AUSTRALIAN COMMISSION ON SAFETY AND QUALITY IN HEALTH CARE

AURA
Antimicrobial Use and Resistance in Australia

July 2024

Australian Passive AMR Surveillance

An update of resistance trends in multidrug-resistant organisms – 2006 to 2023

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

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ISBN: 978-1-922880-79-6

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

Australian Commission on Safety and Quality in Health Care. Australian Passive AMR Surveillance: An update of resistance trends in multidrug-resistant organisms – 2006 to 2023. Sydney; ACSQHC, 2024.

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Note regarding alternative descriptions

No alternative descriptions have been provided. If you need assistance with the structure of any graphs or charts, please email the Australian Commission on Safety and Quality in Health Care at APAS@safetyandquality.gov.au.

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Executive Summary

Antimicrobial-resistant microorganisms, including bacteria, and the resistance genes they carry, can spread readily between people in the community as well as those receiving care in hospitals, aged care homes and primary care services. The spread of antimicrobial resistance (AMR) can occur rapidly and significantly affect patients, the community, health services and the health system. Effective surveillance and monitoring are essential to determine the burden of AMR, and to inform response, infection prevention and control and antimicrobial stewardship (AMS) strategies, and prescribing guidelines.

This report provides analyses of data from Australian Passive AMR Surveillance (APAS). APAS data on antimicrobial susceptibility testing results are contributed by public and private pathology services across Australia. These data are sourced from hospitals, the community and aged care homes. APAS was established by the Australian Commission on Safety and Quality in Health Care (the Commission) as a key component of the Antimicrobial Use and Resistance in Australia (AURA) surveillance program, which is coordinated by the Australian Government Department of Health and Aged Care (the Department).

Detailed information about APAS is included in Appendix 1. The methodology for the analyses and considerations for interpretation of data and analyses are included in Appendix 2.

The focus of this report is trends in multidrug-resistant organisms (MROs), primarily for 2015 to 2023, with some analyses from 2006. The MROs included are:

- Vancomycin resistance in *Enterococcus faecium* (VRE)
- Fluoroquinolone resistance in *Escherichia coli*
- Methicillin resistance in *Staphylococcus aureus* (MRSA).

VRE and MRSA are included in the high priority group in the World Health Organization Bacterial Priority Pathogen List[1] and these bacteria were selected along with fluoroquinolone resistance in *E. coli* because analyses show that resistance rates are trending up. There are opportunities to improve the safety of care provided to Australians through infection prevention and control and AMS programs and antimicrobial prescribing guidelines. This report provides an update of APAS data analyses included in the series of national AURA reports since 2016[2-6] and the previous APAS report on these MROs (2006 to 2017).[7]

Key findings and trends: 2015 to 2023

Vancomycin resistance *in Enterococcus faecium*

- Vancomycin resistance in *E. faecium* remained high in 2023 (42.5% of isolates). Resistance was highest in 2015 (51.9%) then trended downward until 2020 (33.2%) and rose steeply again in 2022. There has been an overall dramatic increase from 5.3% in 2006.
- Vancomycin resistance was generally higher in hospitals (43.5% in 2023) than the community (24.4% in 2023).
- The prevalence of VRE varied amongst states and territories but was highest in Victoria (62.6% in 2023), whereas trends were lower but similar across remoteness areas of Australia.

Fluoroquinolone resistance in *Escherichia coli*

- Fluoroquinolone resistance in *E. coli* has increased from 1.9% in 2006 to 13.4% in 2023.
- Resistance was similar in hospitals and the community (both 13.4% in 2023).
- The prevalence of resistance varied amongst states and territories but was highest in Victoria (21.7% in 2023). High levels of resistance were also observed amongst the very small number of isolates from the Northern Territory (NT).
- Despite low numbers of isolates, the proportion of fluoroquinolone-resistant *E. coli* was highest in very remote Australia (19.4% in 2023).

Methicillin resistance in *Staphylococcus aureus*

- MRSA rates remained relatively steady from 2006 to 2023; ranging from 19.8% in 2006, 2022 and 2023, respectively, to 22.8% in 2010 and 2017, respectively.
- There was a downward trend in MRSA rates from aged care homes from 2016 (35.0%) to 2023 (21.9%). Despite a comparatively very small number of isolates, MRSA remains more prevalent in aged care homes than in hospitals and the community (2023: 19.0% and 21.5%, respectively).
- MRSA was considerably more prevalent in the small number of isolates from the NT (36.4% in 2023) than other jurisdictions. In other jurisdictions, proportions ranged from 10.2% in Tasmania to 26.1% in Western Australia in 2023.
- The prevalence of MRSA was highest in remote and very remote Australia (2023: 31.5% and 33.5%, respectively); this was compared to major cities (19.4% in 2023) where the greatest number of *S. aureus* isolates were collected.

Implications for patient safety

Vancomycin resistance *in Enterococcus faecium*

Prevalence of VRE remains high and concerning, particularly in acute healthcare settings. Optimising infection prevention and control mechanisms to decrease spread, is essential to effectively respond to and better manage VRE in Australia.

Fluoroquinolone resistance in *Escherichia coli*

Increasing resistance in *E. coli* is concerning given it is not the anticipated effect of marked restrictions for prescribing fluoroquinolones in hospitals under AMS programs and also in the community under the Pharmaceutical Benefits Scheme (PBS) and the Repatriation Pharmaceutical Benefits Scheme (RPBS) restrictions. It is possible that high community use of antimicrobials to which these strains are co-resistant, such as amoxicillin and cefalexin, is fuelling this increase. This will likely cause a greater reliance on last-line antimicrobials such as carbapenems to treat serious infections caused by these resistant strains. The resumption of international travel following eased restrictions associated with the COVID-19 pandemic is also likely contributing to increasing resistance patterns. This is a particular concern for travel to and from Asian countries with high levels of resistance to fluoroquinolones and third-generation cephalosporins.[8, 9]

Methicillin resistance in *Staphylococcus aureus*

MRSA remains common across Australia in the community and in hospitals. Strategies for prevention and control of MRSA in all settings continue to be a priority. This is especially where resistance rates are high and MRSA poses a risk to vulnerable populations, including those across remote and very remote regions and northern Australia, where there is a high population of Aboriginal and Torres Strait Islander peoples. The concern for residents of aged care homes, with the increased vulnerability of older people, is compounded by the high volume of antimicrobial prescribing in this setting, much of which appears to be inconsistent with prescribing guidelines.[10]

What will be done to improve patient safety?

In response to the issues identified in analyses in this report, the Commission will continue to:

- Work with developers of prescribing guidelines, including Therapeutic Guidelines Limited, to ensure AMR data informs guidelines, including *Therapeutic Guidelines: Antibiotic*[11]; and for these to be promoted to prescribers through clear communications
- Work with states and territories and the private laboratory sector to encourage consideration of geographic variation of AMR through the use of local antibiograms produced by APAS contributors
- Promote adaptation of national prescribing practices to local resistance patterns and regular review of prescribing guidance by local AMS programs; this will support the use of broad-spectrum antimicrobials only where necessary and limit inappropriate prescribing
- Promote incorporation of concepts of geographical variation in AMR into clinical practice; particularly to support clinicians who regularly work in a range of settings
- Promote use of the *Priority Antibacterial List for Antimicrobial Resistance Containment*[12] as a tool to support AMS services to analyse antimicrobial usage in terms of preferred or optimal prescribing choices
- Use APAS and other AURA data to refine and strengthen guidance for surveillance, prevention and control of specific organisms and resistances, and AMS programs
- Support collaboration and coordination between states and territories, and between hospital and community care settings to explore the drivers of variation and improve local prevention and control efforts to help limit progression of AMR
- Continue to work with the Department, state and territory health authorities, and private pathology services, to achieve nationwide participation in APAS and enhance national surveillance coverage
- Continue to promote infection prevention and control practices in health and aged care settings consistent with the *Australian Guidelines for the Prevention and Control of Infection in Healthcare*[13] and the National and Safety and Quality Standards for acute, primary and community and aged care[14-16]
- Continue to promote AMS programs and compliance with evidence-based prescribing guidelines in health and aged care settings consistent with the National and Safety and Quality Standards for acute, primary and community and aged care.[14-16]

Vancomycin resistance in *Enterococcus faecium*

Enterococcus species, including *E. faecium*, are opportunistic pathogens that cause a variety of infections in people whose physical barriers are compromised through surgery or invasive devices. This species often causes urinary tract, biliary tract and other intra-abdominal infections, and bloodstream infections, and commonly in vulnerable populations, such as the very elderly or those who are immunosuppressed.

Enterococci are naturally resistant to several common antimicrobial classes, including anti-staphylococcal penicillins, cephalosporins, macrolides and lincosamides. Oral amoxicillin is the most common treatment for minor infections. More serious infections are treated with intravenous ampicillin or amoxicillin. Vancomycin is used for serious infections in people who are allergic to penicillins.

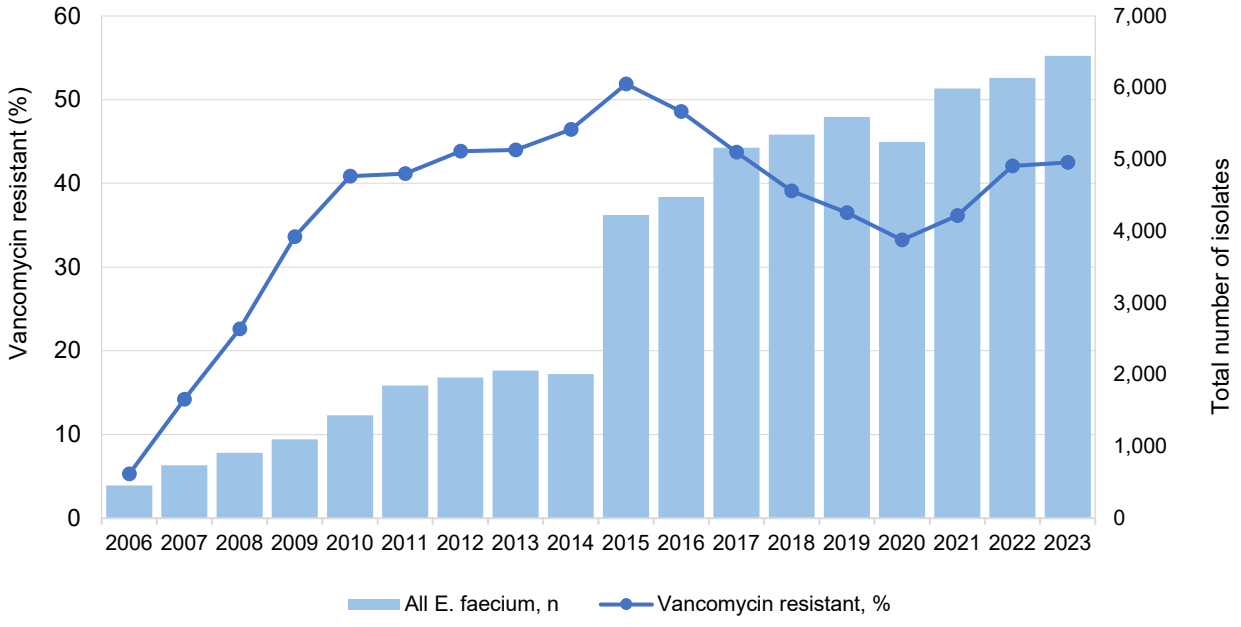
The other main *Enterococcus* species is *E. faecalis*, which is commonly susceptible to both ampicillin and vancomycin. In contrast, high levels of ampicillin resistance have emerged in *E. faecium* worldwide, including in Australia.[17] This has led to the increased use of vancomycin for treatment.

More recently, vancomycin-resistant *E. faecium* (VRE) have also emerged. The two main gene complexes responsible for VRE are *vanA* and *vanB*.[18,19] VRE require treatment with antimicrobials that are usually reserved, such as teicoplanin or daptomycin.

Between 2006 and 2023, there were 28,716 *E. faecium* isolates from the four long-term APAS contributor pathology services. Across all pathology services that contribute to APAS, including the four long-term contributors, data were available for 61,605 isolates over this period. See Appendices 1 and 2 for information about the pathology services that contribute to APAS.

Figure 1 shows the 18-year trend in vancomycin resistance in *E. faecium* reported by all APAS contributors between 2006 and 2023. There was a sharp increase in the proportion of vancomycin-resistant *E. faecium* isolates from 5.3% in 2006 to 51.9% in 2015. There was a steady decreasing trend until 2020 (33.2%) before increasing to over 42% in 2022 and 2023.

Figure 1: Percentage of *Enterococcus faecium* with vancomycin resistance, APAS contributors, 2006–2023



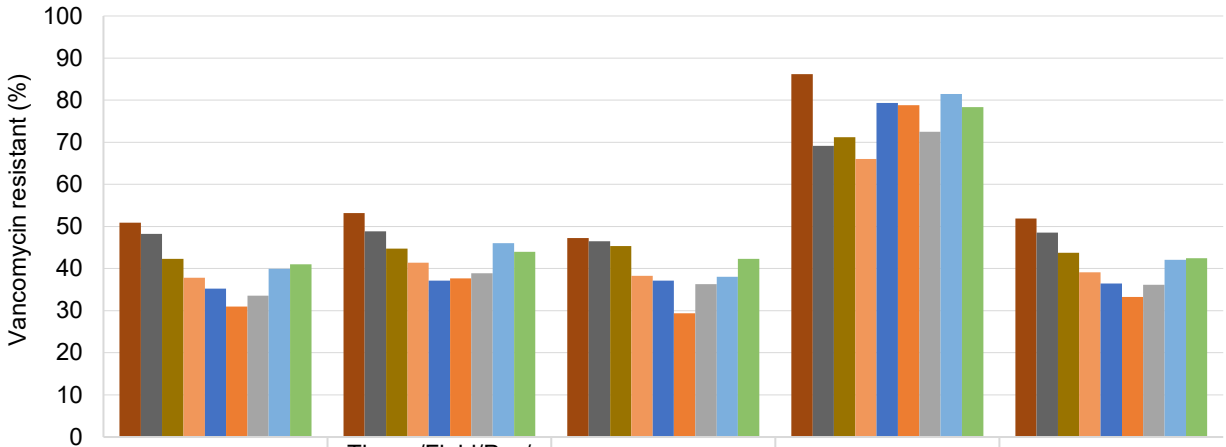
n = denominator for total number of isolates
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

For analyses of 2015 to 2023 data for this report, there were 48,961 *E. faecium* isolates from all APAS contributors.

Vancomycin resistance in *Enterococcus faecium* by specimen type

A little over one-half (57.9%) of *E. faecium* isolates reported by APAS contributors for 2015 to 2023 were from urine. Isolates were next most reported from tissue/fluid/pus/prosthesis (27.3%) and blood (13.3%). Rates of vancomycin resistance in *E. faecium* were high. While the overall proportion of isolates that were vancomycin-resistant decreased from 51.9% in 2015 to 33.2% in 2020, it increased to over 42% in 2022 and 2023. Apart from other specimen types (cerebrospinal fluid, ear nose and throat, enteric, genital, and respiratory), of which there were low numbers, the specimen source did not substantially influence resistance (Figure 2). For more information on specimen types, see Appendix 2.

Figure 2: Percentage of vancomycin-resistant *Enterococcus faecium* by specimen source, APAS contributors, 2015–2023



	Urine	Tissue/Fluid/Pus/ Prosthesis	Blood	Other*	All specimen types
2015, %	50.9	53.2	47.3	86.2	51.9
2016, %	48.3	48.9	46.5	69.1	48.6
2017, %	42.3	44.8	45.3	71.2	43.7
2018, %	37.8	41.4	38.3	66.1	39.1
2019, %	35.3	37.2	37.1	79.3	36.5
2020, %	31.0	37.7	29.4	78.8	33.2
2021, %	33.6	38.9	36.3	72.5	36.2
2022, %	40.0	46.1	38.1	81.5	42.1
2023, %	41.0	44.0	42.3	78.4	42.5
2015, n	2,269	1,324	548	87	4,228
2016, n	2,527	1,258	613	81	4,479
2017, n	3,071	1,363	664	66	5,164
2018, n	3,233	1,398	658	56	5,345
2019, n	3,236	1,550	749	58	5,593
2020, n	3,037	1,470	671	66	5,244
2021, n	3,395	1,691	793	109	5,988
2022, n	3,828	1,674	844	97	6,443
2023, n	3,828	1,674	844	97	6,443
Total, n	28,172	13,356	6,365	728	48,621

n = denominator for total number of isolates

* Other specimen types include cerebrospinal fluid, ear nose and throat, enteric, genital, and respiratory specimens

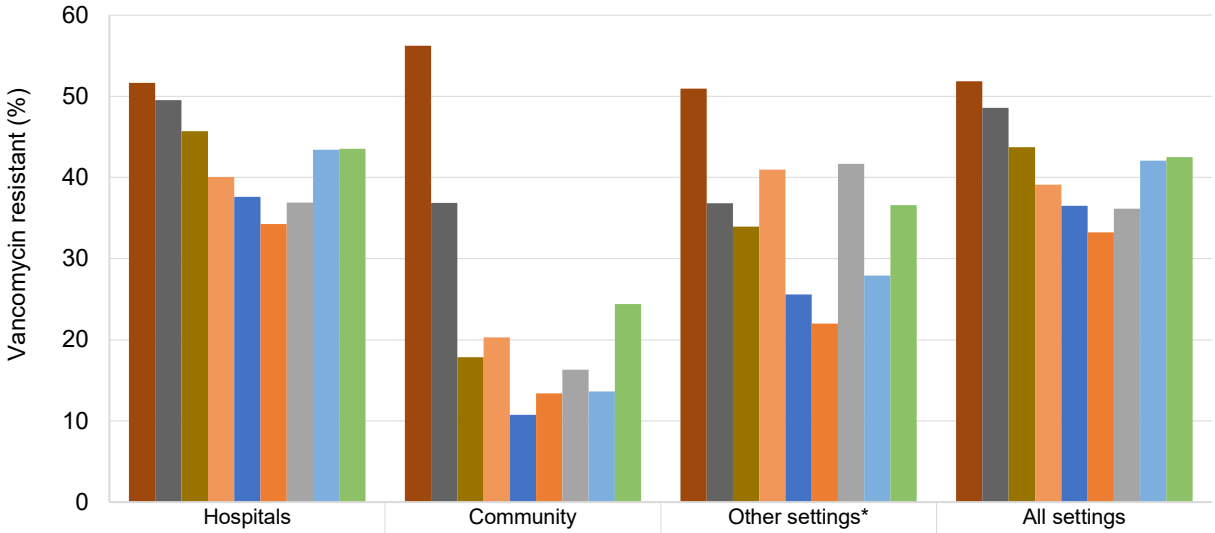
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Vancomycin resistance in *Enterococcus faecium* by setting

The vast majority (94.2%) of *E. faecium* isolates reported by APAS contributors for 2015 to 2023 were from hospitals (public and private). There was a steady decline in the proportion of VRE from hospital settings, falling from 51.6% in 2015 to 34.2% in 2020, although there was an increase to greater than 43% in 2022 and 2023.

Resistance in *E. faecium* isolates from the community was generally lower than those from hospital settings, falling from 56.2% to 10.7% in 2019 and 13.4% in 2020; in 2023, it was 24.4% (Figure 3). It is important to note that it cannot be determined from APAS data whether isolates collected from community settings were associated with prior healthcare exposure to VRE.

Figure 3: Percentage of vancomycin-resistant *Enterococcus faecium* by setting, APAS contributors, 2015–2023



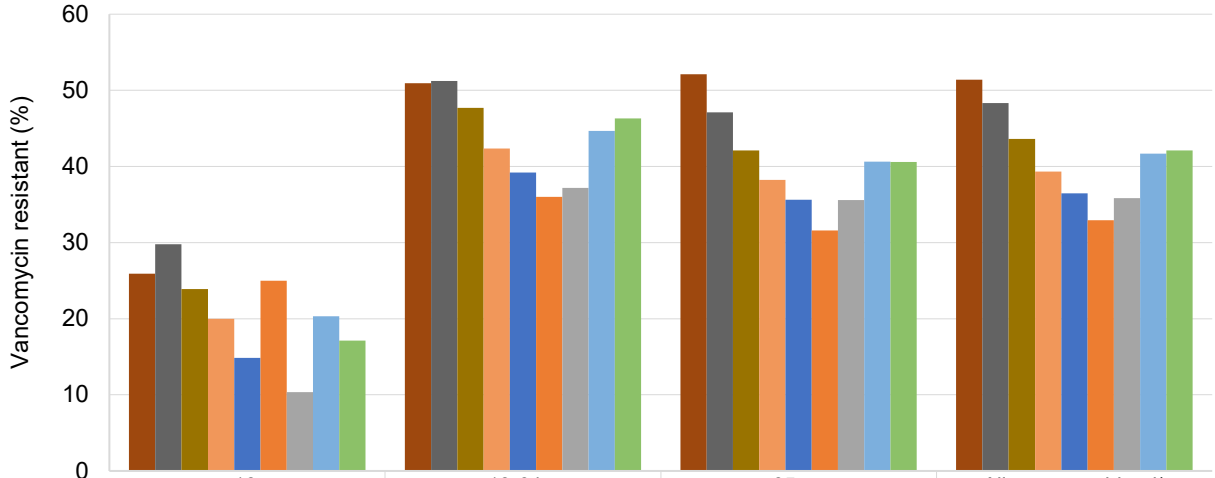
	Hospitals	Community	Other settings*	All settings
2015, %	51.6	56.2	50.9	51.9
2016, %	49.5	36.9	36.8	48.6
2017, %	45.7	17.8	33.9	43.7
2018, %	40.1	20.3	41.0	39.1
2019, %	37.6	10.7	25.6	36.5
2020, %	34.2	13.4	22.0	33.2
2021, %	36.9	16.3	41.7	36.2
2022, %	43.4	13.6	27.9	42.1
2023, %	43.5	24.4	36.6	42.5
2015, n	3,958	217	53	4,228
2016, n	4,140	282	57	4,479
2017, n	4,766	342	56	5,164
2018, n	5,018	266	61	5,345
2019, n	5,336	214	43	5,593
2020, n	4,970	224	50	5,244
2021, n	5,713	227	48	5,988
2022, n	5,837	257	43	6,137
2023, n	6,074	328	41	6,443
Total, n	45,812	2,357	452	48,621

n = denominator for total number of isolates
* Other refers to settings other than hospital or community, including multi-purpose service and aged care homes
Note: Hospitals = public and private.
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Vancomycin resistance in *Enterococcus faecium* by age group

The vast majority of *E. faecium* isolates reported by APAS contributors for 2015 to 2023 were from adults (18–64 years, 31.8%; greater than 65 years, 67.0%); just 1.2% were reported from children (aged less than 18 years) (Figure 4). The proportion of vancomycin resistance in *E. faecium* was lower in children than adults in each year over this period. The resistance trends were similar across all age groups.

Figure 4: Percentage of vancomycin-resistant *Enterococcus faecium* by age group, APAS contributors, 2015–2023



	<18 y	18-64 y	65+ y	All ages combined*
2015, %	25.9	50.9	52.1	51.4
2016, %	29.8	51.2	47.1	48.3
2017, %	23.9	47.7	42.1	43.6
2018, %	20.0	42.3	38.2	39.3
2019, %	14.9	39.2	35.6	36.5
2020, %	25.0	36.0	31.6	32.9
2021, %	10.3	37.2	35.6	35.8
2022, %	20.3	44.6	40.6	41.7
2023, %	17.1	46.3	40.6	42.1
2015, n	54	1,310	2,822	4,186
2016, n	47	1,505	2,927	4,479
2017, n	67	1,629	3,466	5,162
2018, n	75	1,755	3,522	5,352
2019, n	74	1,733	3,751	5,558
2020, n	72	1,680	3,453	5,205
2021, n	58	1,843	4,051	5,952
2022, n	64	1,915	4,109	6,088
2023, n	70	2,020	4,321	6,411
Total, n	581	15,390	32,422	48,393

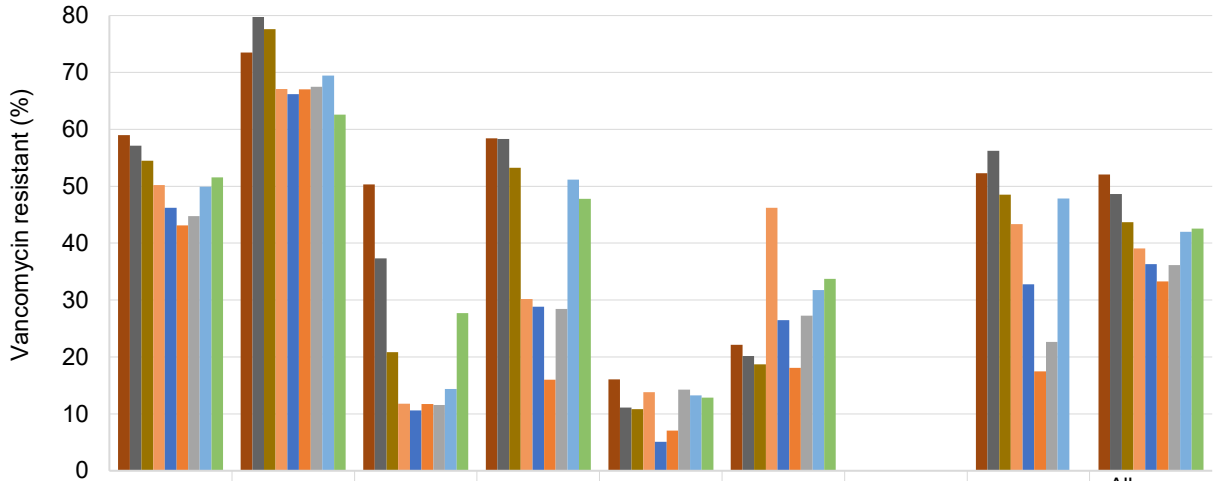
n = denominator for total number of isolates; y = years of age
* Where patient's age was known
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Vancomycin resistance in *Enterococcus faecium* by state and territory

Figures 5–7 show the trends in VRE isolates by state and territory reported from all APAS contributors from 2015 to 2023, with 2023 data mapped to Australian Statistical Area Level 4 (SA4) (Figure 7). Data were analysed based on the known postcode of residence of the person from whom the specimen was taken (see Appendix 2).

There was considerable variation across the states and territories in the number of *E. faecium* isolates and proportion of vancomycin resistance reported by APAS contributors from 2015 to 2023. In 2023, the overall proportion of vancomycin-resistant *E. faecium* isolates ranged from 12.8% in Western Australia (WA) to 62.6% in Victoria (Figure 5). Whilst the number of contributing APAS sites was lower and there were lower numbers of isolates submitted from Victoria, the rates of resistance were the highest nationally. For WA, the proportion of vancomycin-resistant blood isolates (23.0%) was more than double that of urine isolates (10.4%) (Figure 6).

Figure 5: Percentage of vancomycin-resistant *Enterococcus faecium* by state and territory, APAS contributors, 2015–2023



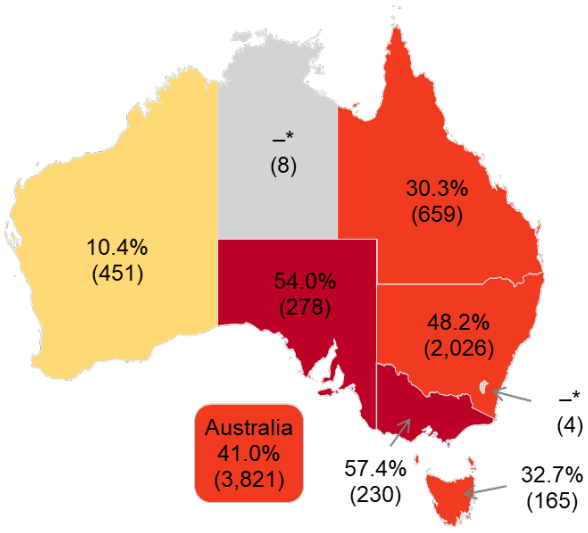
	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	All areas combined*
2015, %	59.0	73.5	50.3	58.4	16.1	22.1		52.3	52.1
2016, %	57.1	79.7	37.3	58.3	11.1	20.2		56.2	48.6
2017, %	54.5	77.6	20.9	53.2	10.8	18.7		48.6	43.7
2018, %	50.2	67.1	11.8	30.2	13.8	46.2		43.4	39.1
2019, %	46.2	66.2	10.6	28.8	5.1	26.5		32.7	36.3
2020, %	43.1	67.0	11.7	16.0	7.0	18.1		17.5	33.3
2021, %	44.8	67.5	11.6	28.4	14.2	27.2		22.7	36.2
2022, %	49.9	69.4	14.4	51.2	13.3	31.8		47.8	42.0
2023, %	51.5	62.6	27.7	47.8	12.8	33.7			42.5
2015, n	1,662	272	725	416	442	104	9	130	3,760
2016, n	2,016	306	868	386	504	114	16	153	4,363
2017, n	2,428	357	1,059	494	518	123	13	138	5,130
2018, n	2,691	401	969	371	536	158	6	173	5,305
2019, n	2,899	491	762	420	572	185	6	171	5,506
2020, n	2,726	449	766	425	511	155	14	166	5,212
2021, n	3,190	452	796	510	632	235	15	150	5,980
2022, n	3,148	543	842	461	686	258	17	138	6,093
2023, n	3,229	473	1,112	550	763	267	13	6	6,413
Total, n	23,989	3,744	7,899	4,033	5,164	1,599	109	1,225	47,762

n = denominator for total number of isolates
* Where postcode of residence was known
Notes:
1. State and territory based on postcode of residence. Data available from the NT were from NT residents who received pathology services interstate. Data from ACT pathology services were not available for 2023, except where ACT residents received pathology services interstate.
2. Postcode of residence was not available in 2015 for NSW Health Pathology South Eastern Sydney Local Health District.
3. Blank cell indicate insufficient number of isolates (<30) to calculate percentage.

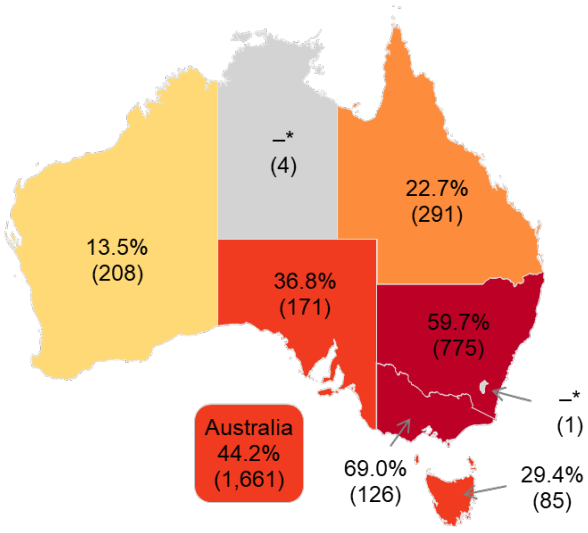
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Figure 6: Vancomycin resistance in *Enterococcus faecium*, by state and territory and specimen source, APAS contributors, 2023

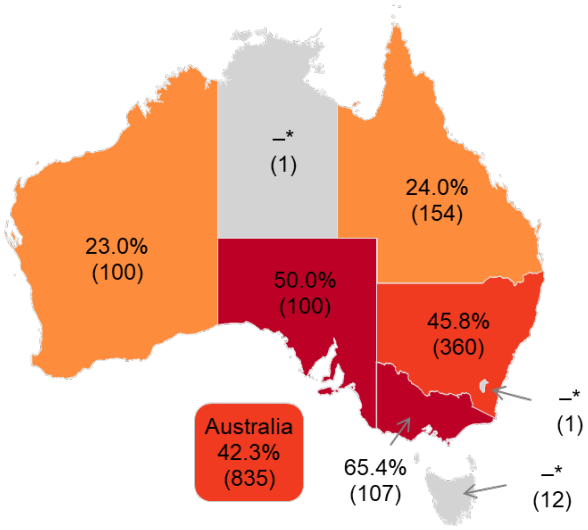
Urine

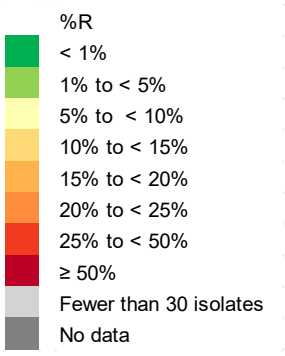


Tissue/fluid/pus/prosthesis



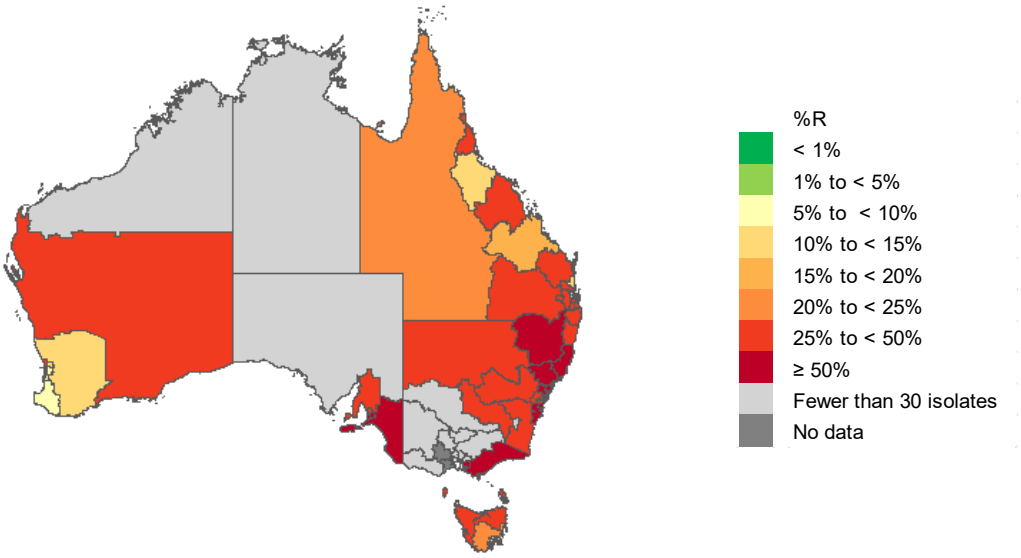
Blood





R = resistant
* Insufficient number of isolates (<30) to calculate percentage
Note: State and territory based on postcode of residence (where known). Data available from the NT were from NT residents who received pathology services interstate. Data from ACT pathology services were not available for 2023, except where ACT residents received pathology services interstate.
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Figure 7: Vancomycin resistance in *Enterococcus faecium*, mapped to Australian SA4 areas, APAS contributors, 2023



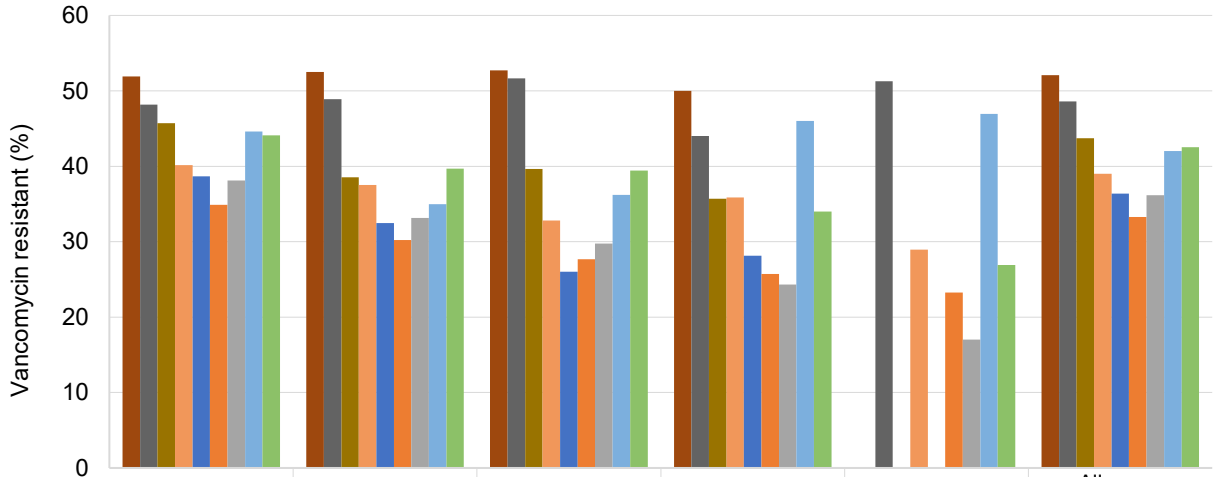
R = resistant; SA4 = Statistical Area Level 4
Note: SA4 based on postcode of residence (where known). Data available from the NT were from NT residents who received pathology services interstate. Data from ACT pathology services were not available for 2023, except where ACT residents received pathology services interstate.
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Vancomycin resistance in *Enterococcus faecium* by remoteness area

Figure 8 shows the trends in VRE by remoteness area reported from all APAS contributors from 2015 to 2023. Data were analysed based on the known postcode of residence of the person from whom the specimen was taken (see Appendix 2).

A little over two-thirds (70.1%) of *E. faecium* isolates reported by APAS contributors for 2015 to 2023 were from patients residing in major cities of Australia. There were similar trends in vancomycin resistance in all remoteness areas during this period (Figure 8). It is important to note that there were low numbers of isolates from remote and very remote areas.

Figure 8: Percentage of *Enterococcus faecium* with vancomycin resistance by remoteness area, APAS contributors, 2015–2023



	Major cities	Inner regional	Outer regional	Remote	Very remote	All areas combined
2015, %	51.9	52.5	52.7	50.0		52.1
2016, %	48.2	48.9	51.6	44.0	51.3	48.6
2017, %	45.7	38.6	39.7	35.7		43.7
2018, %	40.2	37.5	32.8	35.8	28.9	39.0
2019, %	38.7	32.5	26.0	28.1		36.4
2020, %	34.9	30.2	27.7	25.7	23.3	33.3
2021, %	38.1	33.2	29.7	24.3	17.0	36.2
2022, %	44.6	35.0	36.2	46.0	46.9	42.0
2023, %	44.1	39.7	39.4	34.0	26.9	42.5
2015, n	2,469	876	351	42	22	3,760
2016, n	3,010	900	364	50	39	4,363
2017, n	3,655	983	411	56	28	5,133
2018, n	3,838	984	393	53	38	5,306
2019, n	3,984	1,038	392	64	30	5,508
2020, n	3,743	969	423	35	43	5,213
2021, n	4,232	1,173	454	74	47	5,980
2022, n	4,272	1,207	519	50	49	6,097
2023, n	4,408	1,340	563	50	52	6,413
Total, n	33,611	9,470	3,870	474	348	47,773

n = denominator for total number of isolates
Notes:
1. Remoteness area based on postcode of residence (where known).
2. Blank cell indicate insufficient number of isolates (<30) to calculate percentage.
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Fluoroquinolone resistance in *Escherichia coli*

The order *Enterobacterales* encompasses a large group of related bacteria including *Escherichia coli*, which is a common pathogen that causes both community- and hospital-associated infections. *E. coli* is the most common cause of urinary tract infection and bacteraemia in the community and in otherwise healthy people. It is also associated with a variety of infections, including biliary tract and other intra-abdominal infections (including those following surgery, and often mixed with other pathogens), as well as meningitis, and bacteraemia from intravascular lines.

The aminoglycosides (especially gentamicin) are recommended as part of empirical use, pending the results of culture and susceptibility testing. B-lactam antimicrobials, including those combined with β-lactamase inhibitors, are preferred for the treatment of infections caused by *E. coli* when prolonged treatment or a switch from parenteral to oral therapy is considered. In addition to β-lactams, trimethoprim is currently recommended for the oral treatment of lower urinary tract infections.[11]

In Australia, fluoroquinolones are usually only recommended for strains that are likely to be resistant to other classes of antimicrobials. They are also available in a range of formulations, such as oral, intravenous and topical (eye and ear).

E. coli has the capacity to acquire and transmit resistance genes among themselves and to some other genera through horizontal gene transfer. In addition, it has specialised mechanisms to become multidrug-resistant by capturing and accumulating resistance genes (integrons). Few antimicrobials are available for the treatment of highly multidrug-resistant strains, and all are more toxic than β-lactams.

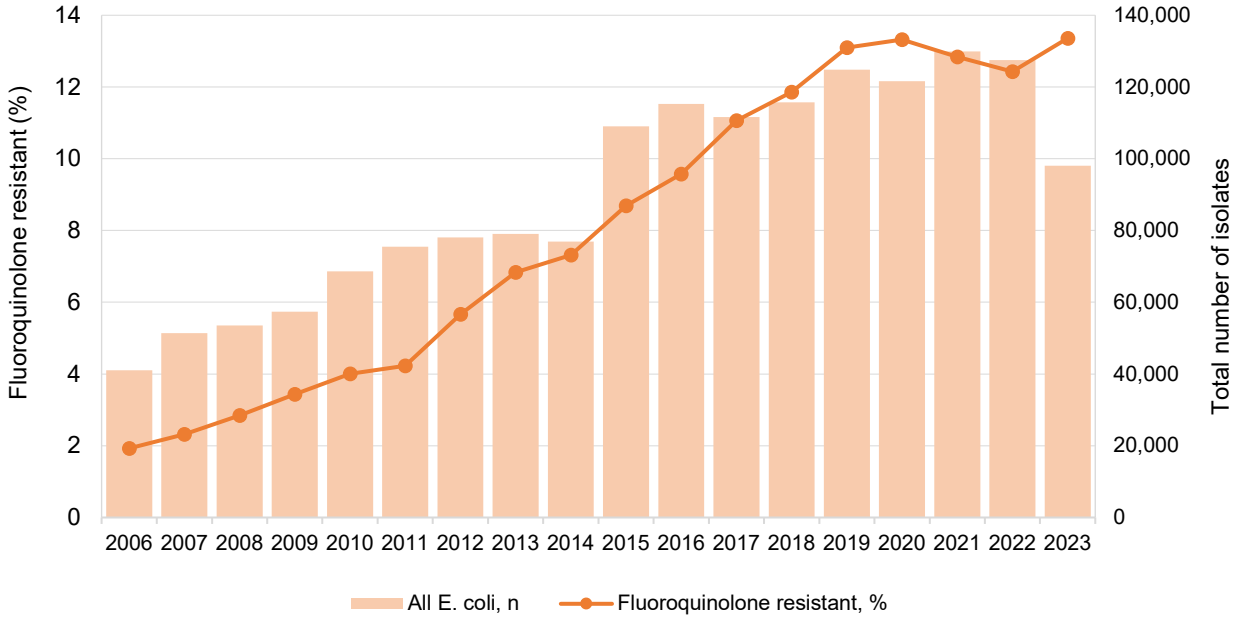
Between 2006 and 2023, there were 1,233,211 *E. coli* isolates from the four long-term APAS contributor pathology services. Across all pathology services that contribute to APAS, including the four long-term contributors, data were available for 1,956,779 isolates over this period. See Appendices 1 and 2 for information about the pathology services that contribute to APAS.

Prevalence of fluoroquinolone resistance was examined using available antimicrobial susceptibility test data for ciprofloxacin (non-urine specimens) and norfloxacin (urine specimens).

Figure 9 shows the 18-year trend in fluoroquinolone resistance in *E. coli* reported by all APAS contributors between 2006 and 2023. The decrease in the number of *E. coli* isolates reported to APAS was attributed to a change to selective reporting practices for isolates from urinary tract infections by three of the four long-term contributors.

There was an increasing trend in the proportion of fluoroquinolone resistant *E. coli* isolates from 1.9% in 2006, peaking at 13.3% in 2020 and decreasing to 12.4% in 2022, but increasing again to 13.4% in 2023 (Figure 9).

Figure 9: Percentage of *Escherichia coli* with fluoroquinolone resistance, APAS contributors, 2006–2023



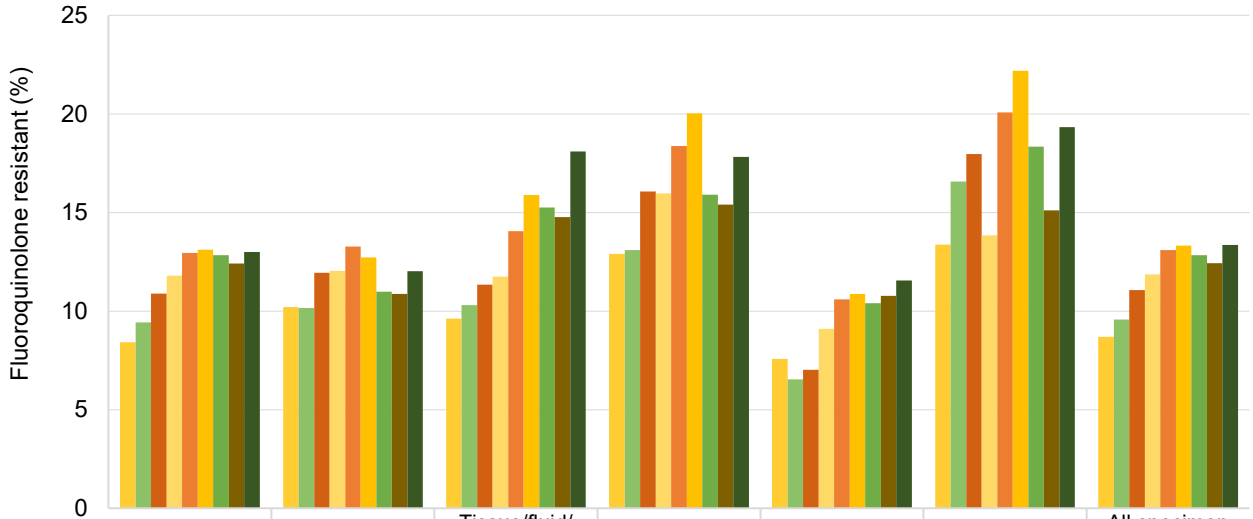
n = denominator for total number of isolates
Note: Selective testing/reporting of fluoroquinolone susceptibility of isolates from urine specimens was implemented in SA Pathology metropolitan (2015) and regional laboratories (2017), Mater Pathology (2020) and Pathology Queensland (2023).
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

For analyses of 2015 to 2023 data for this report, there were 1,342,721 *E. coli* isolates from all APAS contributors.

Fluoroquinolone resistance in *Escherichia coli* by specimen type

The majority (86.3%) of *E. coli* isolates reported by APAS contributors for 2015 to 2023 were from urine. Despite low numbers, resistance was generally higher among *E. coli* isolates from other specimens (cerebrospinal fluid, ear nose and throat, and enteric specimens), followed by tissue/pus/pus/prosthesis and respiratory specimens. Fluoroquinolone resistance was lowest in genital tract isolates. The number of isolates across specimen types varied substantially. In 2023, there was an increase in resistance across all specimen types (Figure 10). For more information on specimen types, see Appendix 2.

Figure 10: Percentage of *Escherichia coli* with fluoroquinolone resistance by specimen source, APAS contributors, 2015–2023



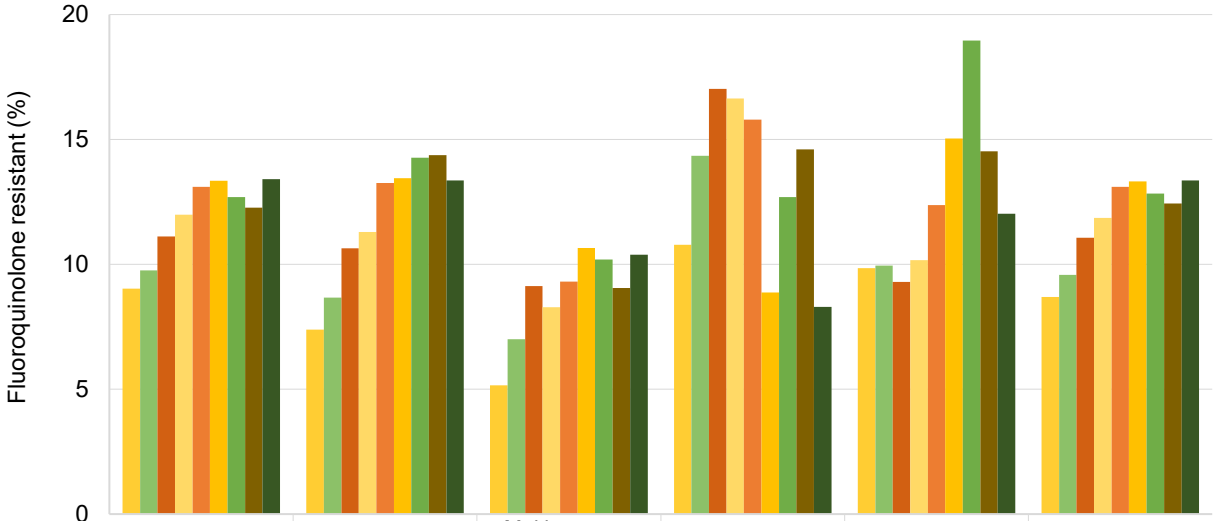
	Urine	Blood	Tissue/fluid/ pus/prosthesis	Respiratory	Genital	Other*	All specimen types
2015, %	8.4	10.2	9.6	12.9	7.6	13.4	8.7
2016, %	9.4	10.2	10.3	13.1	6.5	16.6	9.6
2017, %	10.9	11.9	11.3	16.1	7.0	18.0	11.1
2018, %	11.8	12.0	11.7	16.0	9.1	13.8	11.9
2019, %	12.9	13.3	14.1	18.4	10.6	20.1	13.1
2020, %	13.1	12.7	15.9	20.0	10.9	22.2	13.3
2021, %	12.8	11.0	15.2	15.9	10.4	18.3	12.8
2022, %	12.4	10.9	14.8	15.4	10.8	15.1	12.4
2023, %	13.0	12.0	18.1	17.8	11.6	19.3	13.4
2015, n	92,206	8,357	5,979	1,496	740	217	108,995
2016, n	97,051	9,143	6,621	1,497	810	181	115,303
2017, n	93,039	9,445	6,569	1,569	783	206	111,611
2018, n	96,403	10,004	6,653	1,541	857	224	115,682
2019, n	104,965	10,417	6,864	1,481	831	254	124,812
2020, n	100,454	11,177	7,529	1,318	837	266	121,581
2021, n	108,058	11,568	7,766	1,327	875	300	129,894
2022, n	106,340	11,238	7,267	1,351	966	298	127,460
2023, n	75,684	11,796	7,837	1,325	1,047	357	98,046
Total, n	874,200	93,145	63,085	12,905	7,746	2,303	1,053,384

n = denominator for total number of isolates
* Other refers to cerebrospinal fluid, ear nose and throat, and enteric specimens
Note: Fluoroquinolone resistance was examined using available antimicrobial susceptibility test data for ciprofloxacin (non-urine specimens) and norfloxacin (urine specimens).
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Fluoroquinolone resistance in *Escherichia coli* by setting

Almost all *E. coli* isolates reported by APAS contributors for 2015 to 2023 were from hospitals (84.8%) (public and private) and community settings (13.0%) (Figure 11). There was little difference in the proportion of fluoroquinolone-resistant *E. coli* isolates from hospitals compared to the community. *E. coli* isolates from multi-purpose service settings had the overall lowest fluoroquinolone resistance in this period, while isolates from aged care homes showed greater year-on-year variation.

Figure 11: Percentage of *Escherichia coli* with fluoroquinolone resistance by setting, APAS contributors, 2015–2023



	Hospitals	Community	Multi-purpose service	Aged care home	Other settings*	All settings
2015, %	9.0	7.4	5.2	10.8	9.9	8.7
2016, %	9.8	8.7	7.0	14.3	9.9	9.6
2017, %	11.1	10.6	9.1	17.0	9.3	11.1
2018, %	12.0	11.3	8.3	16.6	10.2	11.9
2019, %	13.1	13.3	9.3	15.8	12.4	13.1
2020, %	13.3	13.4	10.7	8.9	15.0	13.3
2021, %	12.7	14.3	10.2	12.7	19.0	12.8
2022, %	12.3	14.4	9.0	14.6	14.5	12.4
2023, %	13.4	13.4	10.4	8.3	12.0	13.4
2015, n	85,194	20,623	1,357	1,354	467	108,995
2016, n	91,746	20,240	1,572	1,192	553	115,303
2017, n	91,802	16,919	1,337	940	613	111,611
2018, n	94,426	18,581	1,291	715	669	115,682
2019, n	105,122	17,119	1,397	665	509	124,812
2020, n	106,323	13,224	1,314	248	472	121,581
2021, n	115,462	12,050	1,608	252	522	129,894
2022, n	113,415	11,594	1,647	274	530	127,460
2023, n	89,521	6,964	992	253	316	98,046
Total, n	893,011	137,314	12,515	5,893	4,651	1,053,384

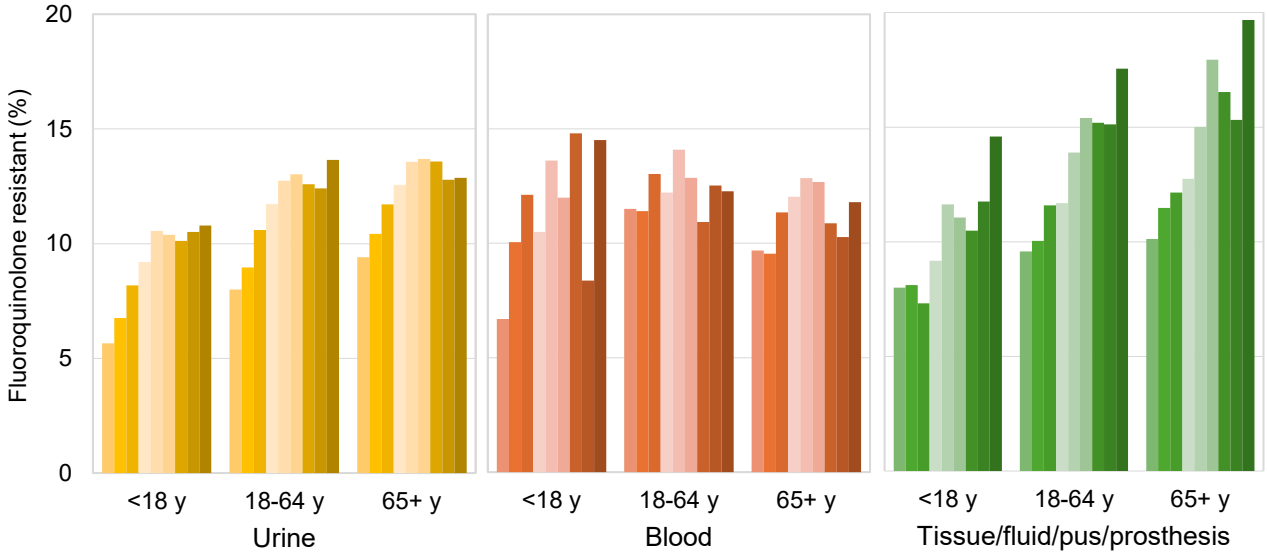
n = denominator for total number of isolates
* Other settings were predominantly corrective services
Note: Hospitals = public and private.
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Fluoroquinolone resistance in *Escherichia coli* by age group

Of *E. coli* isolates from APAS contributors for 2015 to 2023, 90.7% were from adults and 9.3% from paediatric patients (less than 18 years). The highest proportion of fluoroquinolone resistance was seen in tissue/fluid/pus/prosthesis isolates from adults. The proportion of fluoroquinolone-resistant *E. coli* was slightly lower among paediatric patients with urinary tract infections (Figure 12).

Little difference was observed in the proportion of fluoroquinolone resistance across the three age groups for *E. coli* isolated from blood infections (Figure 12).

Figure 12: Percentage of *Escherichia coli* with fluoroquinolone resistance, by specimen source and age group, APAS contributors, 2015–2023



2015, %	5.7	8.0	9.4	6.7	11.5	9.7	8.0	9.6	10.1
2016, %	6.8	9.0	10.4	10.0	11.4	9.5	8.1	10.0	11.5
2017, %	8.2	10.6	11.7	12.1	13.0	11.4	7.3	11.6	12.1
2018, %	9.2	11.7	12.6	10.5	12.2	12.0	9.2	11.7	12.7
2019, %	10.5	12.8	13.6	13.6	14.1	12.8	11.6	13.9	15.0
2020, %	10.3	13.0	13.7	12.0	12.9	12.7	11.1	15.4	17.9
2021, %	10.1	12.6	13.6	14.8	10.9	10.9	10.5	15.2	16.5
2022, %	10.4	12.4	12.8	8.4	12.5	10.3	11.8	15.1	15.3
2023, %	10.8	13.6	12.9	14.5	12.3	11.8	14.6	17.5	19.7
2015, n	9,054	41,239	41,812	239	2,713	5,398	700	3,267	2,005
2016, n	9,365	42,994	44,509	249	2,947	5,954	765	3,616	2,258
2017, n	9,012	40,260	43,602	264	3,016	6,211	711	3,615	2,247
2018, n	9,117	40,849	43,434	286	3,088	6,624	741	3,629	2,267
2019, n	10,149	46,464	49,985	257	3,279	6,932	731	3,757	2,378
2020, n	9,779	43,769	48,591	242	3,398	7,538	769	4,005	2,749
2021, n	10,905	45,759	52,812	277	3,413	7,868	754	4,080	2,929
2022, n	10,785	44,088	52,949	299	3,316	7,639	706	3,802	2,677
2023, n	7,394	31,134	38,806	317	3,519	7,958	713	4,217	2,908
Total, n	85,117	372,922	412,478	2,430	28,689	62,122	5,877	29,771	19,510

n = denominator for total number of isolates; y = years of age
Note: Fluoroquinolone resistance was examined using available antimicrobial susceptibility test data for ciprofloxacin (non-urine specimens) and norfloxacin (urine specimens).
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Fluoroquinolone resistance in *Escherichia coli* by state and territory

Figures 13–15 show the trends in fluoroquinolone resistance in *E. coli* by state and territory reported from all APAS contributors from 2015 to 2023, with 2023 data mapped to Australian SA4 and Statistical Area Level 3 (SA3) (Figure 15). Data were analysed based on the known postcode of residence of the person from whom the specimen was taken (see Appendix 2).

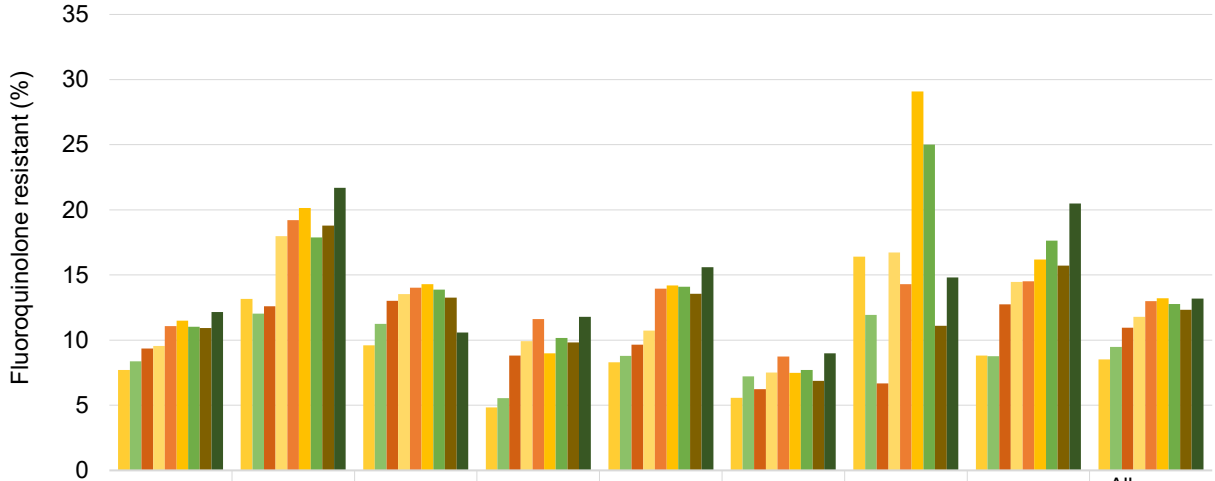
There was considerable variation in the proportion of fluoroquinolone-resistant *E. coli* across Australia (Figure 13). There was an increasing trend observed across all states and territories from 2015 to 2019, which began to stabilise from 2020. The highest proportion of fluoroquinolone

resistance was in patients who resided in Victoria where resistance ranged from 13.2% in 2015 to 21.7% in 2023. The highest yearly proportion of resistance was observed in the Northern Territory (NT) in 2020 (29.1%) but this was attributed to a comparatively small number of isolates in comparison to other jurisdictions.

In Queensland, there was a marked decrease in the number of *E. coli* from urine specimens tested against norfloxacin in 2023, which was associated with a statewide change of antimicrobial susceptibility test panels which include ciprofloxacin but not norfloxacin. In South Australia from 2017, there was a change to a selective antimicrobial susceptibility testing protocol for urinary tract isolates.

With consideration to specimen type, the highest proportion of *E. coli* with fluoroquinolone resistance in 2023 was isolated from tissue/fluid/pus/prosthesis specimens in New South Wales (Figure 14).

Figure 13: Percentage of *Escherichia coli* with fluoroquinolone resistance by state and territory, APAS contributors, 2015–2023



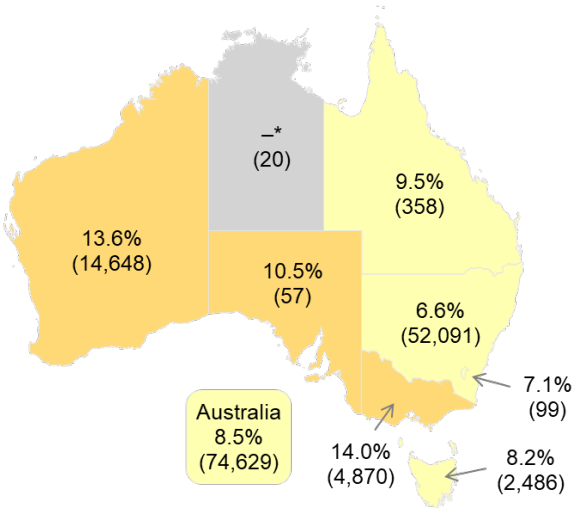
	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	All areas combined*
2015, %	7.7	13.2	9.6	4.8	8.3	5.6	16.4	8.8	8.5
2016, %	8.4	12.0	11.3	5.6	8.8	7.2	11.9	8.8	9.5
2017, %	9.4	12.6	13.0	8.8	9.6	6.2	6.7	12.7	11.0
2018, %	9.6	18.0	13.5	9.9	10.7	7.5	16.7	14.5	11.8
2019, %	11.1	19.2	14.0	11.6	13.9	8.7	14.3	14.5	13.0
2020, %	11.5	20.2	14.3	9.0	14.2	7.5	29.1	16.2	13.2
2021, %	11.0	17.9	13.9	10.2	14.1	7.7	25.0	17.6	12.8
2022, %	10.9	18.8	13.3	9.8	13.6	6.9	11.1	15.7	12.3
2023, %	12.1	21.7	10.6	11.8	15.6	9.0	14.8	20.5	13.2
2015, n	30,309	3,500	37,176	7,006	18,725	1,545	67	3,164	101,492
2016, n	37,019	6,995	38,513	6,588	17,790	1,730	67	3,351	112,053
2017, n	38,682	7,054	39,505	2,203	17,600	1,730	45	3,225	110,044
2018, n	40,287	7,019	39,257	2,391	17,798	1,890	245	3,161	112,048
2019, n	50,406	7,260	39,984	2,231	17,632	1,913	42	3,417	122,885
2020, n	53,284	6,769	36,014	2,171	16,697	1,909	55	3,377	120,276
2021, n	56,709	7,254	39,927	2,291	15,769	3,252	56	3,562	128,820
2022, n	57,478	5,750	38,928	2,350	15,317	3,039	54	3,117	126,033
2023, n	61,279	6,491	6,161	2,241	17,079	3,219	54	122	96,646
Total, n	425,453	58,092	315,465	29,472	154,407	20,227	685	26,496	1,030,297

n = denominator for total number of isolates
* Where of residence was known
Notes:
1. State and territory based on postcode of residence. Data available from the NT were from NT residents who received pathology services interstate. Data from ACT pathology services were not available for 2023, except where ACT residents received pathology services interstate.
2. Postcode of residence was not available in 2015 for NSW Health Pathology South Eastern Sydney Local Health District.

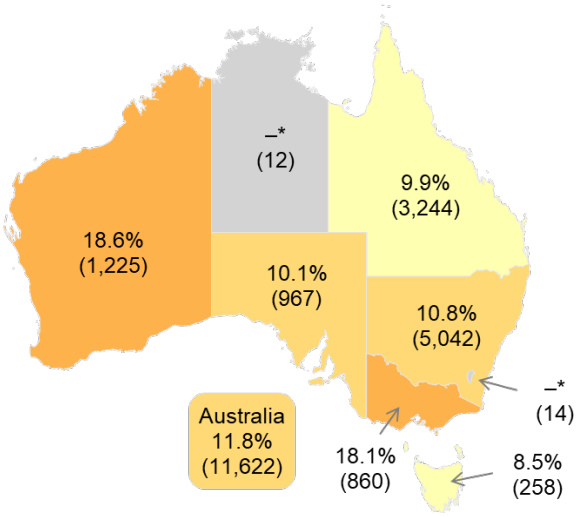
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Figure 14: Fluoroquinolone resistance in *Escherichia coli*, by state and territory and specimen source, APAS contributors, 2023

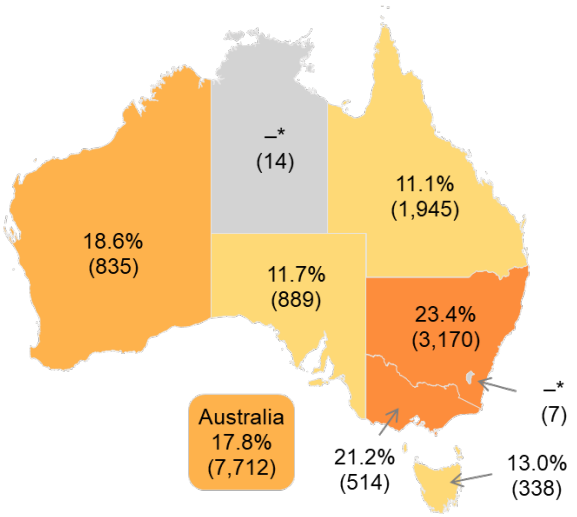
Urine

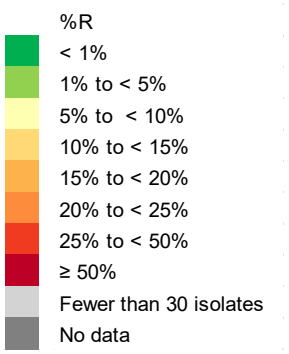


Blood



Tissue/fluid/pus/prosthesis

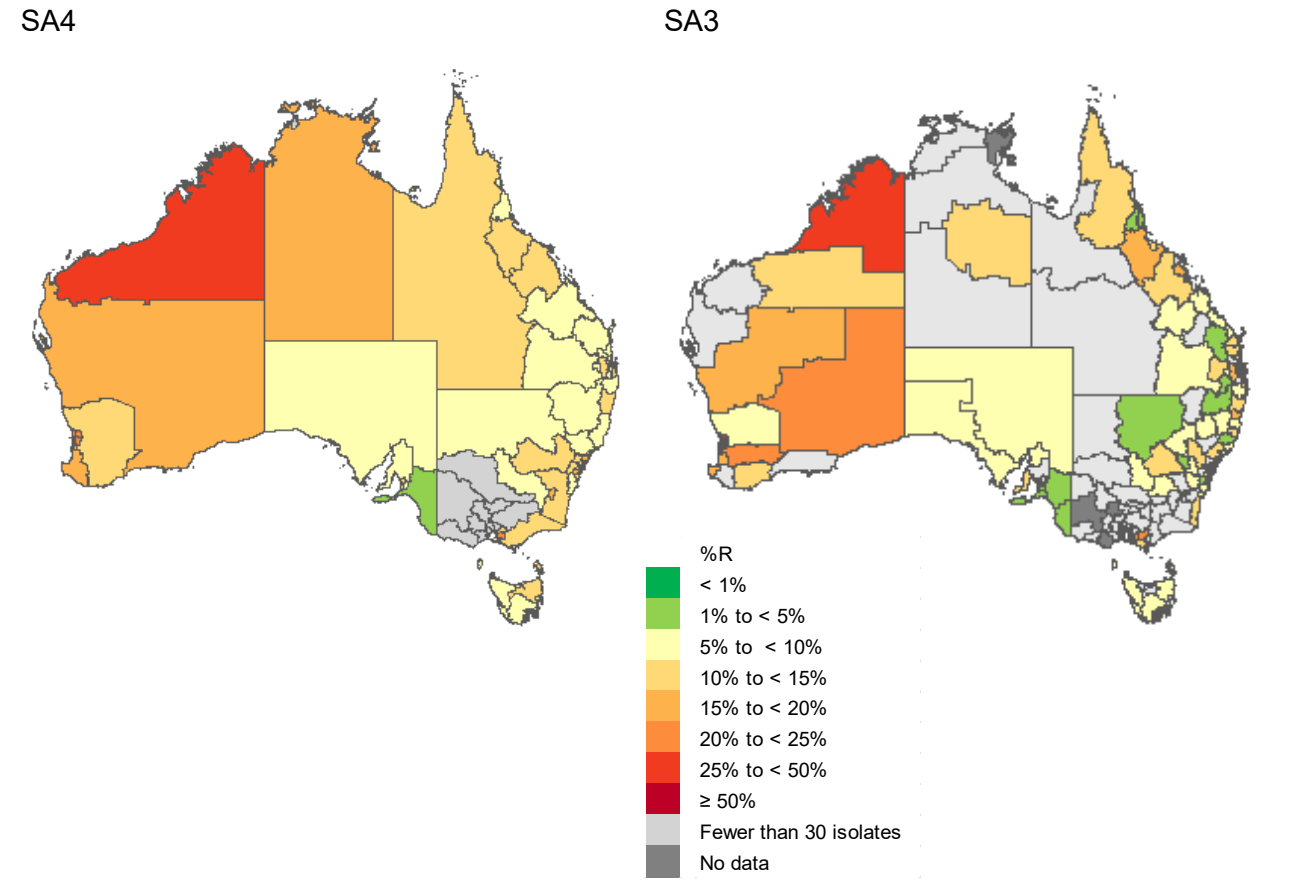




R = resistant
* Insufficient number of isolates (<30) to calculate percentage
Notes:
1. State and territory based on postcode of residence (where known). Data available from the NT were from NT residents who received pathology services interstate. Data from ACT pathology services were not available for 2023, except where ACT residents received pathology services interstate.
2. Fluoroquinolone resistance was examined using available antimicrobial susceptibility test data for ciprofloxacin (non-urine specimens) and norfloxacin (urine specimens).
3. Norfloxacin not available on the EUCAST Vitek® 2 antimicrobial susceptibility test panel commonly used by some laboratories.

Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Figure 15: Ciprofloxacin resistance in *Escherichia coli*, mapped to Australian SA4 and SA3 areas, APAS contributors, 2023



R = resistant; SA4 = Statistical Area Level 4; SA3 = Statistical Area Level 3

Notes:

1. SA4 and SA3 based on postcode of residence (where known). Data available from the NT were from NT residents who received pathology services interstate. Data from ACT pathology services were not available for 2023, except where ACT residents received pathology services interstate.
2. Fluoroquinolone resistance was examined using available antimicrobial susceptibility test data for ciprofloxacin (non-urine specimens) and norfloxacin (urine specimens).
3. Norfloxacin not available on the EUCAST Vitek® 2 antimicrobial susceptibility test panel commonly used by some laboratories.

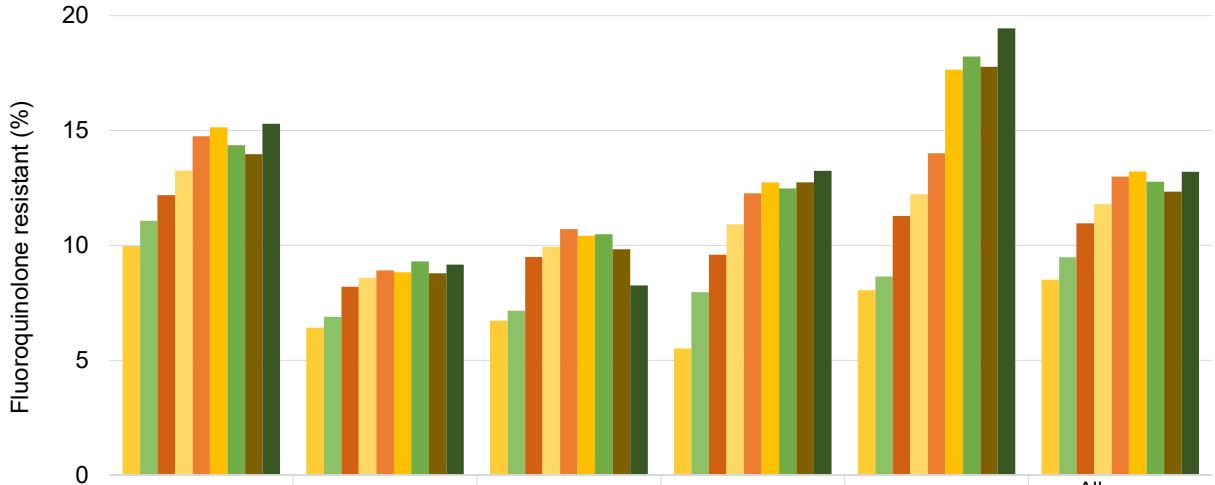
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Fluoroquinolone resistance in *Escherichia coli* by remoteness area

Figure 16 shows the trends in fluoroquinolone resistance in *E. coli* by remoteness area reported from all APAS contributors from 2015 to 2023. Data were analysed based on the known postcode of residence of the person from whom the specimen was taken (see Appendix 2).

A little under two-thirds (61.8%) of *E. coli* were isolated from patients residing in major Australian cities. Fluoroquinolone resistance was generally lower in inner and outer regional areas, and highest in very remote Australia. Proportions increased across all remoteness areas from 2015 to 2019 and stabilised from 2020. In *E. coli* isolates from patients residing in very remote Australia the proportion of fluoroquinolone resistance increased from 8.0% in 2015 to 19.4% in 2023 (Figure 16).

Figure 16: Percentage of *Escherichia coli* with fluoroquinolone resistance by remoteness area, APAS contributors, 2015–2023



	Major cities	Inner regional	Outer regional	Remote	Very remote	All areas combined*
2015, %	10.0	6.4	6.7	5.5	8.0	8.5
2016, %	11.1	6.9	7.2	8.0	8.6	9.5
2017, %	12.2	8.2	9.5	9.6	11.3	11.0
2018, %	13.3	8.6	9.9	10.9	12.2	11.8
2019, %	14.7	8.9	10.7	12.3	14.0	13.0
2020, %	15.1	8.8	10.4	12.7	17.6	13.2
2021, %	14.4	9.3	10.5	12.5	18.2	12.8
2022, %	14.0	8.8	9.8	12.7	17.8	12.3
2023, %	15.3	9.2	8.3	13.2	19.4	13.2
2015, n	58,242	22,816	14,477	3,394	2,572	101,501
2016, n	66,700	24,558	14,708	3,444	2,659	112,069
2017, n	69,781	23,508	11,683	2,648	2,437	110,057
2018, n	69,869	24,272	12,212	3,025	2,683	112,061
2019, n	78,292	26,589	12,836	2,748	2,434	122,899
2020, n	75,552	26,891	12,785	2,699	2,364	120,291
2021, n	79,445	30,134	14,343	2,629	2,278	128,829
2022, n	77,436	29,174	14,513	2,732	2,195	126,050
2023, n	61,043	22,845	9,120	2,138	1,507	96,653
Total, n	636,360	230,787	116,677	25,457	21,129	1,030,410

n = denominator for total number of isolates
Note: Remoteness area based on postcode of residence (where known).
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Methicillin resistance in *Staphylococcus aureus*

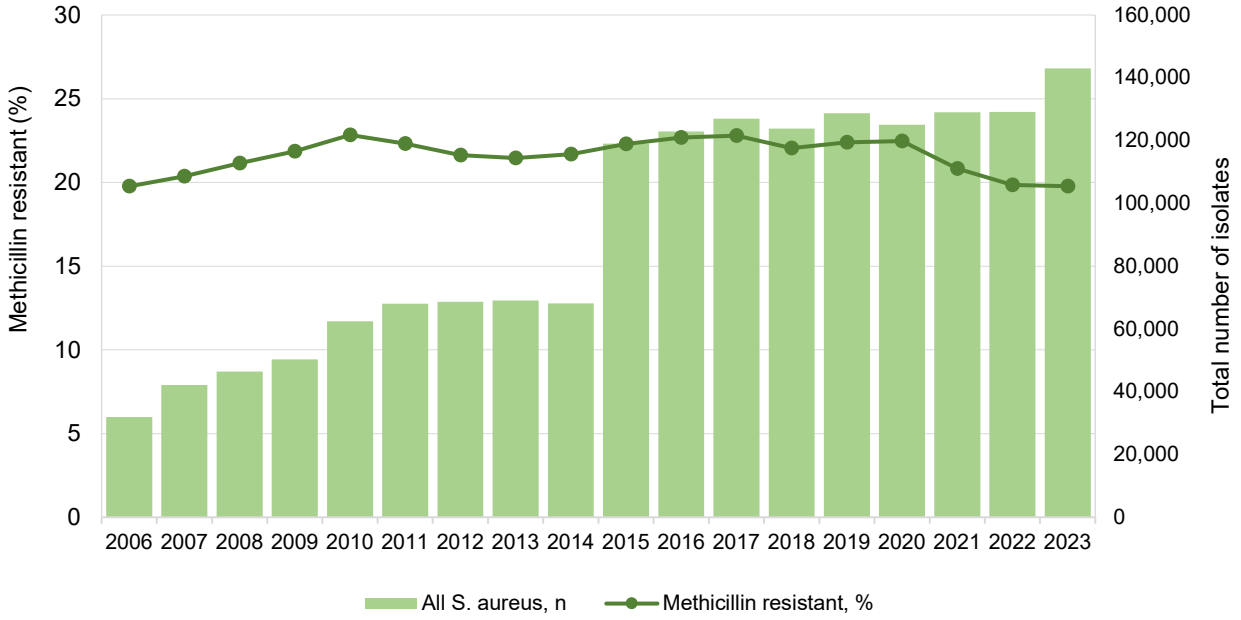
Staphylococcus aureus is a common pathogen that causes a wide variety of infections. Infections may be minor, such as boils, impetigo and wound infections; moderate, such as cellulitis; or serious, such as bone and joint infections, pneumonia, endocarditis and bacteraemia. *S. aureus* is also a common cause of healthcare-associated infection (HAI), especially surgical site infections, intravascular line infections with bacteraemia, and infections of prosthetic devices. Resistance to methicillin, referred to as methicillin-resistant *S. aureus* (MRSA), confers resistance to all β-lactam antimicrobials in community practice and almost all in hospital settings.

Many staphylococcal skin infections can be managed without antimicrobial therapy, but moderate and serious infections require treatment. First-line treatment is flucloxacillin (or dicloxacillin), or first-generation cephalosporins such as cefazolin or cefalexin for penicillin-allergic patients.

Between 2006 and 2023, there were 1,041,304 *S. aureus* isolates from the four long-term APAS contributor pathology services. Across all pathology services that contribute to APAS, including the four long-term contributors, data were available for 1,665,101 isolates over this period. See Appendices 1 and 2 for information about the pathology services that contribute to APAS.

Figure 17 shows the 18-year trend in methicillin resistance in *S. aureus* reported by all APAS contributors between 2006 and 2023. Methicillin resistance has remained stable between 20–23% during this period.

Figure 17: Percentage of *Staphylococcus aureus* with methicillin resistance, APAS contributors, 2006–2023



n = denominator for total number of isolates
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

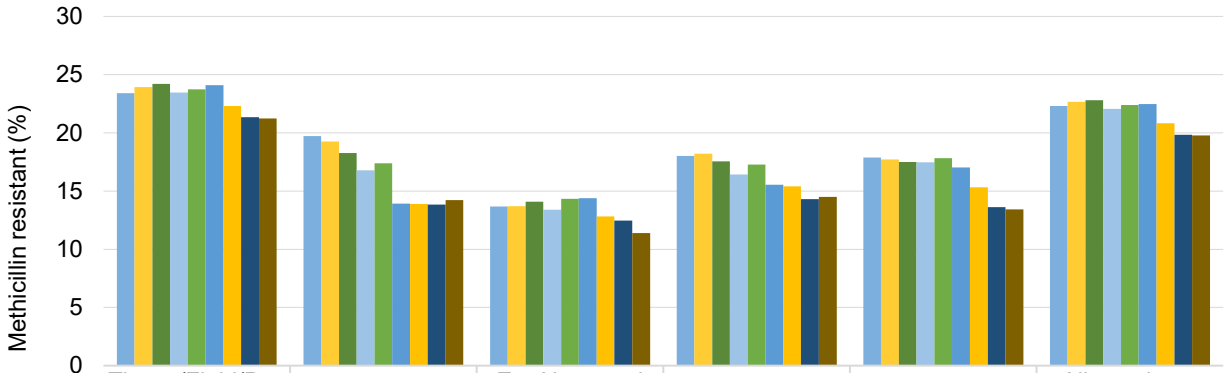
For analyses of 2015 to 2023 data for this report, there were 1,149,190 *S. aureus* isolates from all APAS contributors.

Methicillin resistance in *Staphylococcus aureus* by specimen type

A substantial majority (80.9%) of *S. aureus* isolates were from tissue/fluid/pus/prosthesis specimens, for which the highest proportion of MRSA was observed. Isolates from the ear nose and throat had the lowest proportion of MRSA (Figure 18). For more information on specimen types, see Appendix 2.

Across all specimen types, methicillin resistance was stable at around 22% from 2015 to 2020. There was a slight downward trend to 19.8% in 2022 and 2023. There was a decreasing trend in MRSA isolated from blood specimens from 2016.

Figure 18: Percentage of methicillin-resistant *Staphylococcus aureus* by specimen source, APAS contributors, 2015–2023



	Tissue/Fluid/Pus /Prosthesis	Respiratory	Ear Nose and Throat	Blood Culture	Other*	All specimen types
2015, %	23.4	19.7	13.7	18.0	17.9	22.3
2016, %	23.9	19.3	13.7	18.2	17.7	22.7
2017, %	24.2	18.3	14.1	17.6	17.5	22.8
2018, %	23.5	16.8	13.4	16.4	17.5	22.1
2019, %	23.7	17.4	14.3	17.3	17.8	22.4
2020, %	24.1	13.9	14.4	15.6	17.0	22.5
2021, %	22.3	13.9	12.8	15.4	15.3	20.8
2022, %	21.4	13.8	12.5	14.3	13.6	19.8
2023, %	21.2	14.2	11.4	14.5	13.4	19.8
2015, n	96,809	6,569	5,305	4,643	5,691	119,017
2016, n	99,473	6,928	5,551	4,896	6,019	122,867
2017, n	102,609	7,373	5,839	4,916	6,265	127,002
2018, n	100,044	6,799	5,525	5,040	6,397	123,805
2019, n	103,713	7,122	5,599	5,574	6,686	128,694
2020, n	102,076	6,016	5,040	5,504	6,409	125,045
2021, n	104,699	6,145	5,426	5,892	6,858	129,020
2022, n	116,574	5,729	7,143	6,142	7,377	142,965
2023, n	116,574	5,729	7,143	6,142	7,377	142,965
Total, n	930,027	58,829	51,198	48,645	58,802	1,147,501

n = denominator for total number of isolates

* Other refers to cerebrospinal fluid, ear nose and throat, enteric, and genital specimens

Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

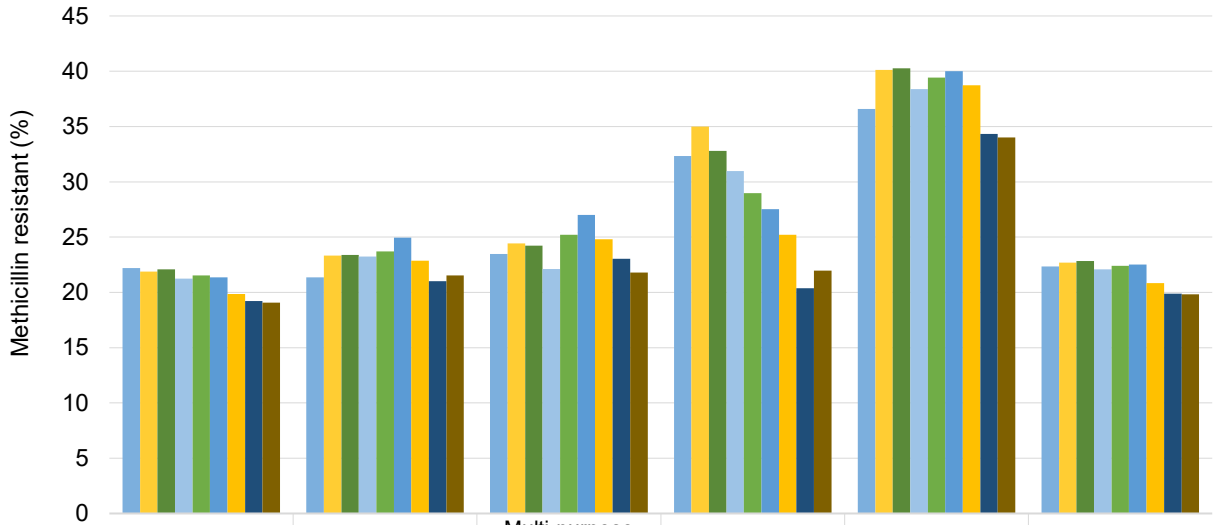
Methicillin resistance in *Staphylococcus aureus* by setting

Almost all *S. aureus* isolates reported by APAS contributors from 2015 to 2023 were from hospitals (public and private) (76.0%) and community settings (19.8%) (Figure 19).

The proportion of MRSA from hospital settings was stable between 2015 and 2020 (range 21.3% to 22.2%). From 2021, there was a slight downward trend to 19.1% in 2023. (Figure 19). The proportion of MRSA in isolates from the community setting increased slightly from 21.4% in 2015 to 24.9% in 2020 and decreased to 21.5% in 2023.

MRSA rates were highest in isolates from other settings (mostly corrective services) across all years, and in aged care homes until 2021. Despite these settings contributing only 2.3% of all *S. aureus* isolates captured by APAS, it suggests that these settings are important reservoirs for MRSA. In aged care homes, both the total number of isolates and proportion of MRSA declined from 2016 (Figure 19).

Figure 19: Percentage of methicillin-resistant *Staphylococcus aureus* by setting, APAS contributors, 2015–2023



	Hospitals	Community	Multi-purpose service	Aged care home	Other settings*	All settings
2015, %	22.2	21.4	23.5	32.3	36.6	22.3
2016, %	21.9	23.3	24.4	35.0	40.1	22.7
2017, %	22.1	23.4	24.2	32.8	40.3	22.8
2018, %	21.3	23.2	22.1	31.0	38.4	22.1
2019, %	21.5	23.7	25.2	29.0	39.4	22.4
2020, %	21.3	24.9	27.0	27.5	40.0	22.5
2021, %	19.9	22.9	24.8	25.2	38.7	20.8
2022, %	19.2	21.0	23.0	20.4	34.3	19.9
2023, %	19.1	21.5	21.8	22.0	34.0	19.8
2015, n	86,039	27,872	2,078	968	1,777	118,734
2016, n	88,556	28,879	2,097	977	2,098	122,607
2017, n	92,357	28,917	2,193	854	2,334	126,655
2018, n	92,338	26,215	1,935	562	2,442	123,492
2019, n	97,423	25,660	2,272	497	2,542	128,394
2020, n	96,255	23,224	2,403	396	2,467	124,745
2021, n	101,340	21,772	2,797	349	2,479	128,737
2022, n	101,915	21,401	2,680	314	2,412	128,722
2023, n	113,117	23,495	2,981	287	2,667	142,547
Total, n	869,340	227,435	21,436	5,204	21,218	1,144,633

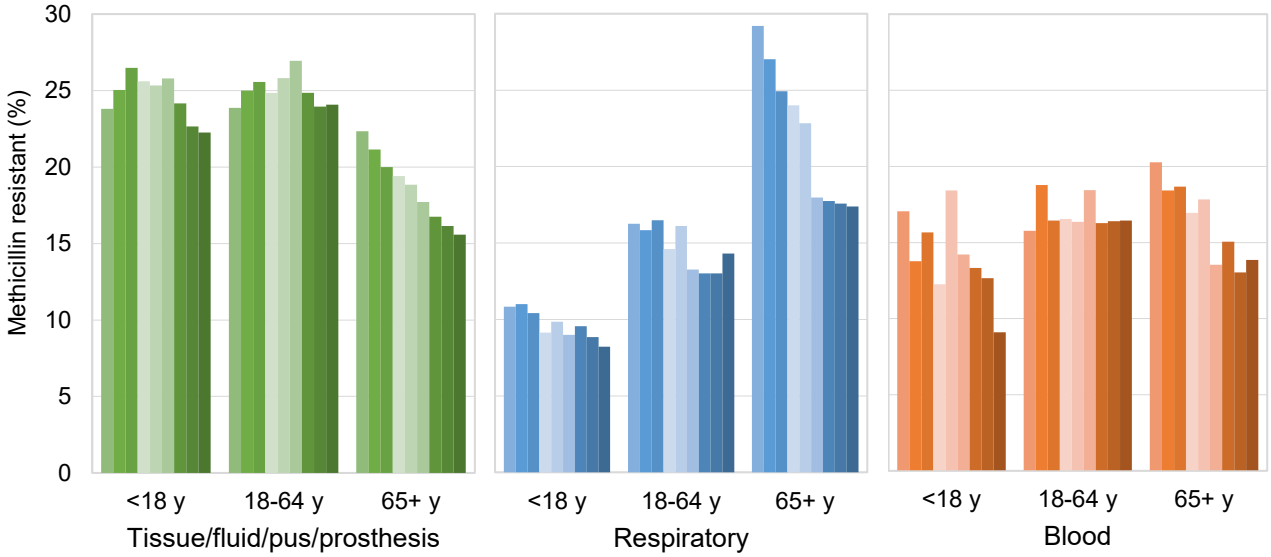
n = denominator for total number of isolates
* Other settings were predominantly corrective services
Note: Hospitals = public and private.
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Methicillin resistance in *Staphylococcus aureus* by age group

Of *S. aureus* isolates collected from all APAS contributors from 2015 to 2023, a slim majority (51.4%) were from the 18–64 years age group and a small proportion (18.5%) were from paediatric patients (aged less than 18 years).

The proportion of *S. aureus* with methicillin resistance was lowest among paediatric patients with respiratory infections (Figure 20). A decreasing trend in the MRSA rate was observed in patients aged 65 years and over across all specimen types. There was little difference in the proportion of MRSA observed in the three age groups for *S. aureus* isolated from blood. However, in 2023, the MRSA rate was 1.6-fold lower in paediatric patients (9.1%) compared to adults (14.9%).

Figure 20: Methicillin-resistant *Staphylococcus aureus*, by specimen source and age group, APAS contributors, 2015–2023



2015, %	23.8	23.9	22.3	10.8	16.3	29.2	17.1	15.8	20.3
2016, %	25.0	25.0	21.1	11.0	15.8	27.0	13.8	18.8	18.4
2017, %	26.5	25.6	20.0	10.4	16.5	24.9	15.7	16.4	18.7
2018, %	25.6	24.8	19.4	9.1	14.6	24.0	12.3	16.5	17.0
2019, %	25.3	25.8	18.9	9.9	16.1	22.8	18.4	16.4	17.8
2020, %	25.8	27.0	17.7	9.0	13.3	18.0	14.2	18.4	13.5
2021, %	24.2	24.9	16.7	9.6	13.0	17.8	13.3	16.3	15.1
2022, %	22.7	23.9	16.1	8.9	13.0	17.6	12.7	16.4	13.0
2023, %	22.3	24.1	15.6	8.2	14.3	17.4	9.1	16.4	13.9
2015, n	19,391	49,679	27,689	1,062	3,272	2,222	346	2,062	2,235
2016, n	19,495	52,334	27,605	1,009	3,414	2,491	363	2,105	2,426
2017, n	20,178	54,109	28,264	1,267	3,580	2,504	351	2,038	2,528
2018, n	18,917	53,228	27,844	1,161	3,347	2,270	359	2,194	2,483
2019, n	18,955	55,296	29,398	1,137	3,543	2,431	380	2,347	2,844
2020, n	17,843	55,008	29,186	1,102	3,048	1,859	387	2,228	2,881
2021, n	18,647	54,895	31,120	1,088	3,119	1,932	405	2,347	3,136
2022, n	18,330	54,183	31,474	1,028	3,059	2,053	403	2,310	3,322
2023, n	21,865	60,539	34,143	1,021	2,837	1,864	396	2,269	3,478
Total, n	173,621	489,271	266,723	8,854	26,382	17,762	3,390	19,900	25,333

n = denominator for total number of isolates; y = years of age
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

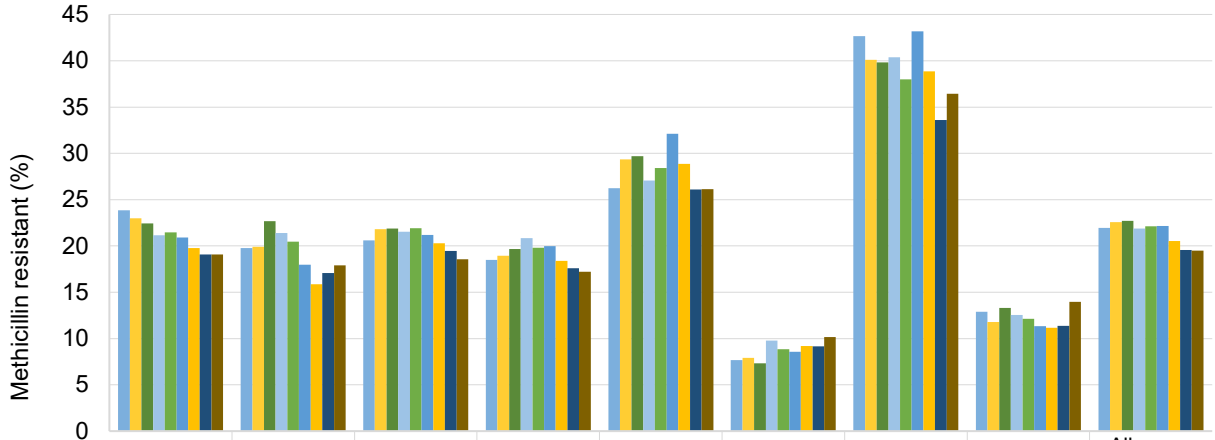
Methicillin resistance in *Staphylococcus aureus* by state and territory

Figures 21–23 show the trends in MRSA isolates by state and territory reported from all APAS contributors from 2015 to 2023, with 2023 data mapped to Australian SA3 areas (Figure 23). Data were analysed based on the known postcode of residence of the person from whom the specimen was taken (see Appendix 2).

The number of *S. aureus* isolates and the prevalence of MRSA differs substantially between states and territories. In 2023, overall MRSA rates ranged from 10.2% in Tasmania to 36.4% in the NT. There was a downward trend in MRSA rates across all states except Tasmania since 2015 (Figure 21).

With consideration to specimen type in 2023, the highest proportions of methicillin resistance were observed in *S. aureus* isolates from tissue/fluid/pus/prosthesis in patients residing in the NT followed by WA. However, there was vast difference between the number of isolates analysed (Figure 22).

Figure 21: Percentage of methicillin-resistant *Staphylococcus aureus* by state and territory, APAS contributors, 2015–2023



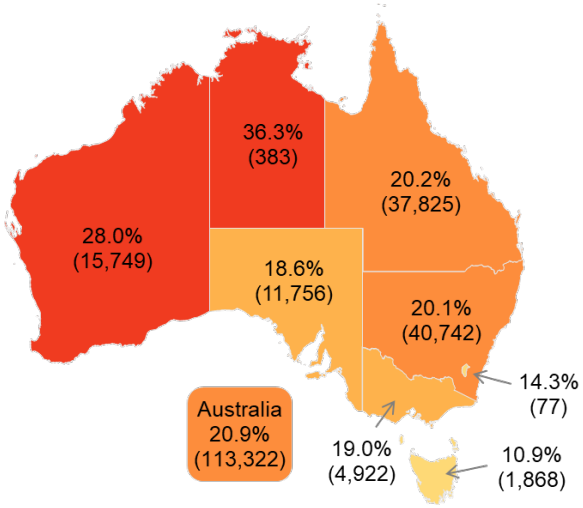
	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	All areas combined*
2015, %	23.9	19.8	20.6	18.5	26.2	7.7	42.7	12.9	21.9
2016, %	23.0	19.9	21.8	18.9	29.4	7.9	40.1	11.8	22.6
2017, %	22.4	22.7	21.9	19.7	29.7	7.3	39.8	13.3	22.7
2018, %	21.1	21.4	21.5	20.8	27.1	9.8	40.4	12.5	21.9
2019, %	21.5	20.5	21.9	19.8	28.4	8.8	38.0	12.1	22.1
2020, %	20.9	18.0	21.2	20.0	32.1	8.6	43.2	11.3	22.2
2021, %	19.8	15.9	20.3	18.4	28.9	9.2	38.8	11.2	20.5
2022, %	19.1	17.1	19.4	17.6	26.1	9.1	33.6	11.4	19.6
2023, %	19.1	17.9	18.6	17.2	26.1	10.2	36.4	14.0	19.5
2015, n	33,283	4,817	35,445	15,433	19,023	1,278	225	2,236	111,740
2016, n	37,338	5,147	37,327	16,360	18,875	1,431	222	2,337	119,037
2017, n	40,276	5,284	38,999	16,512	19,306	1,376	226	2,422	124,401
2018, n	40,099	5,284	38,423	14,731	18,006	1,453	379	2,455	120,830
2019, n	43,532	5,549	39,663	14,286	18,144	1,437	445	2,421	125,477
2020, n	43,288	4,777	39,281	13,273	17,441	1,389	505	2,248	122,202
2021, n	44,564	5,179	41,255	13,392	16,499	2,534	556	2,385	126,364
2022, n	44,962	5,541	41,885	13,267	15,847	2,373	384	2,076	126,335
2023, n	50,003	6,463	46,769	14,428	18,459	2,541	428	93	139,184
Total, n	377,345	48,041	359,047	131,682	161,600	15,812	3,370	18,673	1,115,570

n = denominator for total number of isolates
* Where postcode of residence was known
Notes:
1. State and territory based on postcode of residence. Data available from the NT were from NT residents who received pathology services interstate. Data from ACT pathology services were not available for 2023, except where ACT residents received pathology services interstate.
2. Postcode of residence was not available in 2015 for NSW Health Pathology South Eastern Sydney Local Health District.

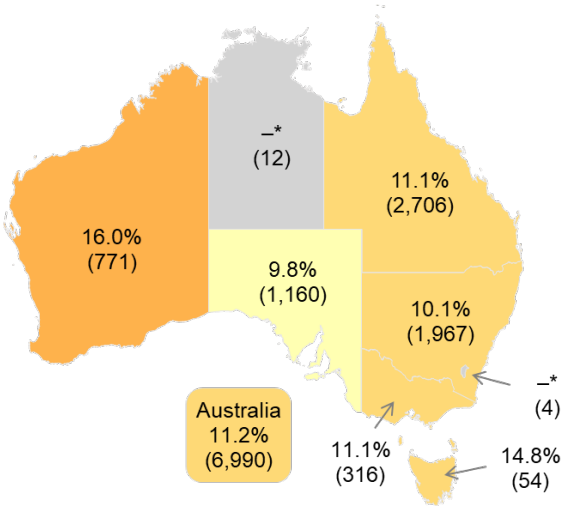
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Figure 22: Methicillin resistance in *Staphylococcus aureus*, by state and territory and specimen source, APAS contributors, 2023

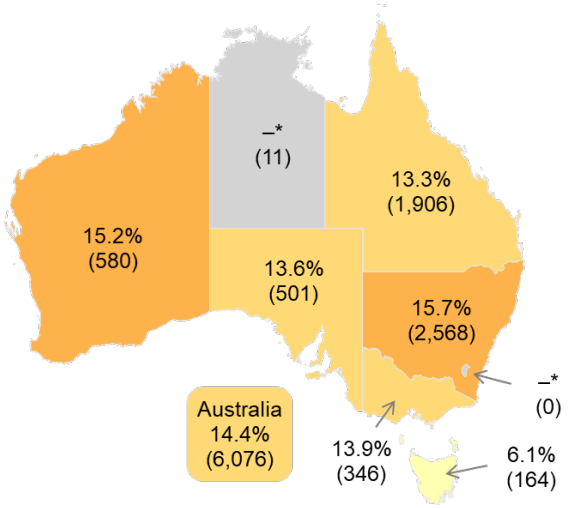
Tissue/fluid/pus/prosthesis



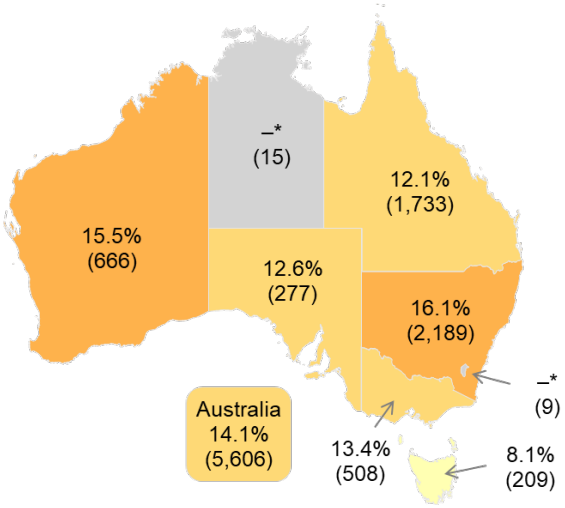
Ear nose and throat

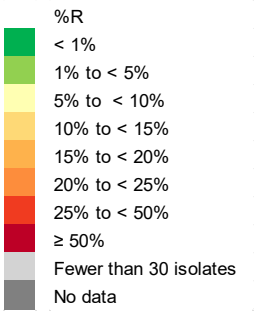


Blood



Respiratory

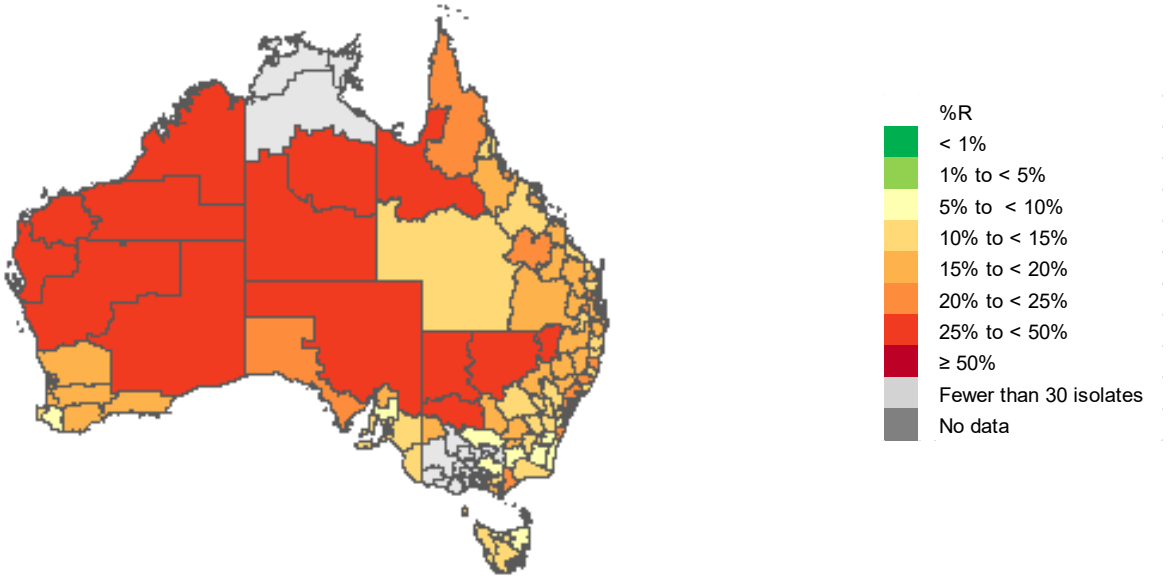




R = resistant
* Insufficient number of isolates (<30) to calculate percentage
Note: State and territory based on postcode of residence (where known). Data available from the NT were from NT residents who received pathology services interstate. Data from ACT pathology services were not available for 2023, except where ACT residents received pathology services interstate.
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

In 2023, the highest rates of MRSA were observed in WA and the NT: Kimberly (44.1%), Alice Springs (39.3%), West Pilbara (39.0%), Gascoyne (38.4%), and East Pilbara (37.5%). The lowest rate was observed in Tasmania in Hobart Inner (4.9%) (Figure 23).

Figure 23: Methicillin resistance in *Staphylococcus aureus*, mapped to Australian SA3 areas, APAS contributors, 2023



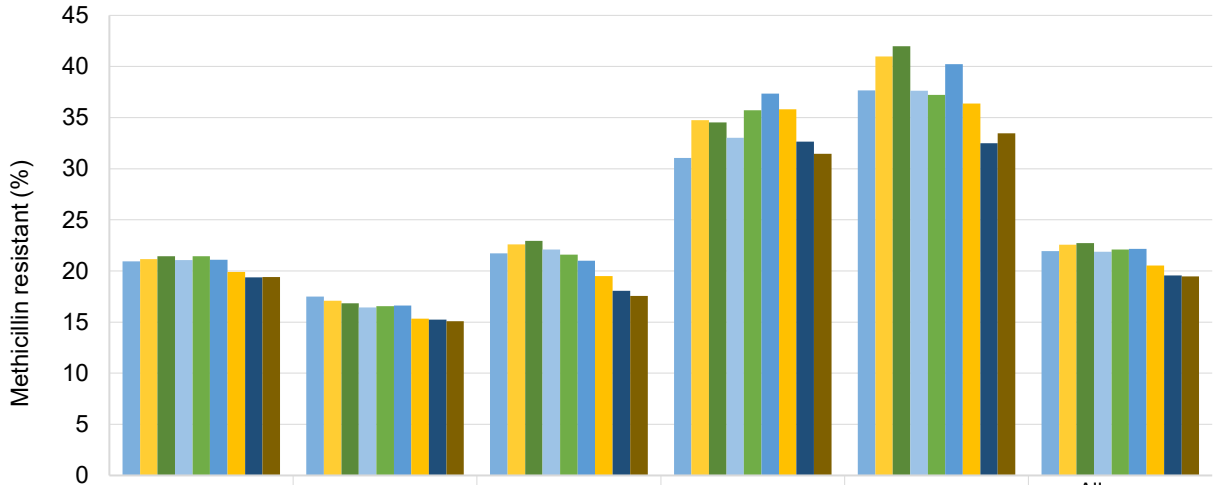
R = resistant; SA3 = Statistical Area Level 3
Note: SA3 based on postcode of residence (where known). Data available from the NT were from NT residents who received pathology services interstate. Data from ACT pathology services were not available for 2023, except where ACT residents received pathology services interstate.
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Methicillin resistance in *Staphylococcus aureus* by remoteness area

Figure 24 shows the trends in MRSA by remoteness area as reported from all APAS contributors from 2015 to 2023. Data were analysed based on the known postcode of residence of the person from whom the specimen was taken (see Appendix 2).

Just over one-half (52.5%) of *S. aureus* isolates were from people residing in major Australian cities. However, methicillin resistance was more prevalent in remote and very remote areas of Australia than in major cities and inner regional areas (Figure 19). MRSA rates have declined slightly in isolates from patients residing in outer regional Australia since 2017. There has also been an overall downward trend in MRSA rates in isolates from people residing in remote (since 2020) and very remote Australia (since 2017).

Figure 24: Percentage of methicillin resistant *Staphylococcus aureus* by remoteness area, APAS contributors, 2015–2023



	Major cities	Inner regional	Outer regional	Remote	Very remote	All areas combined
2015, %	21.0	17.5	21.7	31.1	37.7	21.9
2016, %	21.2	17.1	22.6	34.8	41.0	22.6
2017, %	21.4	16.8	22.9	34.5	42.0	22.7
2018, %	21.1	16.4	22.1	33.0	37.6	21.9
2019, %	21.4	16.5	21.6	35.7	37.2	22.1
2020, %	21.1	16.6	21.0	37.4	40.2	22.2
2021, %	19.9	15.3	19.5	35.8	36.4	20.5
2022, %	19.4	15.3	18.1	32.6	32.5	19.6
2023, %	19.4	15.1	17.6	31.5	33.5	19.5
2015, n	56,956	23,919	17,748	6,005	7,141	111,769
2016, n	61,436	24,698	18,825	6,341	7,751	119,051
2017, n	64,420	25,879	19,607	6,702	7,820	124,428
2018, n	63,600	25,104	18,642	6,156	7,348	120,850
2019, n	66,855	25,831	19,138	6,326	7,340	125,490
2020, n	64,965	24,929	18,751	6,085	7,484	122,214
2021, n	66,343	27,105	19,969	6,028	6,926	126,371
2022, n	67,695	27,147	19,197	6,084	6,223	126,346
2023, n	73,918	30,323	21,194	6,734	7,022	139,191
Total, n	586,188	234,935	173,071	56,461	65,055	1,115,710

n = denominator for total number of isolates
Note: Remoteness area based on postcode of residence (where known).
Source: APAS (NSW, Vic, Qld, SA, WA, Tas, ACT) – see Table A1

Conclusions

Antimicrobials are an integral component of healthcare delivery and need to be readily available and effective. The emergence of antimicrobial resistance (AMR) and consequent reduction in the efficacy of antimicrobials continues to be one of the biggest challenges to the provision of safe, high-quality health services in Australia and internationally. AMR is a critical risk to patient safety as it reduces the number of antimicrobials available to treat and prevent infections. There are also cost implications and risks associated with adverse effects from antimicrobial use, including side effects.

Multidrug-resistant organisms (MROs), including VRE, fluoroquinolone-resistant *E. coli* and MRSA, pose a greater risk given these infections are associated with increased morbidity and mortality.

This report provides some insight to the epidemiology of each MRO included in the analyses. There are opportunities to control the upward trend of AMR and improve the safety of care provided to Australians across acute, primary and community, and aged care settings. Strategies to achieve this include the implementation and improvement of antimicrobial prescribing guidelines, and antimicrobial stewardship (AMS) and infection prevention and control programs. This is especially important for vulnerable Australians including hospitalised patients, aged care home residents and First Nations communities.

The Commission will continue to work with developers of antimicrobial prescribing guidelines, including Therapeutic Guidelines and other expert groups, to ensure they are evidence-based and informed by current Australian AMR data. Development of local prescribing recommendations may become important in view of the variation in AMR patterns across different geographical and service delivery settings.

APAS contributors have ready access to data and functionality to produce antibiograms, which provide an overview of antimicrobial susceptibilities for specific microorganisms. Antibiograms can inform local empiric antimicrobial recommendations and the appropriate adaptation of national guidelines. Local and national guidelines also inform the management of antimicrobial formularies and their associated restriction rules and approval processes. These interventions are key actions for AMS programs and support the implementation of National Safety and Quality Standards for acute and primary and community healthcare services and aged care services.

The report findings also highlight the importance of effective infection prevention and control strategies. Appropriate infection prevention and control programs support the safe delivery of care provided across healthcare settings, within the framework of National Safety and Quality Standards and the *Australian Guidelines for the Prevention and Control of Infections in Healthcare*. In addition to protecting consumers, these programs also work to protect clinicians and visitors in healthcare settings by minimising the risk of transmission of infections and AMR, and by reducing infections so that fewer antimicrobials are used and there is less pressure on AMR.

This report highlights the importance of ongoing surveillance of AMR and infections, and the value of APAS and the Antimicrobial Use and Resistance in Australia (AURA) surveillance program in monitoring the emergence of, and trends in, AMR. The Commission will continue to collaborate with the Australian Government Department of Health and Aged Care, state and territory health departments, and private pathology services to enhance national surveillance of AMR and increase utility of AMR data to inform strategies for its prevention and containment.

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Appendix 1: About APAS

Australian Passive AMR Surveillance (APAS) was established by the Commission in collaboration with Queensland Health in 2015 as a component of the Antimicrobial Use and Resistance in Australia (AURA) surveillance program.

Funding for APAS is provided by the Australian Government Department of Health and Aged Care, with contributions from the states and territories as part of the collection and analysis of their data.

Passive antimicrobial resistance (AMR) surveillance involves the extraction of routine susceptibility testing results from laboratory information systems. APAS uses the Queensland Health OrgTRx information technology infrastructure to collect, analyse and report on de-identified patient-level AMR data contributed by 10 public and private pathology services across Australia. The laboratories that are part of these pathology services detect AMR in isolates referred from public and private hospitals, aged care homes and community settings. Initially, data were captured from January 2015 from all contributing laboratories. Subsequently, historical data have been uploaded by several pathology services. APAS now includes more than 115 million records from 2005 to May 2024.

In addition to national reporting by the Commission, APAS participants have timely access to their own data, which enables comprehensive reporting of local AMR in the form of:

- Longitudinal datasets for specified organism–antimicrobial combinations
- Cumulative antibiograms showing rates of resistance for a range of organisms from a specified specimen type in a selected time period
- Tabulations showing the resistance profiles of organism strains isolated during a selected time period
- Reporting for individual units within hospitals or health services, or at a statewide level.

The Commission thanks the pathology services listed in Table A1 that currently contribute data to APAS.

Table A1: APAS contributor pathology services, July 2024

State/Territory	Pathology service	Notes
New South Wales	NSW Health Pathology*†	All NSW Health Pathology public laboratory services.
Victoria	Alfred Health	Public health service catchment for Alfred Health.
	Monash Health	Public health service catchment for Monash Health.
Queensland	Mater Pathology Brisbane*	Queensland public and private patients.
	Pathology Queensland*	All Queensland Health public hospitals and health services.
South Australia	SA Pathology*	Public health catchments for South Australia.
Western Australia	PathWest Laboratory Medicine	All Western Australia public hospitals.
Tasmania	Launceston General Hospital§	Combined data from these two contributing laboratories capture most public patient data for Tasmania.
	Royal Hobart Hospital	
Australian Capital Territory	ACT Pathology#	All public and some private ACT health services.

* NSW Health Pathology (South Western Sydney and Sydney Local Health Districts), Mater Pathology Brisbane, Pathology Queensland and SA Pathology since 2006
† NSW Health Pathology West since 2010
§ Launceston General Hospital since 2021
\# No data from ACT Pathology for 2023
Note: Data are only available from the Northern Territory for residents who received pathology services interstate.

Appendix 2: Methodology

Data extraction

Data were extracted from the Australian Passive AMR Surveillance (APAS) system on 1 May 2024. All data analyses for this report were performed using Microsoft Excel 365.

Results from isolates detected in infection control and environmental sampling were excluded because they were not representative of isolates from clinical infections.

Pathology services

At the time of data extraction, the 10 pathology services listed in Table A1 were contributing data to APAS.

APAS data report on antimicrobials tested using European Committee on Antimicrobial Susceptibility Testing (EUCAST)[20], Clinical and Laboratory Standards Institute (CLSI)[21, 22], or Calibrated Dichotomous Sensitivity (CDS)[23] methods. Pathology services in Victoria, Queensland, South Australia (SA), Tasmania, and the Australian Capital Territory (ACT) use EUCAST; PathWest uses CLSI; NSW Health Pathology services use CLSI, CDS, and EUCAST.

APAS provides categorical data (susceptible, intermediate, resistant) based on interpretive criteria. It is acknowledged that there are differences in the interpretation of results obtained by each method, and the Commission is working with stakeholders to promote alignment with a single method in Australia.

Representativeness

Historical data were available from 2006 for the four pathology services that have continuously contributed to APAS: NSW Health Pathology (South Western Sydney and Sydney Local Health Districts), Mater Pathology Brisbane, Pathology Queensland and SA Pathology. All pathology services that contribute to APAS are listed in Table A1.

Data from ACT Pathology were not available since November 2022 for the analyses for this report, pending re-integration of the service with APAS following implementation of a new laboratory information system in late 2022. The data for 2023 will be available when the re-integration project is completed.

It is important to note that, for historical data, there may have been changes since 2006 in the number of facilities from which the pathology services have received isolates, and numbers are likely to have varied from year to year, along with laboratory criteria and methods. There have also been breakpoint changes over time.

In addition, several public laboratories have been reconfigured or renamed during the period to which the analyses relate; these changes were not addressed in detail in this report.

Jurisdictions with state- or territory-wide public pathology services (Queensland, SA, Western Australia, New South Wales [NSW] and the ACT) were most representative. Queensland was comprehensively represented due to the participation in APAS by Mater Pathology Brisbane. NSW has transitioned all public laboratories to the statewide NSW Health Pathology service; the laboratory names used in this report reflect current naming conventions, and all NSW Health Pathology laboratories contributed data, including historical data from 2010 to APAS from May 2024.

Data from Victoria were limited as there were only two contributing sites. Data were not available from the Northern Territory.

Some public laboratories undertake testing for private facilities and in the community.

Isolates and specimen types

Data were only included where there were at least 30 isolates for each analysis. Analyses were conducted only when the proportion of isolates that were tested against a single antimicrobial was at least 75%.

The results of duplicate testing were included in the data collected for APAS. Duplicate testing means that the same bacterial strain was tested and reported from repeated specimens and similar specimens from a single infection episode. This was appropriate clinical laboratory practice from a patient management perspective. The impact of these duplicates was minimised for analyses of APAS data by using algorithms based on resistance patterns, and selected time periods for which duplicates were not counted. Only the first isolate for the first specimen of each specimen type per year was included in the dataset for analyses. A repeat isolate from the same specimen type was not included.

For APAS analysis, specimen types are allocated into nine categories: acid fast bacilli, blood culture, cerebrospinal fluid, ear, nose and throat, enteric, genital, respiratory, tissue/fluid/pus/prosthesis, and urine. Respiratory specimens include sputum, lung aspirates, tracheal aspirates and endotracheal aspirates as well other unknown primary sites, and some pathology services do not provide the primary site from which the respiratory specimen was taken.

For *Escherichia coli*, prevalence of fluoroquinolone resistance was examined using available antimicrobial susceptibility test data for ciprofloxacin (non-urine specimens) and norfloxacin (urine specimens).

Setting

Where available, the settings from which the isolates were obtained were included in the analyses. These were assigned by the pathology service that contributed the data for the specimen and include aged care, community, multi-purpose service, public hospital, and private hospital. Facilities may also be categorised as other, such as correctional services.

It is important to note that, for historical data, there may have been changes since 2006 in the range and acuity of services offered in some settings, particularly those categorised as multi-purpose services. Information about each of these changes is not routinely available.

In this report, aged care home and multi-purpose service data were sometimes combined with data from settings other than hospitals or community due to a smaller sample size and limited representativeness across states and territories and the potential impact of a change in referral patterns for one large pathology service for this setting from mid-2018.

Location

The postcode of residence of the person from whom the specimen was taken, where known, was used to stratify the data in terms of location by state or territory, and local area and remoteness using the ABS Australian Statistical Geography Standard (ASGS).[24,25]

Main Structure and Greater Capital City Statistical Areas has seven hierarchical levels including states and territories and Statistical Area Levels 4 and 3 (SA4 and SA3). SA4 and SA3 create a standard framework for the analysis of geographical data at a regional level through clustering groups that have similar regional characteristics. SA4s are the largest sub-state regions, which are formed by aggregated SA3s.

The Remoteness Areas Structure within the ASGS divides Australia into five categories of remoteness on the basis of a measure of relative access to services. The five Remoteness Areas for Australia are major cities, inner regional, outer regional, remote and very remote.

Data characteristics

APAS data differ from targeted antimicrobial resistance surveillance data in that a smaller range of agents are tested, there are varied antimicrobial testing and reporting practices, and three different testing systems are used in Australia.

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