hospitals to monitor use in this setting will help improve prescribing.

Stratification of ED and OT usage at the beginning of 2021 saw a substantial drop in the national aggregate antibacterial usage rates. The increasing participation of hospitals with a high proportion of day procedures relative to inpatient procedures was raising concerns that benchmarking usage rates was not appropriate due to differences in overnight stays. In addition, many smaller and remote hospitals have joined NAUSP over recent years, and many of them have EDs where patients are treated but very rapidly transferred to larger sites. Settings where there is frequent antimicrobial use without keeping patients overnight are not amenable to utilising OBD as a measure of activity in that setting. Reported NAUSP usage rates are a surrogate for actual patient consumption. While the change in denominator limits the ability to compare usage with recent years, going forward it is anticipated that redefining the data definitions will better reflect acute inpatient use and allow more robust benchmarking. The separation of theatre and emergency from other acute care also optimises analysis of usage using the PAL. Analysis of 2021 data has highlighted a concerning proportionate amount of *Curb* antibacterial use, particularly in private hospitals. Potential reasons for higher rates of inappropriate prescribing in private hospitals include less onsite access to infectious diseases expertise and less resourcing for AMS education and training compared with public hospitals.

At federal level, there is opportunity to facilitate access to monthly standardised surgical procedure data to assist benchmarking of antimicrobial usage in the OT. Approximately one-quarter of hospitalisations in Australia involve surgery, with private hospitals performing slightly more than half (59%) of all surgeries.[27] Inappropriate usage of antimicrobials for surgical prophylaxis is a focus area for AMS. Use of theatre case numbers as a denominator for antimicrobial usage rates in theatre is aimed at facilitating benchmarking relative to the number of procedures rather than relative to the proportion of patients that stay overnight, which is represented by the OBD metric. Despite this, many NAUSP contributor hospitals have experienced difficulties in obtaining theatre case numbers, and there is wide variation between sites regarding which procedures are included as theatre cases.

Systemic antifungal usage in Australian hospitals continues to increase annually. Some of the increased usage may be attributed to the increasing prevalence of patients on immunosuppressive treatments, with the consequent increased risk of invasive fungal disease. Antifungal resistance is an increasing concern, particularly with the emergence of multi-drug resistant fungi such as *Candida auris*. Recently published Australian consensus guidelines for antifungal stewardship have emphasised the importance of educational strategies to improve antifungal prescribing, including post-prescription review and feedback. The variation between large tertiary hospitals may be attributed to the different casemix - for example, some organ transplants are performed by a very small subset of principal referral hospitals.

However, even for hospitals that do have similar casemix and acuity, wide variation in the use of some agents is difficult to explain without local knowledge. This report, as well as regularly published benchmarking reports, can and should be used to highlight and investigate substantial variations in practice.

Appendix 1: Contributors

Table A1: Hospitals that contributed data included in the analyses for the National Antimicrobial Utilisation Surveillance Program Annual Report 2021

State or territory	Hospital		
New South Wales	Armidale hospital	Bellinger River District hospital	Belmont hospital
	Blacktown hospital	Blue Mountains hospital	Bowral hospital
	Campbelltown hospital	Canterbury hospital	Cessnock District hospital
	Chris O'Brien Lifehouse	Coffs Harbour hospital	Concord hospital
	Deniliquin hospital	Dubbo Base hospital	Fairfield hospital
	Forbes District hospital	Glen Innes District hospital	Gloucester Soldier's Memorial hospital
	Gosford hospital	Gosford Private hospital	Grafton Base hospital
	Griffith Base hospital	Gunnedah hospital	Hornsby Ku-Ring-Gai hospital
	Inverell District hospital	John Hunter hospital	Kareena Private hospital
	Kempsey District hospital	Lismore Base hospital	Lithgow hospital
	Liverpool hospital	Macksville District hospital	Maitland hospital
	Milton-Ulladulla hospital	Mona Vale hospital	Moree hospital
	Mount Druitt hospital	Mudgee District hospital	Muswellbrook hospital
	Narrabri hospital	Nepean hospital	Nepean Private hospital
	Newcastle Mater	Northern Beaches hospital	Orange Health Service
	Port Macquarie Base hospital	Prince of Wales hospital	Royal North Shore hospital
	Royal Prince Alfred hospital	Ryde hospital	Scott Memorial hospital
	Shellharbour hospital	Shoalhaven hospital	Singleton District hospital
	St George hospital	St Vincent's hospital Sydney	Sutherland hospital
	Sydney Adventist hospital	Tamworth hospital	The Tweed hospital
	Wagga Wagga Base hospital	Westmead Private hospital	Wollongong hospital
	Wyong hospital		
Australian Capital Territory	Calvary Public hospital Bruce	Canberra hospital	
Queensland	Atherton hospital	Buderim Private hospital	Bundaberg hospital
	Caboolture hospital	Gladstone hospital	Gold Coast University hospital
	Greenslopes hospital	Gympie Health Service	Hervey Bay hospital
	Innisfail hospital	Ipswich hospital	Kingaroy hospital
	Logan hospital	Mackay Base hospital	Mareeba hospital
	Maryborough hospital	Mater hospital Brisbane	Mater Mackay
	Mater Mother's hospital	Mater Private hospital Brisbane	Mater Private hospital Springfield
	Mater Redland Private	Mater Rockhampton	Mount Isa hospital
	Nambour General hospital	Queen Elizabeth 2 Jubilee hospital	Redland hospital
	Robina hospital	Rockhampton hospital	Royal Brisbane and Women's hospital
	St Andrew's War Memorial hospital	St Stephen's hospital Hervey Bay	St Vincent's Private hospital Brisbane
	St Vincent's Private hospital Northside	Stars – Surgical Treatment and Rehabilitation Services	Sunshine Coast University hospital
	Toowoomba hospital	Townsville hospital	Warwick hospital
	Wesley hospital		

State or territory	Hospital		
Northern Territory	Alice Springs hospital	Darwin Private hospital	Gove District hospital
	Katherine District hospital	Palmerston Regional hospital	Royal Darwin hospital
	Tennant Creek hospital		
South Australia	Berri hospital	Calvary Adelaide Private hospital	Calvary North Adelaide Private hospital
	Flinders Medical Centre	Flinders Private hospital	Gawler Health Service
	Lyell McEwin hospital	Memorial hospital	Modbury hospital
	Mount Barker District Memorial hospital	Mount Gambier hospital	Noarlunga hospital
	Port Augusta hospital	Port Lincoln hospital	Queen Elizabeth hospital
	Royal Adelaide hospital	St Andrew's hospital	
Tasmania	Launceston General hospital	North West Regional hospital	Royal Hobart hospital
Victoria	Albury Wodonga - Albury hospital	Albury Wodonga - Wodonga hospital	Angliss hospital
	Austin hospital	Ballarat Base hospital	Bendigo hospital
	Box Hill hospital	Cabrini Brighton hospital	Cabrini Malvern hospital
	Casey hospital	Central Gippsland Health	Dandenong hospital
	Frankston hospital	Geelong hospital	Holmesglen Private hospital
	Maroondah hospital	Mersey Women's hospital	Monash Medical Centre
	Monash Moorabbin hospital	Peter MacCallum Cancer Centre	Rosebud hospital
	Royal Melbourne hospital	South Eastern Private hospital	St John of God Geelong hospital
	St Vincent's hospital Melbourne	St Vincent's Private East Melbourne hospital	St Vincent's Private Fitzroy hospital
	St Vincent's Private hospital Kew	St Vincent's Private hospital Werribee	Swan Hill District Health
	The Northern hospital	Warrnambool Base hospital	Werribee Mercy hospital
	West Gippsland hospital	Western Health Footscray hospital	Western Health Sunshine hospital
Western Australia	Albany hospital	Armidale Kalamunda Group	Bentley Health Service
	Broome hospital	Bunbury Regional hospital	Busselton Health
	Derby hospital	Esperance hospital	Fiona Stanley hospital
	Geraldton hospital	Hedland Health Campus	Joondalup Health Campus
	Kalgoorlie Health Campus	Karratha Health Campus	King Edward Memorial hospital
	Kununurra hospital	Mount hospital	Narrogin hospital
	Northam hospital	Osborne Park hospital	Rockingham hospital
	Royal Perth hospital	Sir Charles Gairdner hospital	St John of God Bunbury hospital
	St John of God Midland hospital	St John of God Murdoch hospital	St John of God Subiaco 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 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.[28] 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.[29] The NAUSP team notifies contributors if data anomalies are identified or if resubmission of data is required.

Measurement of consumption 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'.[10] 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 A2).

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 defined daily dose (DDD) values from 1 January 2019[30]

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

Utilisation rates in this report have been calculated using the DDD values as at 1 January 2019.[30] 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 A2, 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 dayss (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 OBD 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 OBD (this is not the same as the aggregate, as larger hospitals are over-represented in NAUSP data for most states and territories.)
- Median: the middle value of individual 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 occupied bed days (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 have 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 do not include antimicrobial use in sub-acute specialties. Outpatient usage and day-only usage are 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 defined daily doses (DDDs) assigned by the World Health Organization (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		

ATC classification	Generic name	DDD (g)	Route
J01DB	First-generation cephalosporins		
J01DB01	Cefalexin	2	O
J01DB03	Cefalotin	4	P
J01DB04	Cefazolin	3	P
J01DC	Second-generation cephalosporins		
J01DC01	Cefoxitin	6	P
J01DC02	Cefuroxime	0.5	O
J01DC04	Cefaclor	1	O
J01DD	Third-generation cephalosporins		
J01DD01	Cefotaxime	4	P
J01DD02	Ceftazidime	4	P
J01DD04	Ceftriaxone	2	P
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

ATC classification	Generic name	DDD (g)	Route
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
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
J01X	Other antibacterials		
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

ATC classification	Generic name	DDD (g)	Route
J01XX	Other antibacterials		
J01XX01	Fosfomycin	3	O
J01XX01	Fosfomycin	8	P
J01XX08	Linezolid	1.2	O, P
J01XX09	Daptomycin	0.28	P
J04	Antimycobacterials		
J04AB03	Rifampicin	0.6	O, P
A07AA	Intestinal anti-infectives		
A07AA11	Rifaximin	0.6	O
A07AA12	Fidaxomicin	0.4	O

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

Source: https://www.who.int/tools/atc-ddd-toolkit/atc-classification

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.

ATC: Anatomical Therapeutic Classification; DDD: defined daily dose; MR: modified release; O: oral; P: parenteral.

Source: WHO (2019)[30]

Table A5(i): 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

ATC: Anatomical Therapeutic Classification.
Source: https://www.who.int/tools/atc-ddd-toolkit/atc-classification

Table A5(ii): Topical antimicrobials: Vaginal

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

ATC: Anatomical Therapeutic Classification.
Source: https://www.who.int/tools/atc-ddd-toolkit/atc-classification

Appendix 5: Antibacterials included in the Priority Antibacterial List[11], according to the Access, Review (Curb and Contain) classification

Table A6: Priority Antibacterial List

Access	Review	
	Curb	Contain
Amoxicillin	Amoxicillin – clavulanic acid	Amikacin
Ampicillin	Azithromycin	Aztreonam
Benzathine benzylpenicillin	Cefaclor	Cefepime
Benzylpenicillin	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.
Emergency presentations (EP)	The arrival of a patient at the emergency department and the earliest occasion of clerical registration or triage.
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 Australian Institute of Health and Welfare). 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 defined daily doses (DDDs) used per 1,000 occupied bed days (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: Usage (density) rate = $\frac{\text{Number of DDDs/time period}}{\text{OBD/time period}} \times 1{,}000$
Total acute hospital usage rate	Aggregated usage rate for all acute care inpatient locations in a hospital (excluding emergency department and operating theatre)
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.amr.gov.au/australias-response/objective-5-integrated-surveillance-and-response-resistance-and-usage/surveillance-antimicrobial-use-and-resistance-human-health and

https://www.safetyandquality.gov.au/our-work/antimicrobial-resistance/antimicrobial-use-and-resistance-australia-surveillance-system.

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All information in this publication is correct as at December 2023

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