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Contents

Executive Summary

This report provides analyses of data on confirmed critical antimicrobial resistances (CARs) submitted to the National Alert System for Critical Antimicrobial Resistances (CARAlert) for 2021, and trend data between 2017 and 2021. These data come from 28 confirming laboratories with at least one confirming laboratory in each state and territory. In 2021, CARs were confirmed from 70 originating laboratories.

There was an overall 18% decrease of CARs reported between 2020 (*n* = 1,586) and 2021 (*n* = 1,295). Carbapenemase-producing *Enterobacterales* (CPE) continue to be of concern as this CAR poses a significant risk to patient safety. Bacteria that produce carbapenemase enzymes are almost always resistant to other important antibiotic classes, such as other β-lactams, β-lactamase inhibitor combinations, fluoroquinolones and aminoglycosides. This means that effective treatment options for infections may be limited, and lengths of stay for hospital admissions may increase.

National overview of key findings: 2021 compared to 2020

- CPE (including those with ribosomal methyltransferase or transmissible colistin resistance) was the most frequently reported CAR (600/1,295, 46%) in 2021, followed by daptomycin-nonsusceptible *Staphylococcus aureus* (DNSA) (265/1,295, 20%)
- The total number of CPE (either alone or in combination with other CARs) reported in 2021, compared to 2020, decreased by 7% (*n* = 600 in 2021; *n* = 645 in 2020). The decrease was mostly seen in Victoria; slight increases were seen in Queensland and South Australia
- There was an increase in the number of reports of carbapenemase-producing *Pseudomonas aeruginosa* (*n* = 68 in 2021; *n* = 44 in 2020, up 55%). The majority of reports were from New South Wales (48/68, 71%), and just over 1 in 3 (17/48, 35%) were from a single institution
- There was a ten-fold decrease in the overall number of reports of multidrug-resistant (MDR) *Shigella* species (*n* = 30 in 2021; *n* = 298 in 2020), most notably in New South Wales (*n* = 7 in 2021; *n* = 169 in 2020, down 96%)
- There was a decrease in the number of ceftriaxone-nonsusceptible *Salmonella* species (*n* = 24 in 2021; *n* = 32 in 2020, down 25%)
- There were eight reports of MDR *Mycobacterium tuberculosis* in 2021, compared to 18 reports in 2020
- Excluding *Neisseria gonorrhoeae*, where the setting was known, the majority of CARs were reported from public hospitals (664/1,007, 66%). There were 189 (19%) CARs reported from community settings, 98 (10%) from private hospitals, and 56 (5%) from aged care homes.

Implications for patient and community safety

Rates of carbapenemase-producing *Enterobacterales* in Australian hospitals

Enterobacterales commonly cause urinary tract, biliary tract and other intra-abdominal infections, and blood stream infections. Patients are likely to be affected by CPE predominantly where they have been hospitalised for a range of conditions.

There was a 7% decrease in the number of carbapenemase- and/or ribosomal methyltransferase-producing *Enterobacterales* reports in 2021 compared to 2020 (*n* = 600 in 2021; *n* = 645 in 2020). There has been a gradual decline in reports of this CAR between January 2019 and November 2020. Numbers increased slightly in the first half of 2021 but have remained steady for the rest of the year. Factors that may have contributed to this decline include improvements in recognition and infection control efforts over this period.

One-fifth of hospitals that reported CPE in 2021 did so for the first time (26/130, 20%). This CAR has also contributed to invasive disease in Australian patients of all ages. In 2021, 1 in 12 reports from clinical specimens were from blood. Eighty-eight percent (518/592) of all CPE were from hospital settings, where the setting was known.

Carbapenemase types identified in Australia to date primarily include IMP, NDM and OXA-48-like. Reports of KPC types increased in 2021, with reports from four jurisdictions, most were from one institution (Victoria [6], New South Wales [1], Queensland [1] and Western Australia [1]). The range and number of CPE types will continue to evolve because of changing local and global epidemiology. Each carbapenemase type has a slightly different spectrum of activity against different β-lactam antimicrobials. Typing of CPE is important for supporting appropriate antimicrobial prescribing to treat infections caused by a CPE.

Changes in community-onset critical antimicrobial resistances

Infections caused by *Shigella* species are generally food-borne or sexually transmitted, and are notifiable nationally. Reports of MDR *Shigella* species decreased significantly by 90% in 2021 (*n* = 30), compared to 2020 (*n* = 298), with no jurisdiction having more than 10 cases reported. The proportion of shigellosis notifications that were MDR decreased in 2021, compared to 2020; this occurred most notably in New South Wales and Queensland.

Whilst *Neisseria gonorrhoeae* was the most commonly reported CAR from the community setting between 2017 and 2020, reports of azithromycin-nonsusceptible *N. gonorrhoeae* (MIC < 256 mg/L) (low-level resistance) continued to decline in 2021. There was one report of a ceftriaxone-nonsusceptible and/or azithromycin-nonsusceptible *N. gonorrhoeae* (MIC < 256 mg/L) from Western Australia.

The reductions in 2021 reports of CARs that cause community-onset infections, such as MDR *Shigella* and *N. gonorrhoeae*, corresponded with continuing lockdowns and travel restrictions associated with the coronavirus 2019 (COVID-19) pandemic, which coincided with reduced social contact.

Critical antimicrobial resistances in aged care homes

In aged care homes, skin and soft tissue infections are the most common reason for antimicrobial prescriptions.[1] *S. aureus* commonly cause skin and soft tissue infections which may be spread by contact with contaminated surfaces and hands of healthcare workers, visitors and residents. Given the frequent movement of residents between aged care homes and hospitals, there is a higher transmission risk of CARs in this setting.

In 2021, there were 56 CARs reported from aged care homes. Of these reports, 89% (50/56) were from clinical isolates, and nearly all were DNSA (28/56, 50%) or CPE (27/56, 48%).

Over 79% (22/28) of the reports of DNSA in aged care homes were from Queensland; the number of reports of DNSA from aged care homes was similar to reports from hospitals. These results may reflect variation between laboratories in their routine testing and reporting practices of this CAR.

Health service demand and complexity of care

Data reported to the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System signal implications for health service delivery, as a result of antimicrobial resistance (AMR). From previous work undertaken, there has been substantial overall variation in antimicrobial usage (AU) in hospitals in 2018 and 2019, for multiple antimicrobial classes, across the states and territories. It is expected that additional hospital data for AU for 2020 will be available in the coming months; this information will be important in the context of the COVID-19 pandemic. Variation in 2018 and 2019 was notably seen in classes of reserve-line antimicrobials that may be associated with treatment of CARs:

- Carbapenem usage increased in all states and territories except for South Australia
- Fluoroquinolone usage decreased in most states and territories

- Usage of third-generation cephalosporins was unchanged in New South Wales/Australian Capital Territory, decreased in Western Australia and Queensland/Northern Territory, and increased in all other states and territories
- Trimethoprim use decreased in all states and territories, except Western Australia.[2-4]

Critical antimicrobial resistances increase hospital length of stay, deaths and health service resource needs. Estimates of the impacts of AMR vary by organism, and are not available for the majority of CARs. Recent estimates of the impact of CPE include an additional 29 inpatient days, compared to non-CPE cases, after the isolation of the organism.[5] Patients with MDR infections were also less likely to receive appropriate antimicrobial therapy initially.[5] For vancomycin-resistant enterococci, when they first emerged, estimated increases per case were 61.9% for hospital costs and an additional 13.8 days length of stay.[6]

What will be done to improve patient safety?

In response to the issues identified in analyses of CARAlert data between 2017 and 2021, the Commission will continue to:

- Monitor CARs reported to CARAlert in 2022, maintain the CARAlert system and communicate key findings to states, territories, the Australian Government Department of Health and relevant experts
- Liaise directly with states and territories and clinical stakeholders regarding specific CARs reported to CARAlert
- Promote compliance with the *Australian Guidelines for the Prevention and Control of Infection in Healthcare*[7] as required by the National Safety and Quality Health Service (NSQHS) Standards
- Develop guidance for specific organisms, which complement the *Australian Guidelines for the Prevention and Control of Infection in Healthcare*[7], such as the *Recommendations for the control of carbapenemase-producing* Enterobacterales *(CPE): A guide for acute care health service organisations*[8]
- Liaise with the Aged Care Quality and Safety Commission and aged care provider organisations regarding the importance of infection prevention and control in aged care homes, consistent with the mandatory Aged Care Quality Standards, and specific considerations for the response to CPE and other CARs
- Promote implementation of resources and systems that support the implementation of the antimicrobial stewardship (AMS) actions of the NSQHS Standards
- Support collaboration between states and territories and hospital and community care settings to prevent and control CARs
- Review prescribing practices in light of current and emerging resistances and inform guideline development, such as in collaboration with *Therapeutic Guidelines: Antibiotic*.

Results from CARAlert, 2021

Information about the National Alert System for Critical Antimicrobial Resistances (CARAlert), and methods used for the analyses presented in this report are included in Appendices 1 and 2.

Between 1 January 2021 and 31 December 2021, a total of 1,295 CARs from 70 originating laboratories across Australia were entered into CARAlert by 22 of the 28 confirming laboratories nationally that contribute to CARAlert (Appendix 3). There was an average of 108 entries per month.

Critical antimicrobial resistances by state and territory

Most CARs were reported for patients who lived in the most populous states (New South Wales, 521/1,295, 40%; Victoria, 245/1,295, 19%; and Queensland, 330/1,295, 25%). There were less than 10 reports from Tasmania and the Northern Territory, and fewer than 30 reports from South Australia and the Australian Capital Territory (Table 1).

Carbapenemase-producing *Enterobacterales* (CPE) (including those with ribosomal methyltransferase or transmissible resistance to colistin) was the most frequently reported CAR (600/1,295, 46.3%) in 2021. Compared to 2020, there was a 7% decrease in overall reports of CPE in 2021 (*n* = 600 in 2021; *n* = 645 in 2020); the greatest decrease was seen in Victoria (*n* = 128 in 2021; *n* = 197 in 2020, down 35%). There was also a decrease in reports from Western Australia (*n* = 28 in 2021; *n* = 33 in 2020, down 15%). Increases in CPE reports were seen in South Australia (*n* = 26 in 2021, *n* = 20 in 2020, up 30%), and Queensland (*n* = 161 in 2021; *n* = 129 in 2020, up 25%). No CPE were reported from Tasmania in 2021.

Daptomycin-nonsusceptible *Staphylococcus aureus* (DNSA) increased 24% in 2021 (*n* = 265 in 2021; *n* = 213 in 2020). The greatest increase was in Queensland (*n* = 133 in 2021; *n* = 106 in 2020, up 25%).

In 2021, the number of azithromycin-nonsusceptible *Neisseria gonorrhoeae* (low-level) reports declined by 6% (*n* = 250 in 2021; *n* = 267 in 2020). The greatest decline was seen in Queensland (*n* = 13 in 2021; *n* = 41 in 2020, down 68%). There was an increase in reports of this CAR in Victoria (*n* = 45 in 2021; *n* = 25 in 2020, up 80%). There were no reports of this CAR from South Australia.

Reports of multidrug-resistant (MDR) *Shigella* species decreased overall by 90% from 2020 to 2021 (*n* = 30 in 2021; *n* = 298 in 2020). Decreases were seen across all jurisdictions with the greatest decrease seen in reports from New South Wales.

Carbapenemase-producing *Pseudomonas aeruginosa* (48/66) and carbapenemase-producing *Acinetobacter baumannii* complex (8/17) were reported predominantly from New South Wales. *Candida auris* was reported from Victoria (*n* = 1). *Enterobacterales* with transmissible resistance to colistin, other than in association with CPE, were reported from Victoria (*n* = 6) and Western Australia (*n* = 2).

Table 1: Number of critical antimicrobial resistances reported to CARAlert, by state and territory, 2021 and 2020

Species	Critical resistance	State or territory, 2021								Year		Relative change*
		NSW	Vic	Qld	SA	WA	Tas	NT	ACT	2020	2021	
Acinetobacter baumannii complex	Carbapenemase-producing	7	2	2	0	4	0	0	0	15	15	–
	Carbapenemase- and ribosomal methyltransferase-producing	1	1	0	0	0	0	0	0	10	2	▼ 80.0%
Candida auris	–	0	1	0	0	0	0	0	0	5	1	▼ 80.0%
Enterobacterales	Carbapenemase-producing (alone or in combination with other CARs)	243	128	161	26	28	0	3	11	645	600	▼ 7.0%
	Carbapenemase-producing	216	109	157	23	26	0	3	11	541	545	▲ 0.7%
	Carbapenemase- and ribosomal methyltransferase-producing	2	5	1	2	1	0	0	0	32	11	▼ 65.6%
	Carbapenemase-producing and transmissible colistin resistance	25	14	3	1	1	0	0	0	70	44	▼ 37.1%
	Carbapenemase- and RMT-producing and transmissible resistance to colistin	0	0	0	0	0	0	0	0	2	0	▼ 100%
	Ribosomal methyltransferase-producing	0	2	1	2	3	0	0	1	4	9	▲ 125%
	Transmissible colistin resistance[†]	0	6	0	0	2	0	0	0	9	8	▼ 11.1%
Enterococcus species	Linezolid-nonsusceptible	3	0	0	4	5	0	0	1	19	13	▼ 31.6%
Mycobacterium tuberculosis	Multidrug-resistant – at least rifampicin- and isoniazid-resistant strains	0	5	2	1	0	0	0	0	18	8	▼ 55.6%
Neisseria gonorrhoeae	Azithromycin-nonsusceptible (low-level)[§]	167	45	13	0	15	5	1	4	267	250	▼ 6.4%
	Azithromycin-nonsusceptible (high-level)[#]	0	0	0	0	0	0	0	0	1	0	▼ 100%
	Ceftriaxone-nonsusceptible	0	0	0	0	0	0	0	0	3	0	▼ 100%
	Ceftriaxone-nonsusceptible and azithromycin-nonsusceptible (low-level)	0	0	0	0	1	0	0	0	0	1	–

Continued

Table 1: *continued*

Species	Critical resistance	State or territory, 2021								Year		
		NSW	Vic	Qld	SA	WA	Tas	NT	ACT	2020	2021	Relative change*
Pseudomonas aeruginosa	Carbapenemase-producing	48	11	0	0	7	0	0	0	42	66	▲ 57.1%
	Carbapenemase- and ribosomal methyltransferase-producing	0	2	0	0	0	0	0	0	2	2	–
Salmonella species	Ceftriaxone-nonsusceptible	2	9	12	0	1	0	0	0	32	24	▼ 25.0%
Shigella species	Multidrug-resistant	7	**9**	5	1	8	0	0	0	298	30	▼ 89.9%
Staphylococcus aureus	Daptomycin-nonsusceptible	43	24	133	17	39	3	0	6	213	265	▲ 24.4%
	Daptomycin- and vancomycin-nonsusceptible	0	0	0	0	0	0	0	0	1	0	▼ 100%
	Linezolid-nonsusceptible	0	0	1	0	0	0	0	0	2	1	▼ 50.0%
	Vancomycin-nonsusceptible	0	0	0	0	0	0	0	0	0	0	–
Streptococcus pyogenes	Penicillin reduced susceptibility	0	0	0	0	0	0	0	0	0	0	–
	Total (reported by 31 January 2022)	**521**	**245**	**330**	**51**	**113**	**8**	**4**	**23**	**1,586**	**1,295**	**▼ 18.3%**

RMT = ribosomal methyltransferase; – = not applicable

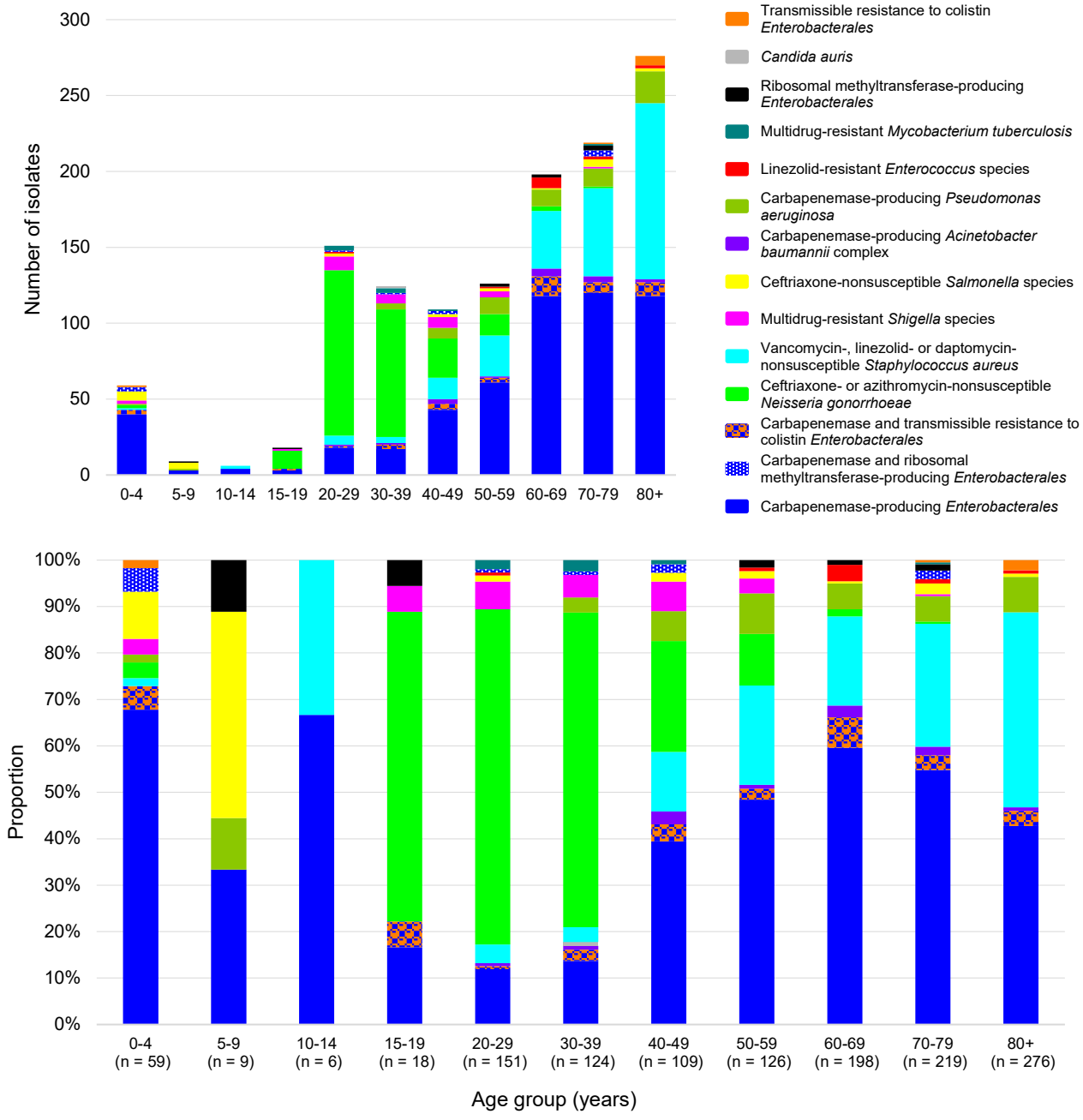
* Relative change = absolute change between 2020 and 2021, for each CAR, expressed as a percentage of 2020 base
† When not seen in combination with CPE
§ Azithromycin MIC ≥ 256 mg/L
# Azithromycin MIC < 256 mg/L

Critical antimicrobial resistances by age group

CARs were isolated from patients of all ages; the median age was 60–69 years (Figure 1). Just over three-quarters of CPE were isolated from people aged 50 years and older (453/600, 76%). Azithromycin-nonsusceptible *N. gonorrhoeae* and MDR *Shigella* species were the predominant CAR reported for the age groups 20–29 and 30–39 years.

Only 5.7% (74/1,295) of all CARs were reported in children aged less than 15 years; CPE (*n* = 53) and ceftriaxone-nonsusceptible *Salmonella* species (*n* = 10) were most frequently reported for this age group (63/74, 85%). For the 0–4-year age group, CPE was the most frequently reported CAR (*n* = 46); followed by ceftriaxone-nonsusceptible *Salmonella* species (*n* = 6).

Figure 1: Critical antimicrobial resistances reported to CARAlert, by age groups, 2021



Critical antimicrobial resistances by facility type

Excluding azithromycin-nonsusceptible *N. gonorrhoeae*, which is generally isolated in the community, the majority of CARs were detected in either hospitalised patients or hospital outpatients (762/1,007, 76%). Smaller proportions were isolated in the community (189/1,007, 19%) and in aged care homes (56/1,007, 5%) (Table 2).

Table 2: Number of critical antimicrobial resistance isolates reported to CARAlert, by setting, national, 2021

Species	Critical resistance	Setting					Total
		Public hospitals	Private hospitals	Aged care homes	Community	Unknown	
Acinetobacter baumannii complex	Carbapenemase-producing	12	1	0	1	1	15
	Carbapenemase- and ribosomal methyltransferase-producing	1	1	0	0	0	2
Candida auris	–	0	0	0	1	0	1
Enterobacterales	Carbapenemase-producing	414	57	23	43	8	545
	Carbapenemase and ribosomal methyltransferase-producing	9	0	1	1	0	11
	Carbapenemase-producing and transmissible colistin resistance	37	1	3	3	0	44
	Ribosomal methyltransferase-producing	6	1	0	1	1	9
	Transmissible colistin resistance	6	0	1	1	0	8
Enterococcus species	Linezolid-nonsusceptible	12	0	0	1	0	13
Mycobacterium tuberculosis	Multidrug-resistant – at least rifampicin- and isoniazid-resistant	7	0	0	1	0	8
Neisseria gonorrhoeae	Azithromycin-nonsusceptible (low-level)	46	0	0	189	15	250
	Azithromycin-nonsusceptible (high-level)	0	0	0	0	0	0
	Ceftriaxone-nonsusceptible	0	0	0	0	0	0
	Ceftriaxone-nonsusceptible and azithromycin-nonsusceptible (low-level)	0	0	0	1	0	1
Pseudomonas aeruginosa	Carbapenemase-producing	50	8	0	6	2	66
	Carbapenemase- and ribosomal methyltransferase-producing	1	1	0	0	0	2
Salmonella species	Ceftriaxone-nonsusceptible	12	1	0	9	2	24
Shigella species	Multidrug-resistant	11	1	0	12	6	30
*Staphylococcus aureus**	Daptomycin-nonsusceptible	86	25	28	109	17	265
	Daptomycin- and vancomycin-nonsusceptible	0	0	0	0	0	0
	Linezolid-nonsusceptible	0	1	0	0	0	1
	Vancomycin-nonsusceptible	0	0	0	0	0	0
Streptococcus pyogenes	Penicillin reduced susceptibility	0	0	0	0	0	0
Total (reported by 31 January 2021)		**710**	**98**	**56**	**379**	**52**	**1,295**

High-level = azithromycin MIC ≥ 256 mg/L; Low-level = azithromycin MIC < 256 mg/L

* For CARAlert, *S. aureus* complex includes *S. argenteus* and *S. schweitzeri*

Note: Information on setting for *Neisseria gonorrhoeae* is often not available.

CPE accounted for just under two-thirds of all reports from hospitals (518/808, 64%). In the community, over three-quarters of reports were ceftriaxone or azithromycin-nonsusceptible *N. gonorrhoeae* (190/379, 50%) or DNSA (109/379, 29%). Almost all reports from aged care homes were DNSA (28/56, 50%) or CPE (27/56, 48%).

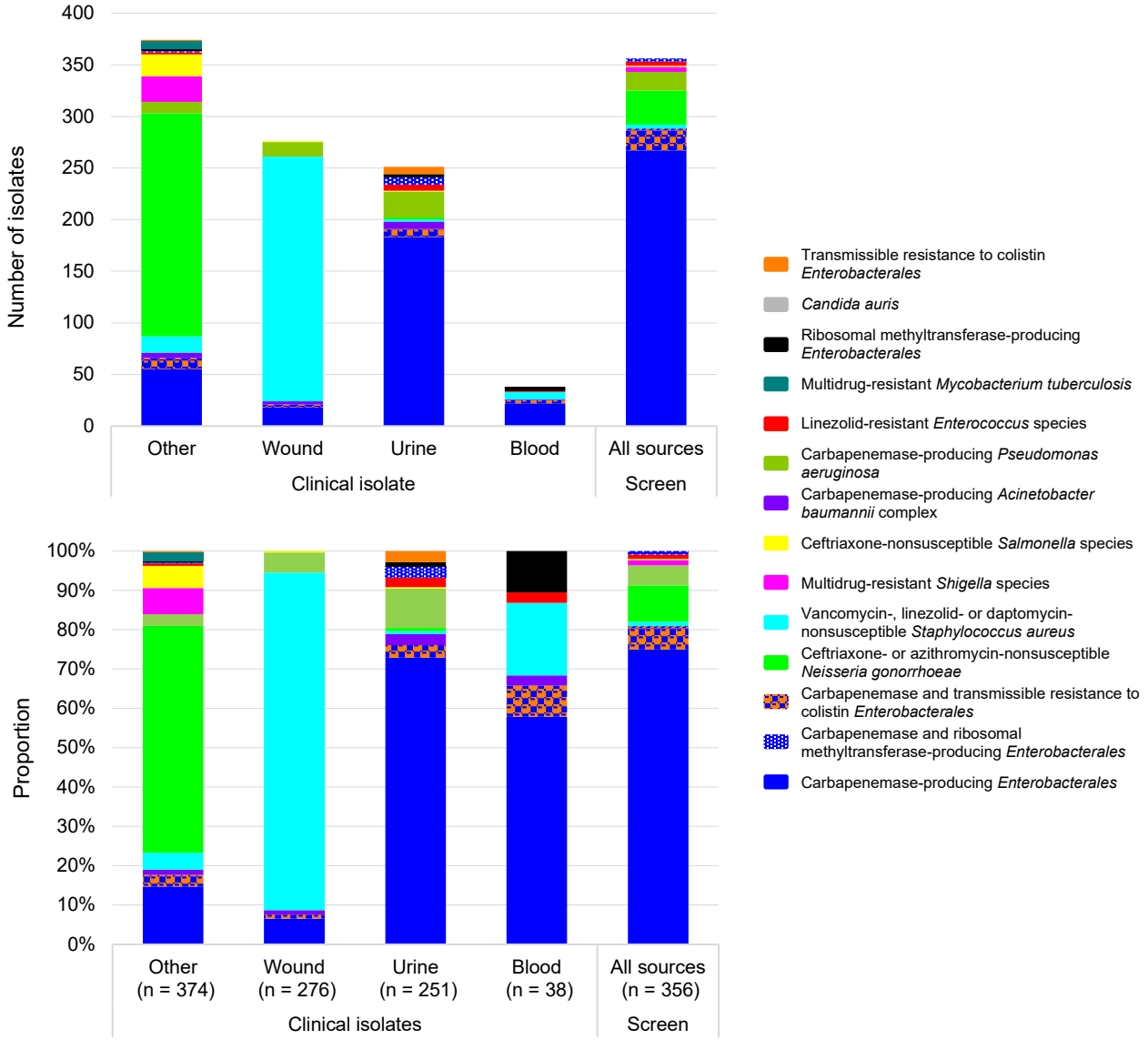
Critical antimicrobial resistances by specimen type

A substantial majority of all CARs reported in 2021 were from clinical specimens (939/1,295, 73%), which are specimens collected for diagnostic purposes, rather than for screening. These included wound (*n* = 276), urine (*n* = 251), blood (*n* = 38) and other (*n* = 374) such as genital or respiratory specimens (Figure 2).

Of CPE reports, 52% (311/600) were from clinical specimens. Sixty-four percent (198/311) of isolates from clinical specimens were from urine. Urine is an important specimen for certain CARs, including *Enterobacterales*, as the urinary tract is a common site of infection. Almost 1 in 12 (25/311, 8%) CPE from clinical specimens were from blood cultures. CPE comprised 66% (25/38) of all CARs confirmed from blood specimens, highlighting the clinical spectrum of CPE infections compared to other CARs.

Four other CARs were also reported from blood cultures in 2021: DNSA (*n* = 7), ribosomal methyltransferase-producing *Enterobacterales* (*n* = 4), carbapenemase-producing *A. baumannii* complex (*n* = 1), and linezolid-nonsusceptible *Enterococcus* species (*n* = 1).

Figure 2: Critical antimicrobial resistances reported to CARAlert, by specimen type, 2021



Note: 'Other' refers to specimen types other than urine, wound or blood, such as genital, faecal or respiratory tract.

Summary by CAR, with trend data for 2017–2021

Data for each CAR for 2021, nationally and by state and territory, are shown in Figures 3 to 28. Trend data for 2017 to 2021 are also presented, where applicable.

Acinetobacter baumannii complex

The *Acinetobacter baumannii* complex is a group of environmental organisms that have caused prolonged outbreaks in hospital settings, such as intensive care and severe burns units. *A. baumannii* infections are associated with patients with compromised physical barriers and immunity, most commonly in hospital (Table 3). The most common infections caused by this species complex are ventilator-associated pneumonia and severe burn infections. Reporting of carbapenemase-producing *A. baumannii* complex to CARAlert began in July 2019 (Figure 3).

There were 17 reports of carbapenemase-producing *A. baumannii* complex in 2021: eight from New South Wales, four from Western Australia, three from Victoria, and two from Queensland (Figures 3 and 4). OXA-23-like types were dominant (*n* = 13, either alone [11] or in combination with NDM [2]). Five NDM types (alone [3] or in combination with OXA-23-like [2]) were reported. A fall in numbers compared to 2020 (*n* = 25) may reflect changes in hospital practices following the onset of the coronavirus 2019 (COVID-19) pandemic.

Figure 3: Carbapenemase-producing *Acinetobacter baumannii* complex, number reported to CARAlert by specimen type, 2019–2021, national

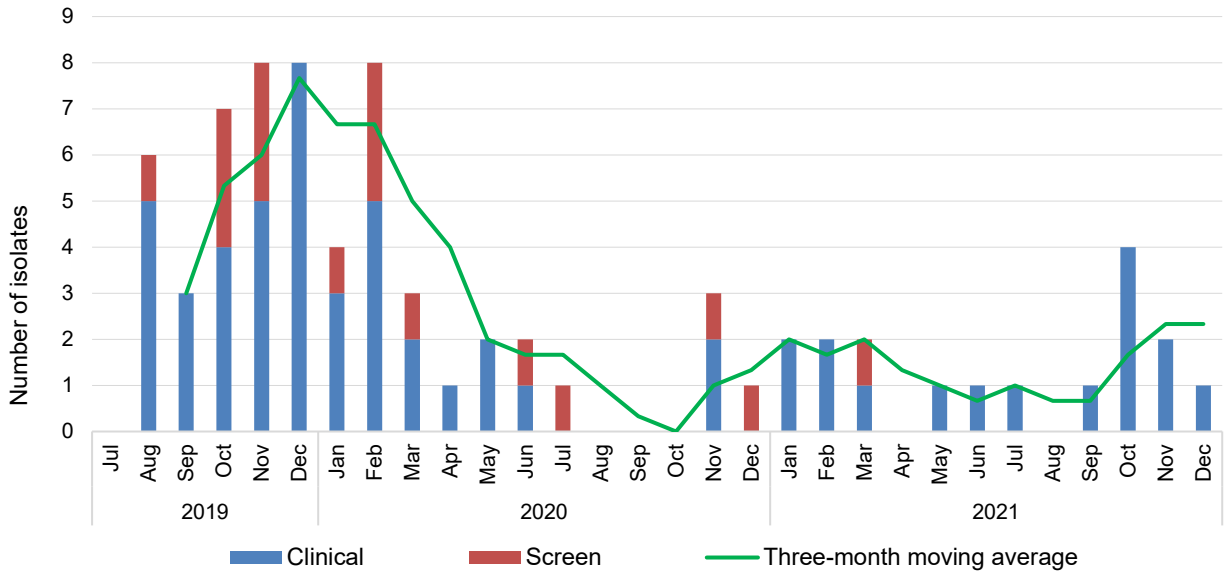


Figure 4: Carbapenemase-producing *Acinetobacter baumannii* complex, number reported to CARAlert by carbapenemase type and specimen type, state and territory, 2021

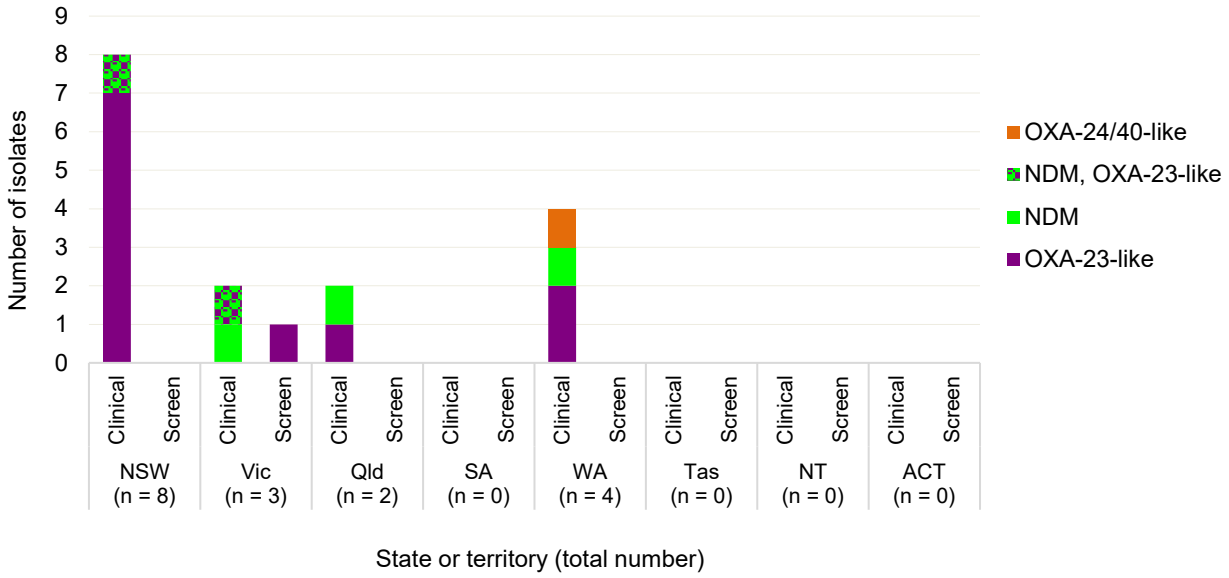


Table 3: Carbapenemase-producing *Acinetobacter baumannii* complex, number reported to CARAlert by setting, state and territory, 2021

	State or territory								
Setting	**NSW**	**Vic**	**Qld**	**SA**	**WA**	**Tas**	**NT**	**ACT**	**Total**
Total	**8**	**3**	**2**	**0**	**4**	**0**	**0**	**0**	**17**
Public hospital	6	3	1	0	3	0	0	0	13
Private hospital	1	0	0	0	1	0	0	0	2
Aged care home	0	0	0	0	0	0	0	0	0
Community	0	0	1	0	0	0	0	0	1
Unknown	1	0	0	0	0	0	0	0	1

Candida auris

Reporting to CARAlert for *Candida auris* began in July 2019. *C. auris* is an uncommon, MDR *Candida* species that has been associated with international outbreaks of invasive infections in healthcare facilities.

In 2021, one *C. auris* was reported from Victoria. Previously, five *C. auris* were reported in 2020: three from Victoria and two from New South Wales; and there were three reports in 2019; two from New South Wales and one from Western Australia.

Enterobacterales

Infections of the urinary tract, biliary tract, intra-abdomen, and blood stream are commonly associated with *Enterobacterales*. There was a decrease in the number of reports of carbapenemase- and/or ribosomal methyltransferase-producing *Enterobacterales* in 2020, compared with 2017 to 2019. While there were sporadic increases in reports over the five years, the downward trend continued in 2021 (Figures 5 and 6). The overall number of CPE reports

decreased slightly in 2021 (*n* = 600) compared to 2020 (*n* = 645). There was a decrease in reports from Victoria (*n* = 128 in 2021; *n* = 197 in 2020, down 35%), and a slight increase in the number reported from Queensland (Figure 9).

Carbapenemases were found in 25 species (11 genera) of *Enterobacterales*, with 10 carbapenemase types reported (Figure 7). Three carbapenemase types - IMP (370/600, 61.7%), NDM (146/600, 24.3%) and OXA-48-like (45/600, 7.5%) - when produced alone, accounted for 93.5% (561/600) of all *Enterobacterales* with a confirmed carbapenemase.

IMP types alone accounted for 62% (370/600) of all carbapenemases; they were found in 21 different species (Figure 7). *Enterobacter cloacae* complex accounted for 45% (165/370) of all IMP types and 28% (165/600) of all CPE.

NDM carbapenemase types were found mainly in *Escherichia coli* (62/146, 42%), and OXA-48-like types in *E. coli* and *Klebsiella pneumoniae* (19/45, 42% for both species).

Monthly trends for the top five carbapenemase types (IMP; NDM; OXA-48-like; KPC; NDM-OXA-48-like) reported over five years are shown in Figure 8 (national); and three-year trends by state and territory are shown in Figure 10.

The number of IMP types reported in 2021 was similar to 2020 (*n* = 370 in 2021; *n* = 387 in 2020). IMP-types accounted for 77% (124/161) of all CPE reported from Queensland, and 75% (182/243) from New South Wales. All the strains that have been genetically sequenced to date (212/370, 57%) were $bla_{\text{IMP-4}}$ (*n* = 225), $bla_{\text{IMP-59}}$ (*n* = 5), $bla_{\text{IMP-27}}$ (*n* = 1), or $bla_{\text{IMP-38}}$ (*n* = 1).

The number of NDM types reported in 2021 was also similar to 2020 (*n* = 146 in 2021; *n* = 157 in 2020). NDM types, either alone or in combination, were found in all states and territories except Tasmania and the Australian Capital Territory. In South Australia, NDM types accounted for over two-thirds (17/26, 65%) of all CPE reported. In Victoria, NDM types accounted for 46% (59/128) of all CPE reported. Four different genes were found in the strains sequenced (97/146, 66%): $bla_{\text{NDM-1}}$ (41/97; 42%), $bla_{\text{NDM-7}}$ (29/97; 30%), $bla_{\text{NDM-5}}$ (26/97; 27%), and $bla_{\text{NDM-4}}$ (1/97; 1%).

Reports of OXA-48-like CPE decreased by 27% in 2021 (*n* = 45) compared with 2020 (*n* = 21). Over 46% (21/45) of the isolates with OXA-48-like were sequenced. Four genes were reported; the most common was $bla_{\text{OXA-48}}$ (9/21, 43%), followed by $bla_{\text{OXA-181}}$ (8/21, 38%), $bla_{\text{OXA-232}}$ (3/21, 14%) and $bla_{\text{OXA-244}}$ (1/21, 5%).

Reports of KPC-producing *Enterobacterales* increased in 2021 compared to 2020 (*n* = 9 in 2021; *n* = 3 in 2020). KPC types were predominantly reported from Victoria (*n* = 6), half of which were from one institution. Three other states reported single cases (New South Wales, Queensland, and Western Australia).

Other carbapenemase types reported were OXA-23-like (*n* = 7), IMI (*n* = 3) and SME (*n* = 1).

Co-production of carbapenemase was seen at low levels (19/600, 3.2%). The co-produced genes in 2021 were IMP+OXA-48-like (*n* = 8), NDM+OXA-48-like (*n* = 6), IMP+NDM (*n* = 5).

In 2021, there was variation in the proportion of isolates reported from clinical and screening specimens by state and territory (Figure 11). This may be due to differences in local infection control policies or in response to local outbreaks. Relatively fewer reports from screening specimens were identified in Western Australia and the Australian Capital Territory.

There were notable regional differences in the distribution of the top five carbapenemases by specimen type (Figure 12) and by setting (Table 4).

The clinical impact of each of the CPE types, and the potential impact of co-infection, are not well understood.[9] This aspect of the data provided by CARAlert will be monitored.

Since 2016, 256 hospitals have reported at least one CPE. CPE were reported from 130 hospitals during 2021. One-fifth (26/130, 20%) of these hospitals did not have a CPE during the period 2016

to 2020. One hundred and twenty-six hospitals that had CPE notifications prior to 2021 did not have any reports in 2021.

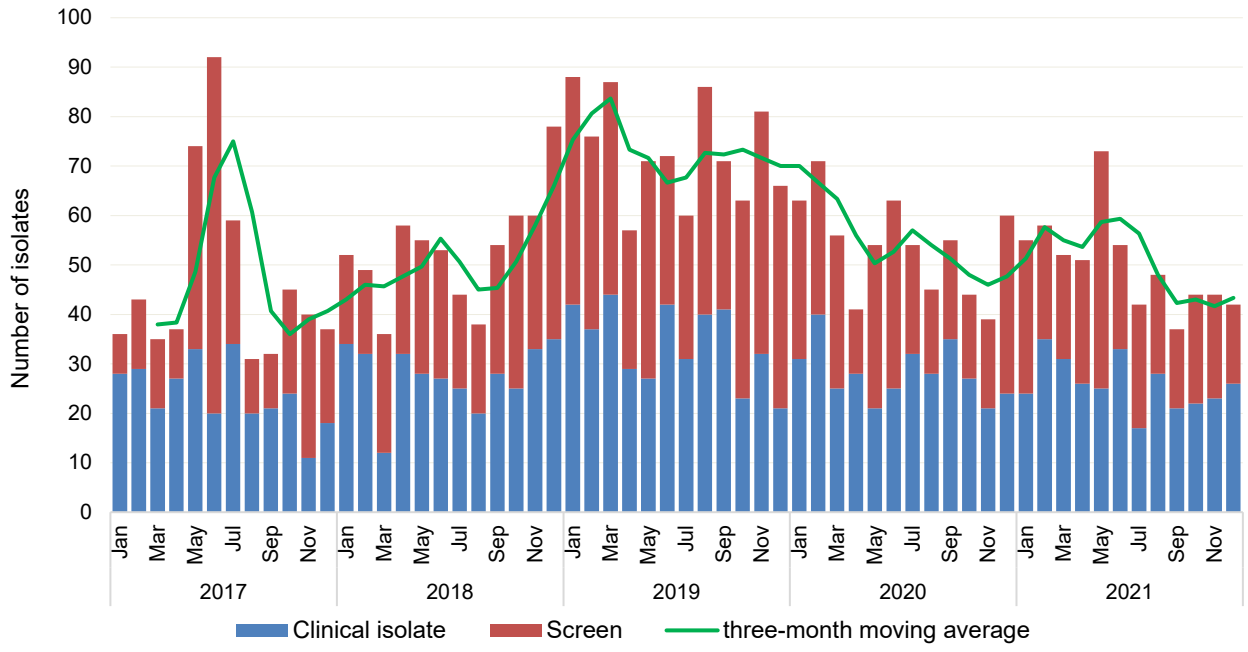
Ribosomal methyltransferases (RMT) were detected in 20 isolates of *Enterobacterales*, representing four species; 55% (11/20) of these also had a carbapenemase. The RMTs were mostly found among *K. pneumoniae* (12/20, 60%) and *E. coli* (5/20, 25%). Four RMT genes were found: *rmtB* (8/20, 40%), *armA* (8/20, 40%), *rmtF* (3/20, 15%), and *rmtC* (1/20, 5%).

A vast majority of transmissible resistance to colistin (MCR) was reported in isolates that co-produced a carbapenemase (44/52, 85%); $bla_{\text{IMP-4}}$ (*n* = 39), NDM (*n* = 4; $bla_{\text{NDM-1}}$, [2]; $bla_{\text{NDM-4}}$ [1]; $bla_{\text{NDM-5}}$, [1]), or $bla_{\text{KPC-2}}$ (*n* = 1). All isolates co-producing a carbapenemase harboured *mcr-9*. Co-production of CPE and MCR was mostly found among *E. cloacae* complex (32/44, 73%), 97% (31/32) of which harboured $bla_{\text{IMP-4}}$; six other species were reported. *mcr-9* has recently been found among several species of *Enterobacterales*[10] often on an IncHI2 plasmid, and the expression of *mcr-9* was inducible by subinhibitory concentrations of colistin. Preliminary evidence suggests that *mcr-9* is frequently not expressed.[11]

MCR alone was reported in eight *E. cloacae* complex (*mcr-10.1*, *n* = 6; or *mcr-9.1*, *n* = 2). There were no reports of *mcr-1*.

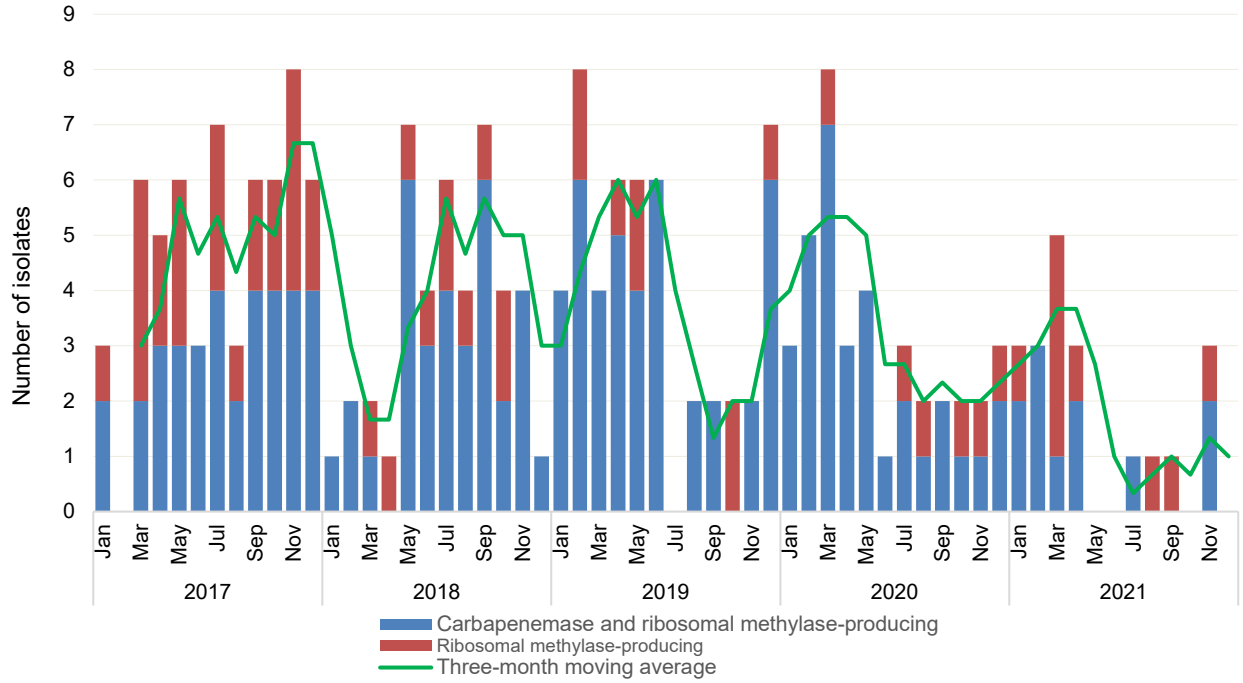
National data

Figure 5: Carbapenemase-producing *Enterobacterales*, number reported to CARAlert by month and specimen type, 2017–2021, national



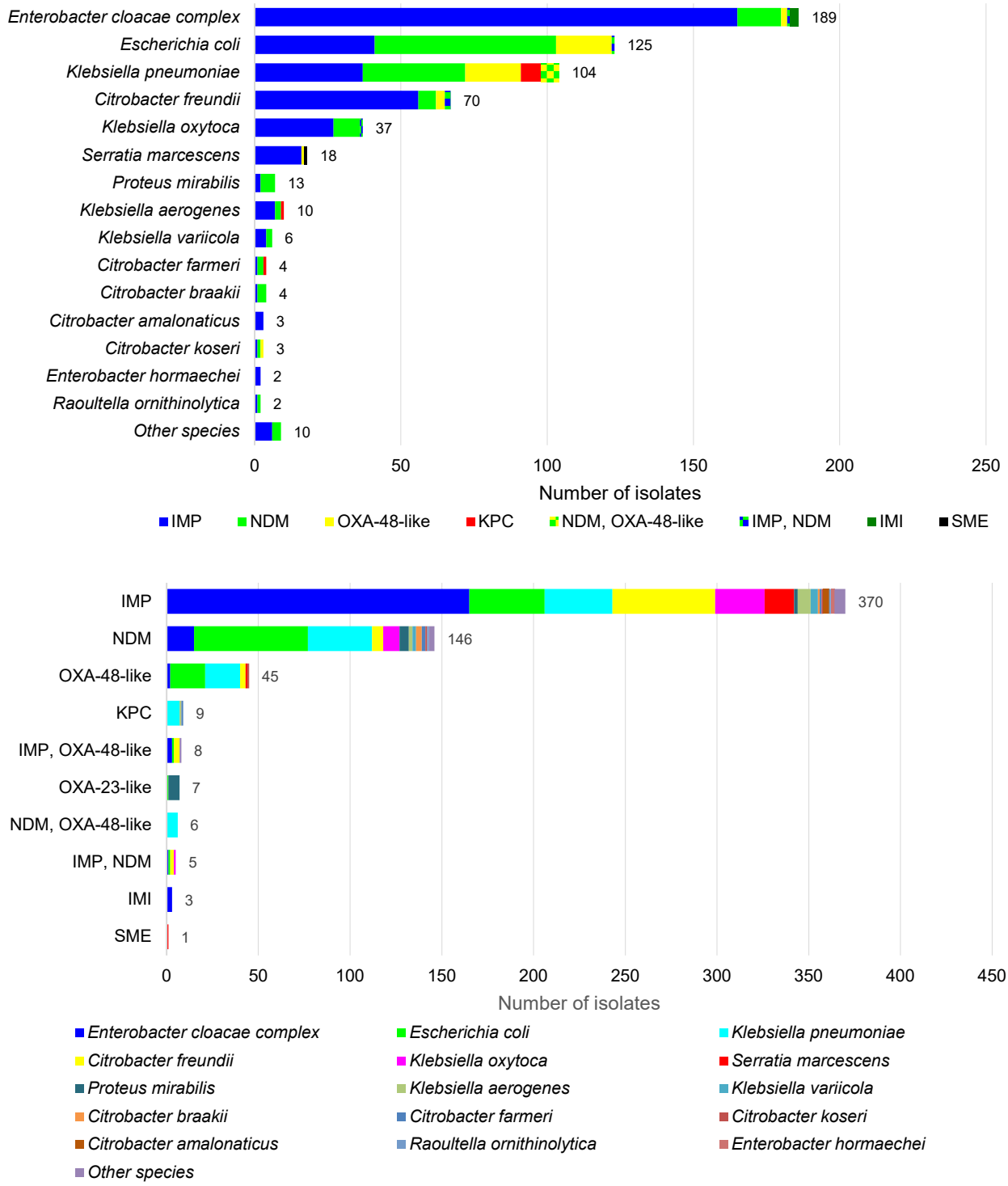
Note: Carbapenemase-producing *Enterobacterales*, including those co-producing ribosomal methyltransferase and/or transmissible colistin resistance.

Figure 6: Ribosomal methyltransferase-producing *Enterobacterales*, number reported to CARAlert by month, 2017–2021, national



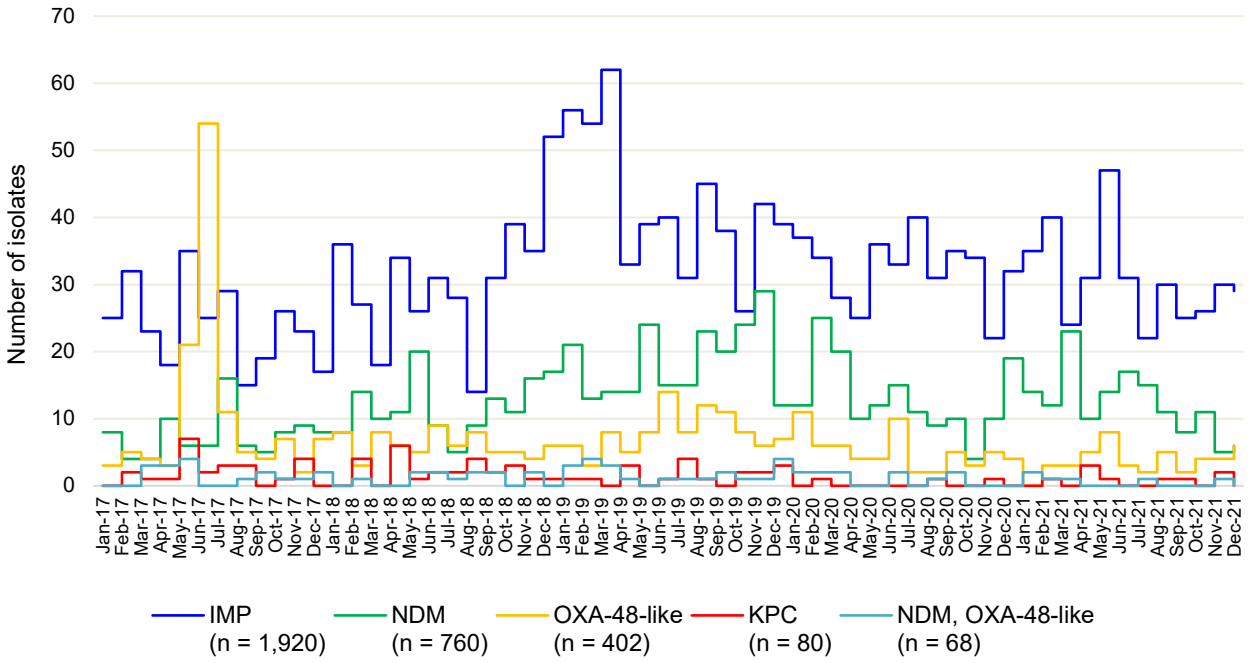
Note: Ribosomal methyltransferase-producing *Enterobacterales*, including those with carbapenemases.

Figure 7: Carbapenemase-producing *Enterobacterales**, number reported to CARAlert by species and carbapenemase type, 2021, national



* Carbapenemase-producing (*n* = 545), carbapenemase-producing plus transmissible colistin resistance (*n* = 44), carbapenemase- and ribosomal methyltransferase-producing (*n* = 11)

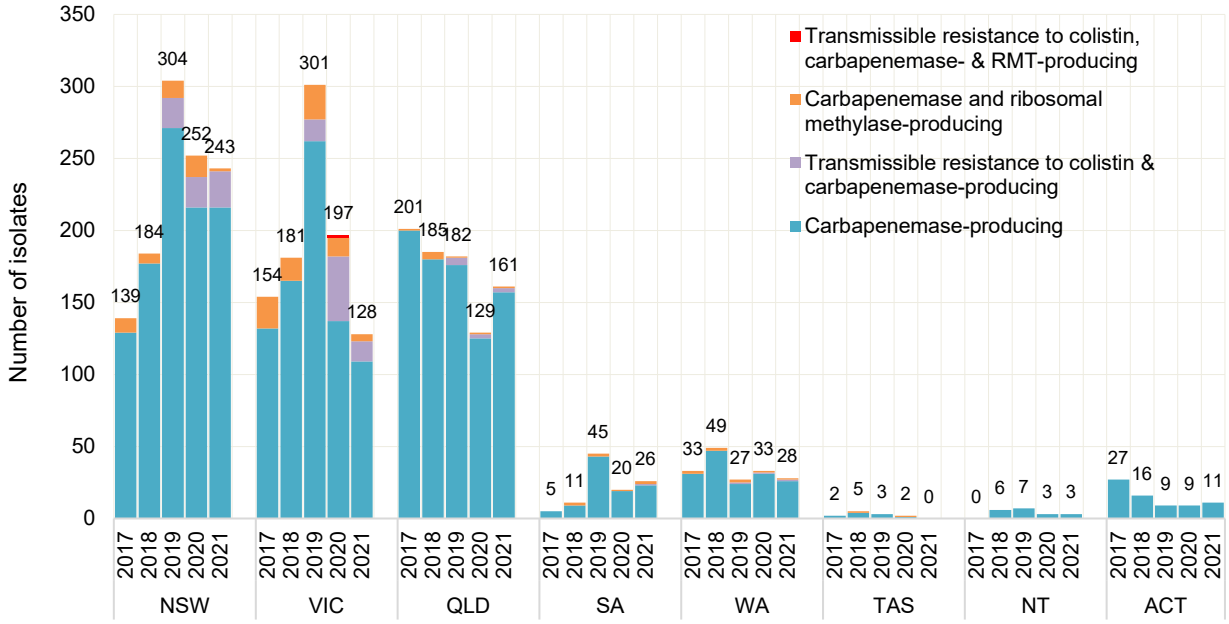
Figure 8: Trend for the top five carbapenemase types* reported to CARAlert, by month, 2017 – 2021, national



* Alone or in combination with another type for the reporting period indicated

State and territory data

Figure 9: Carbapenemase-producing *Enterobacterales,* number reported to CARAlert by state and territory, 2017–2021



Note: Transmissible colistin resistance reported from July 2019.

Figure 10: Three-year trend for the top four carbapenemase types from *Enterobacterales* reported to CARAlert, by state and territory and nationally, (three-month moving average), 2019–2021

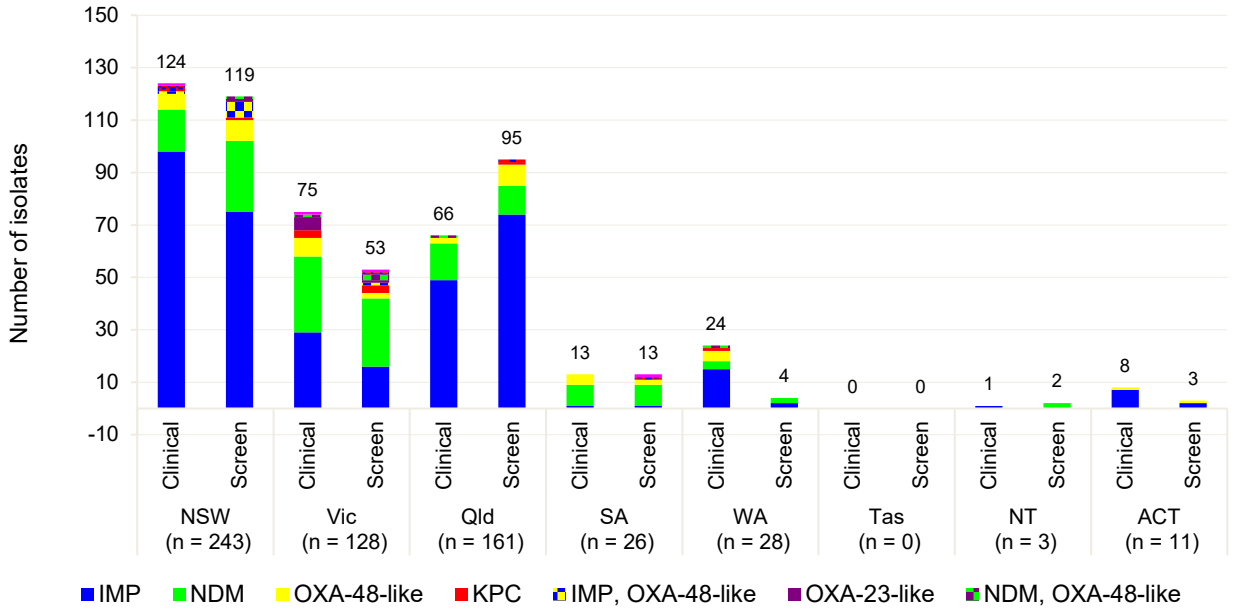
Type	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Australia
IMP	20 10	24 2	17 4	0 0	2 0	0 0	1 0	1 0	57 26
NDM	8 1	9 3	6 0	6 0	1 0	0 0	1 0	1 0	24 7
OXA-48-like	3 0	7 0	2 0	1 0	1 0	0 0	0 0	1 0	11 2
KPC	1 0	2 0	1 0	0 0	0 0	0 0	0 0	0 0	2 0
All types	28 14	35 8	19 5	7 0	4 1	1 0	1 0	2 0	84 42

Note: Line graphs represent three-month moving average for the period 1 January 2019 to 31 December 2021, for each type, where maximum monthly average was greater than one.

Straight green line in cell = no carbapenemase type for that state or territory during the reporting period

Blank cell = maximum monthly average was one or less

Figure 11: Carbapenemase-producing *Enterobacterales**, number reported to CARAlert by carbapenemase type and specimen type, by state and territory, 2021



* Carbapenemase-producing (*n* = 545), carbapenemase-producing plus transmissible colistin resistance (*n* = 44), carbapenemase- and ribosomal methyltransferase-producing (*n* = 11)

Other types: IMI (n = 3: Vic [2], SA [1]); SME (n = 1: NSW)

Figure 12: Top five carbapenemase-producing *Enterobacterales* types reported to CARAlert by specimen type, by state and territory, 2017–2021

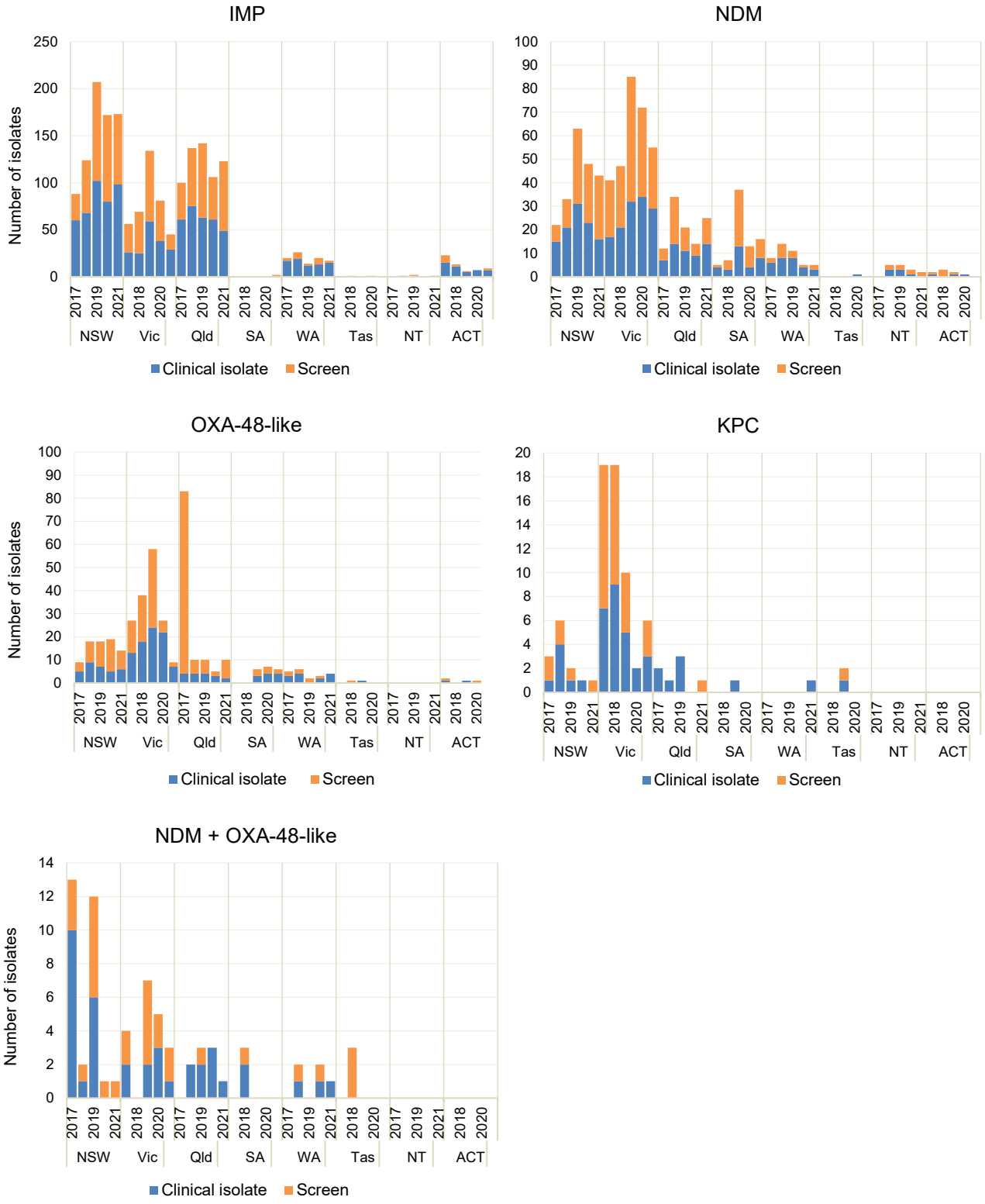


Table 4: Top five carbapenemase types from *Enterobacterales*, number reported to CARAlert by setting, state and territory, 2021

Carbapenemase type†	Setting	State or territory								Total
		NSW	Vic	Qld	SA	WA	Tas	NT	ACT	
IMP	**Total**	**173**	**45**	**123**	**2**	**17**	**0**	**1**	**9**	**370**
	Public hospital	151	38	75	2	7	0	1	8	282
	Private hospital	7	3	29	0	4	0	0	1	44
	Aged care home	9	1	10	0	2	0	0	0	22
	Community	6	2	7	0	4	0	0	0	19
	Unknown	0	1	2	0	0	0	0	0	3
NDM	**Total**	**43**	**55**	**25**	**16**	**5**	**0**	**2**	**0**	**146**
	Public hospital	39	44	15	14	2	0	2	0	116
	Private hospital	1	3	3	0	0	0	0	0	7
	Aged care home	1	0	1	0	0	0	0	0	2
	Community	2	7	4	2	3	0	0	0	18
	Unknown	0	1	2	0	0	0	0	0	3
OXA-48-like	**Total**	**14**	**9**	**10**	**6**	**4**	**0**	**0**	**2**	**45**
	Public hospital	14	5	5	6	1	0	0	2	33
	Private hospital	0	0	4	0	1	0	0	0	5
	Aged care home	0	0	0	0	0	0	0	0	0
	Community	0	3	1	0	2	0	0	0	6
	Unknown	0	1	0	0	0	0	0	0	1
KPC	**Total**	**1**	**6**	**1**	**0**	**1**	**0**	**0**	**0**	**9**
	Public hospital	1	4	0	0	0	0	0	0	5
	Private hospital	0	1	1	0	0	0	0	0	2
	Aged care home	0	0	0	0	0	0	0	0	0
	Community	0	1	0	0	0	0	0	0	1
	Unknown	0	0	0	0	1	0	0	0	1
IMP, OXA-48-like	**Total**	**7**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**8**
	Public hospital	7	1	0	0	0	0	0	0	8
	Private hospital	0	0	0	0	0	0	0	0	0
	Aged care home	0	0	0	0	0	0	0	0	0
	Community	0	0	0	0	0	0	0	0	0
	Unknown	0	0	0	0	0	0	0	0	0

* Top five carbapenemase types account for 96.3% (578/600) of all carbapenemase-producing *Enterobacterales* reported for this period. Other types were OXA-23-like (*n* = 7, NSW, Vic); NDM+OXA-48-like (*n* = 6, NSW, Vic, Qld, WA); IMP+NDM (*n* = 5, NSW, Vic, Qld, SA); IMI (*n* = 3, Vic, SA); and SME (*n* = 1, NSW)

† Alone or coproduced with another type for the reporting period indicated

Enterococcus species

Enterococcus species including *Enterococcus faecalis* and *Enterococcus faecium*, commonly cause urinary tract, biliary tract and other intra-abdominal infections, and blood stream infections. In 2021, reports of linezolid-nonsusceptible *Enterococcus* species decreased compared to 2020 (*n* = 13 in 2021; *n* = 19 in 2020, down 32%) (Figure 13).

There were no reports of linezolid-nonsusceptible *Enterococccus* species from Victoria, Queensland, Tasmania, and the Northern Territory in 2021 (Figure 14). Variation in the number of reports from the states and territories may be due to differences in testing and reporting practices by the originating laboratories.

Figure 13: Linezolid-nonsusceptible *Enterococcus* species, number reported to CARAlert by month, 2017 – 2021, national

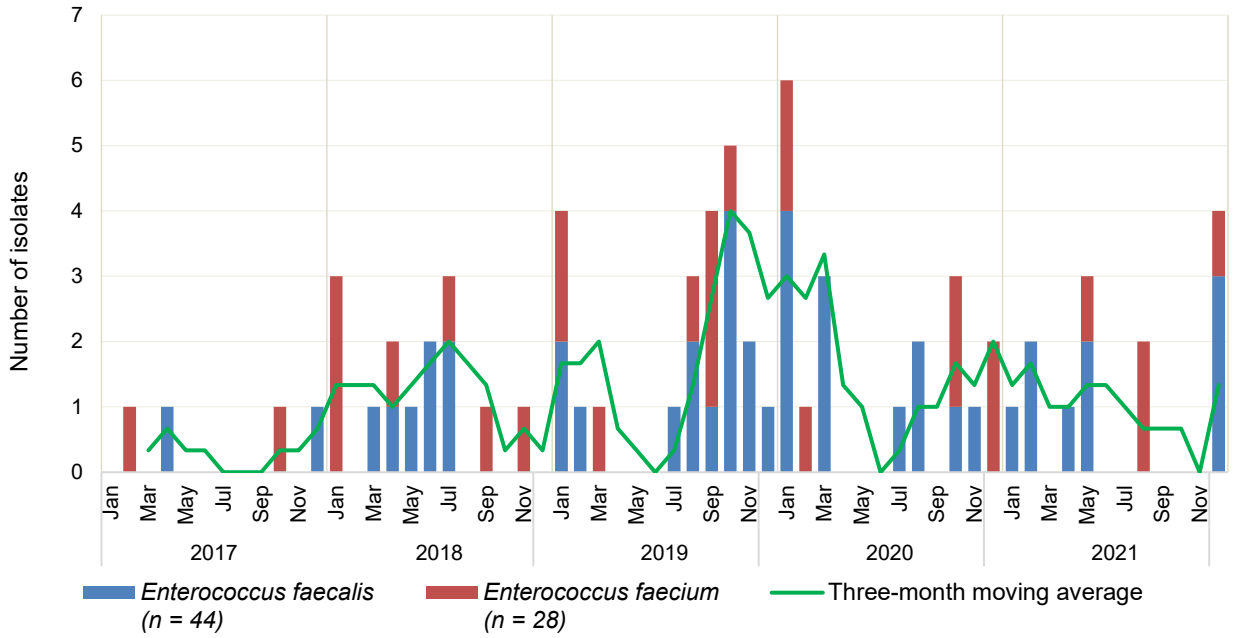
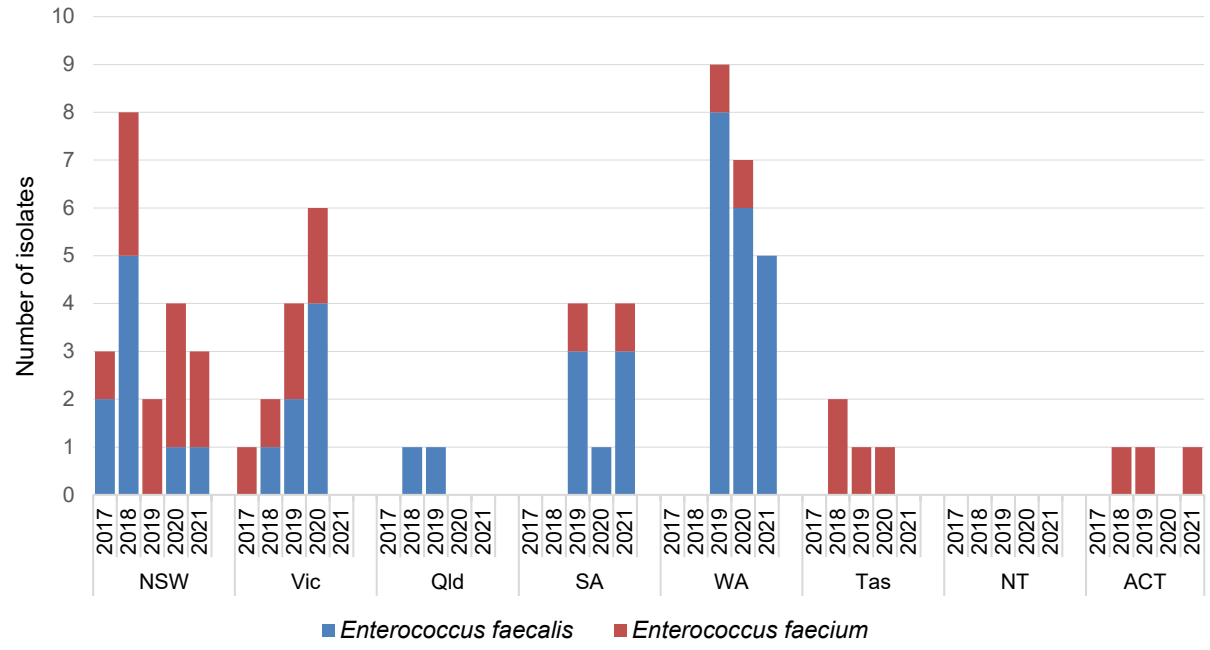


Figure 14: Linezolid-nonsusceptible *Enterococcus* species, number reported to CARAlert by state and territory, 2017–2021



Mycobacterium tuberculosis

Mycobacterium tuberculosis causes tuberculosis, which has a variety of clinical manifestations, but most commonly presents as lung disease. Low numbers of MDR *M. tuberculosis* were reported to CARAlert from 2017 to 2021 (Figure 15). In 2021, almost 2 in 3 of the MDR *M. tuberculosis* reports were from Victoria (5/8, 62%) (Figure 16).

Figure 15: Multidrug-resistant *Mycobacterium tuberculosis,* number reported to CARAlert by month, 2017 – 2021, national

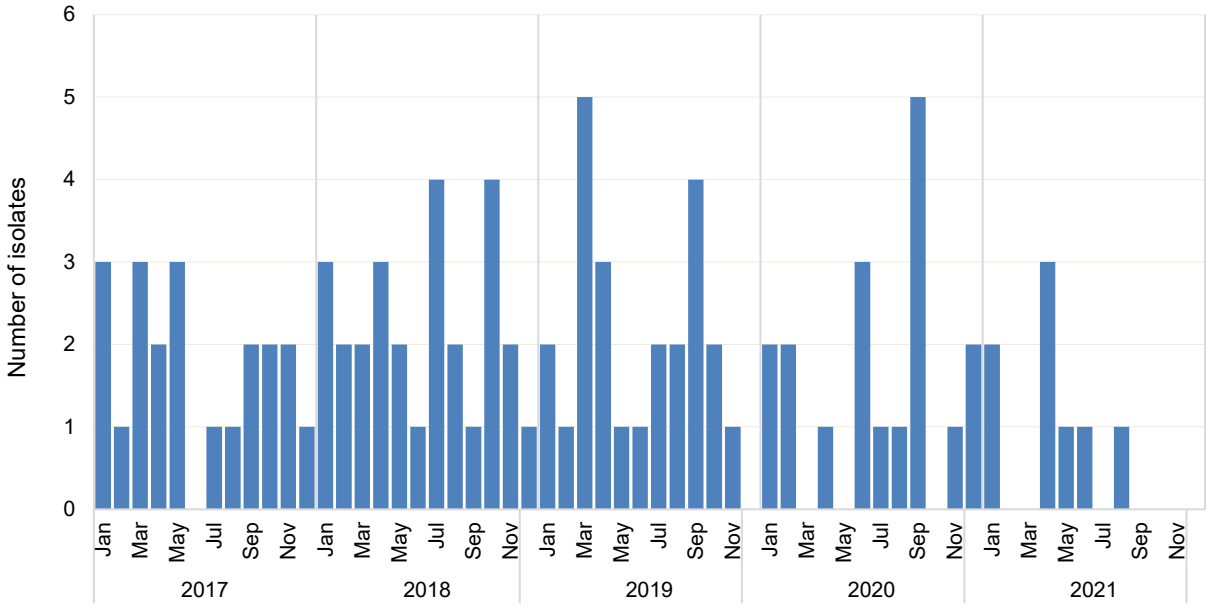
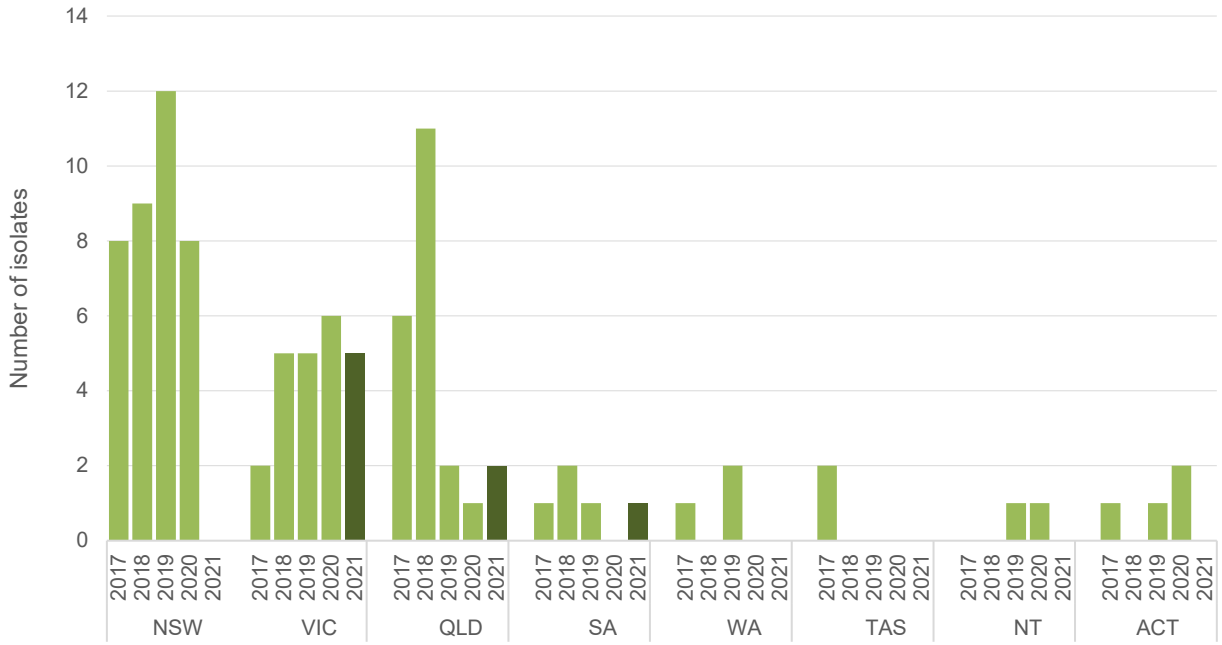


Figure 16: Multidrug-resistant *Mycobacterium tuberculosis*, number reported to CARAlert by state and territory, 2017–2021



Note: Dark bars indicate values for 2021.

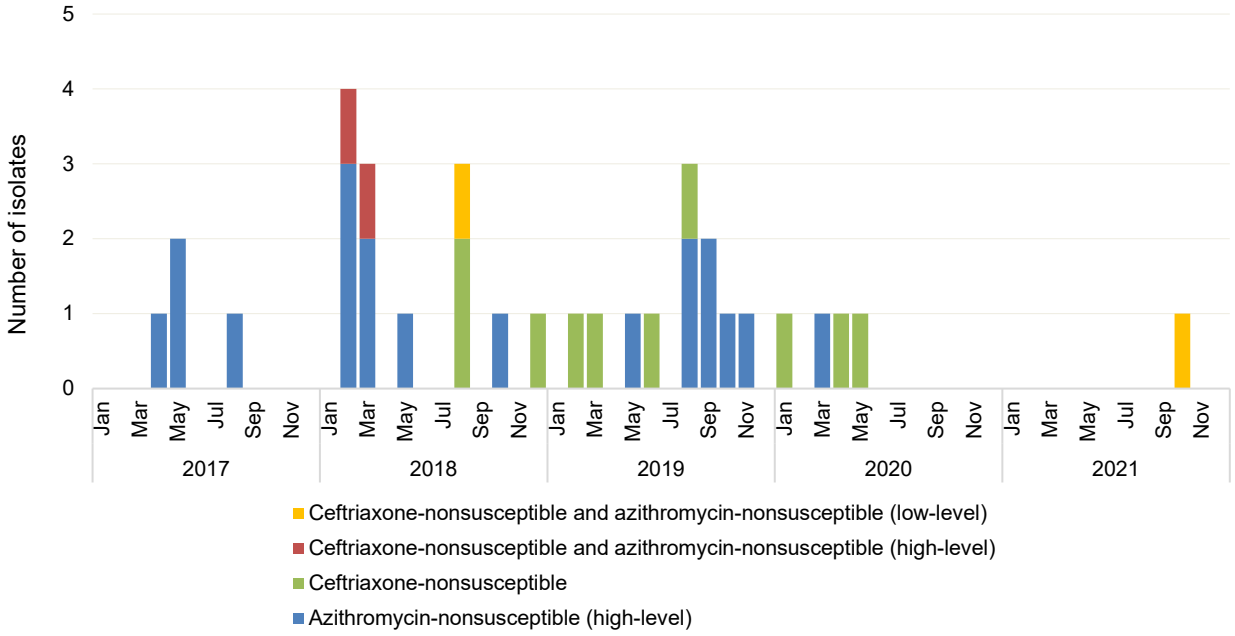
Neisseria gonorrhoeae

Neisseria gonorrhoeae causes gonorrhoea, a largely sexually transmitted infection that most commonly manifests as urethritis in men and cervicitis in women. In 2021, there was one report of a ceftriaxone-nonsusceptible and azithromycin-nonsusceptible (low-level) *N. gonorrhoeae* from Western Australia. There were sporadic reports of ceftriaxone-nonsusceptible and/or azithromycin-nonsusceptible (high-level) *N. gonorrhoeae* between 2017 and 2020 (Figure 17). Ceftriaxone-nonsusceptible isolates were reported for the first time in 2018 (*n* = 6); there were four reports of this CAR in 2019, and three in 2020.

No azithromycin-nonsusceptible (high-level) *N. gonorrhoeae* were reported in 2021.

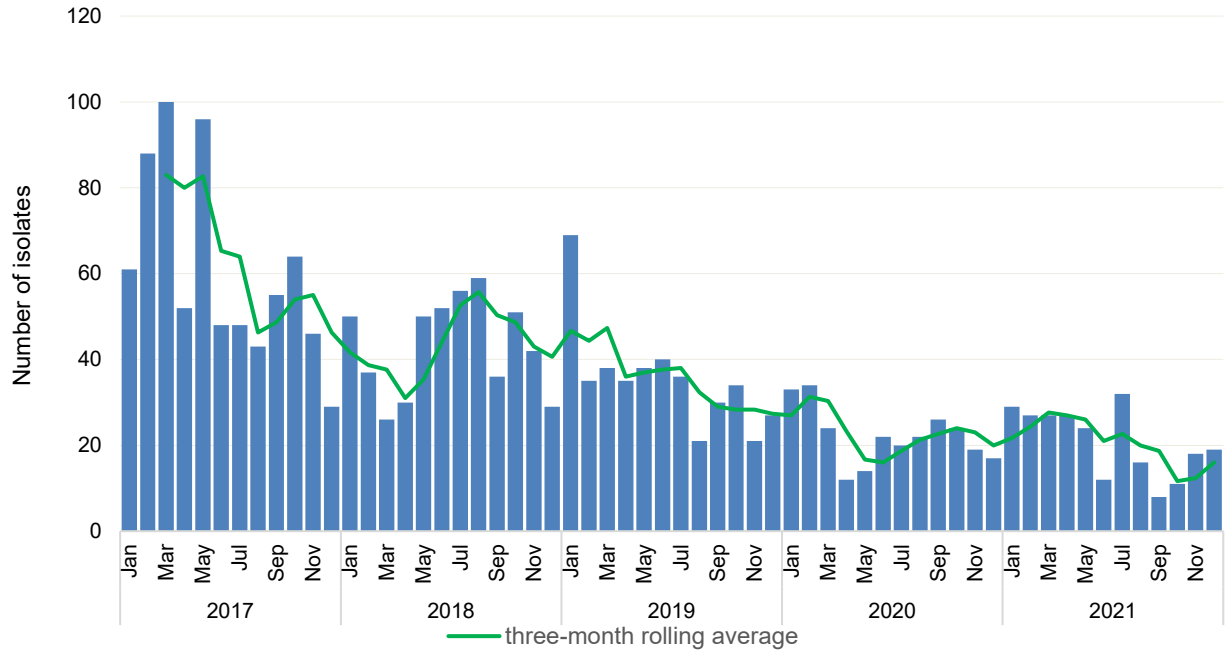
Reports of azithromycin-nonsusceptible (low-level) *N. gonorrhoeae* decreased from 2017 to 2020 (Figure 18). The majority of reports over the period were from New South Wales and Victoria (Figure 19). There was a slight decrease in the total number of reports of this CAR in 2021 compared to 2020 (*n* = 250 in 2021; *n* = 267 in 2020, down 6%). There was a three-fold decrease in the number from Queensland (*n* = 13 in 2021; *n* = 41 in 2020), and a two-fold increase in the number of reports from Victoria (*n* = 45 in 2021; *n* = 25 in 2020) over the two-year period.

Figure 17: Ceftriaxone-nonsusceptible and/or azithromycin-nonsusceptible (high-level) *Neisseria gonorrhoeae,* number reported to CARAlert by month, 2017–2021



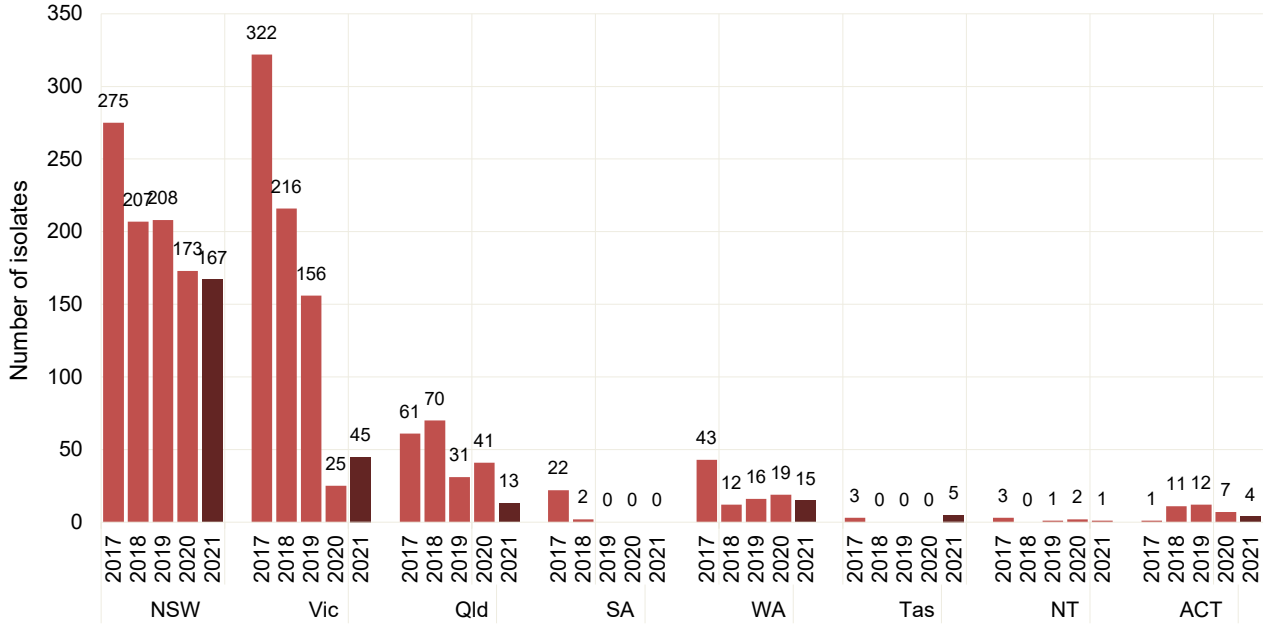
Low-level = azithromycin MIC < 256 mg/L; High-level = azithromycin MIC ≥ 256 mg/L

Figure 18: Azithromycin-nonsusceptible (low-level) *Neisseria gonorrhoeae,* number reported to CARAlert by month, 2017–2021



Low-level = azithromycin MIC < 256 mg/L

Figure 19: Azithromycin-nonsusceptible (low-level) *Neisseria gonorrhoeae,* number reported to CARAlert by state and territory, 2017–2021



Low-level = azithromycin MIC < 256 mg/L

Note: Dark bars indicate values for 2021.

Pseudomonas aeruginosa

Pseudomonas aeruginosa infections primarily affect hospitalised or immunocompromised patients. Patients with catheters or drains may be considered at high risk for carbapenemase transmission. Reporting for carbapenemase-producing *P. aeruginosa* began in July 2019.

In 2021, 68 carbapenemase-producing *P. aeruginosa* were reported from three jurisdictions (New South Wales, Victoria, and Western Australia). This was a 1.5-fold increase from 2020 (*n* = 44) (Figures 20 and 21). Eighty-eight percent were either GES [*n* = 50] or VIM [*n* = 10] types. GES-types dominated the reports from New South Wales (*45*/50, 90%), while VIM-types were most common in reports from Victoria (7/10, 70%). NDM-types were reported from all three states who reported this CAR.

Where setting was known, 91% (60/66) of carbapenemase-producing *P. aeruginosa* were reported from hospitals (Table 5).

Figure 20: Carbapenemase-producing *Pseudomonas aeruginosa*, number reported to CARAlert by specimen type, 2021

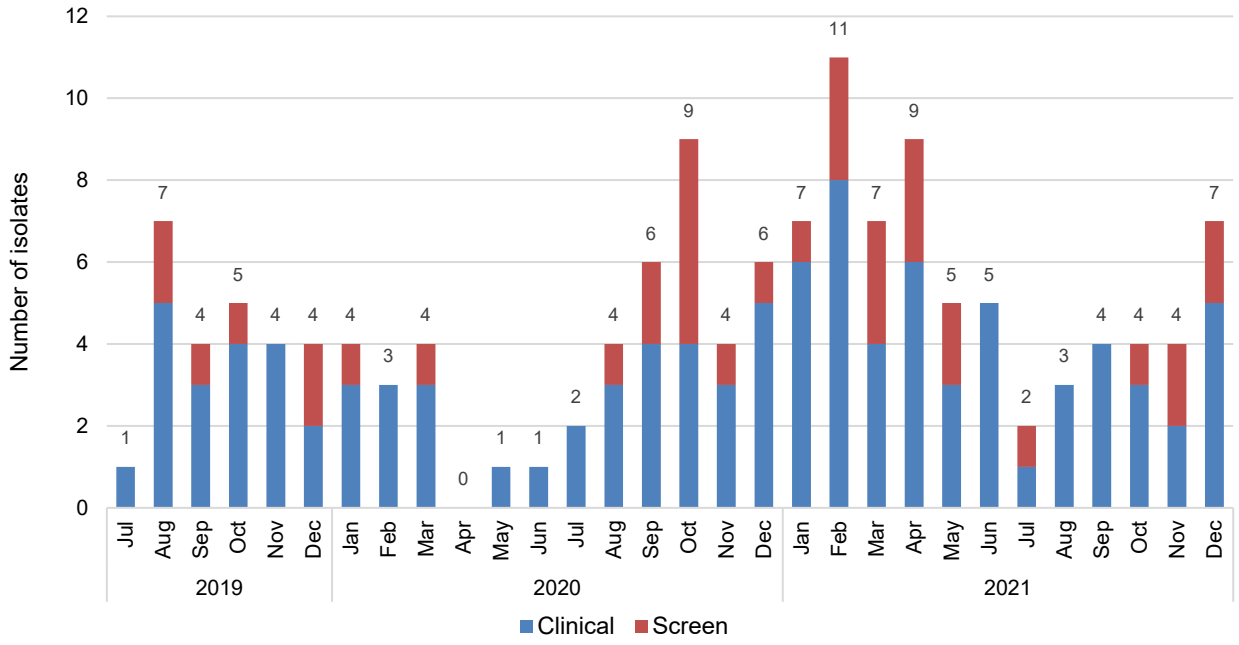


Figure 21: Carbapenemase-producing *Pseudomonas aeruginosa*, number reported to CARAlert by carbapenemase type and specimen type, by state and territory, 2021

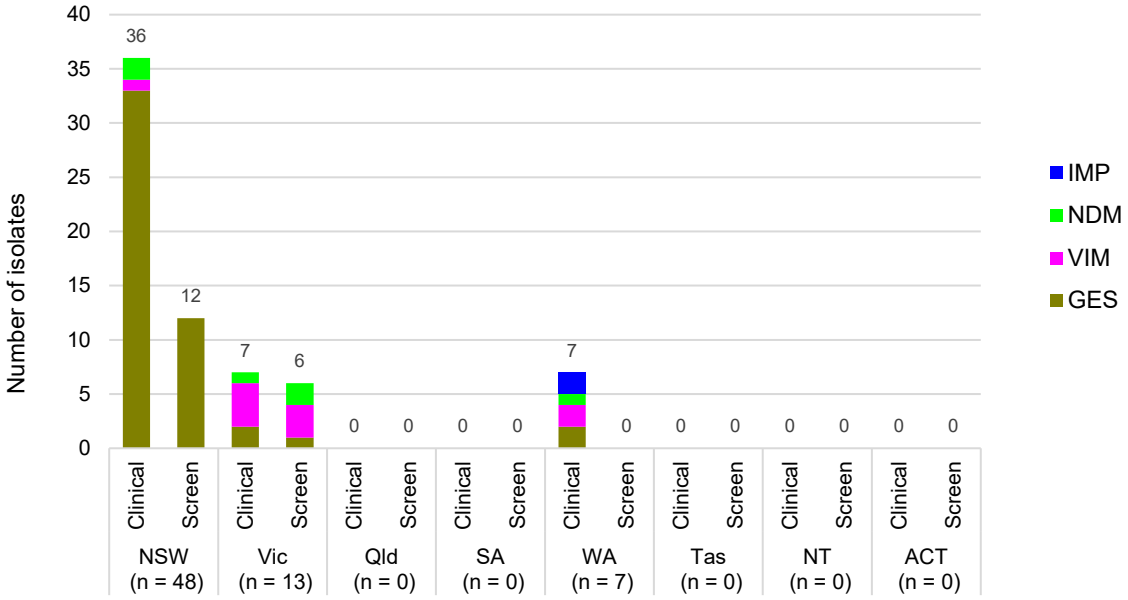


Table 5: Carbapenemase-producing *Pseudomonas aeruginosa*, number reported to CARAlert by setting and state and territory, 2021

Setting	State or territory								Total
	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	
Total	**48**	**13**	**0**	**0**	**7**	**0**	**0**	**0**	**68**
Public hospitals	38	9	0	0	4	0	0	0	51
Private hospitals	6	1	0	0	2	0	0	0	9
Aged care homes	0	0	0	0	0	0	0	0	0
Community	3	2	0	0	1	0	0	0	6
Unknown	1	1	0	0	0	0	0	0	2

Salmonella species

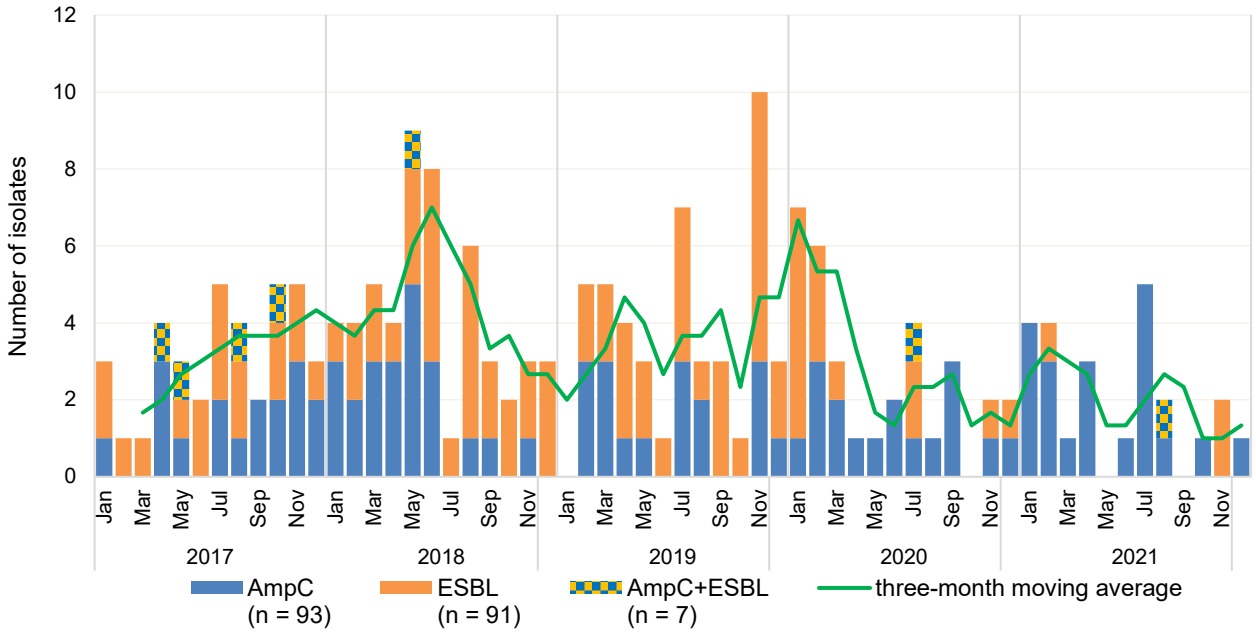
Salmonella species are important causes of bacterial gastroenteritis. Most cases are acquired through food-borne transmission. The number of reports of ceftriaxone-nonsusceptible *Salmonella* species decreased in 2021 compared to 2020 (*n* = 24 in 2021; *n* = 32 in 2020) (Figure 22). The greatest decrease was seen in New South Wales (*n* = 2 in 2021; *n* = 8 in 2020). There was a slight increase in reports from Victoria (*n* = 9 in 2021; *n* = 6 in 2020) (Figure 23). There were no reports from South Australia, Tasmania, the Northern Territory, and the Australian Capital Territory.

Almost all the ceftriaxone-nonsusceptible *Salmonella* reports were from non-typhoidal species (23/24, 96%). One typhoidal species was reported from New South Wales.

The ceftriaxone-nonsusceptible *Salmonella* non-typhoidal species contained a plasmid-mediated AmpC (pAmpC) (20/23, 87%), or extended-spectrum β-lactamase (ESBL) (3/23, 13%). The typhoidal species contained both pAmpC and ESBL. Where the variant was known, the pAmpC were all CMY-2.

Reports from public hospitals are likely due to admissions associated with severe disease acquired in the community (Table 6).

Figure 22: Ceftriaxone-nonsusceptible *Salmonella* species*, number reported to CARAlert by month, 2017–2021



* Non-typhoidal *Salmonella* species (*n* = 180) and typhoidal *Salmonella* species (*n* = 11)

Figure 23: Ceftriaxone-nonsusceptible *Salmonella* species, number reported to CARAlert by state and territory, 2017–2021

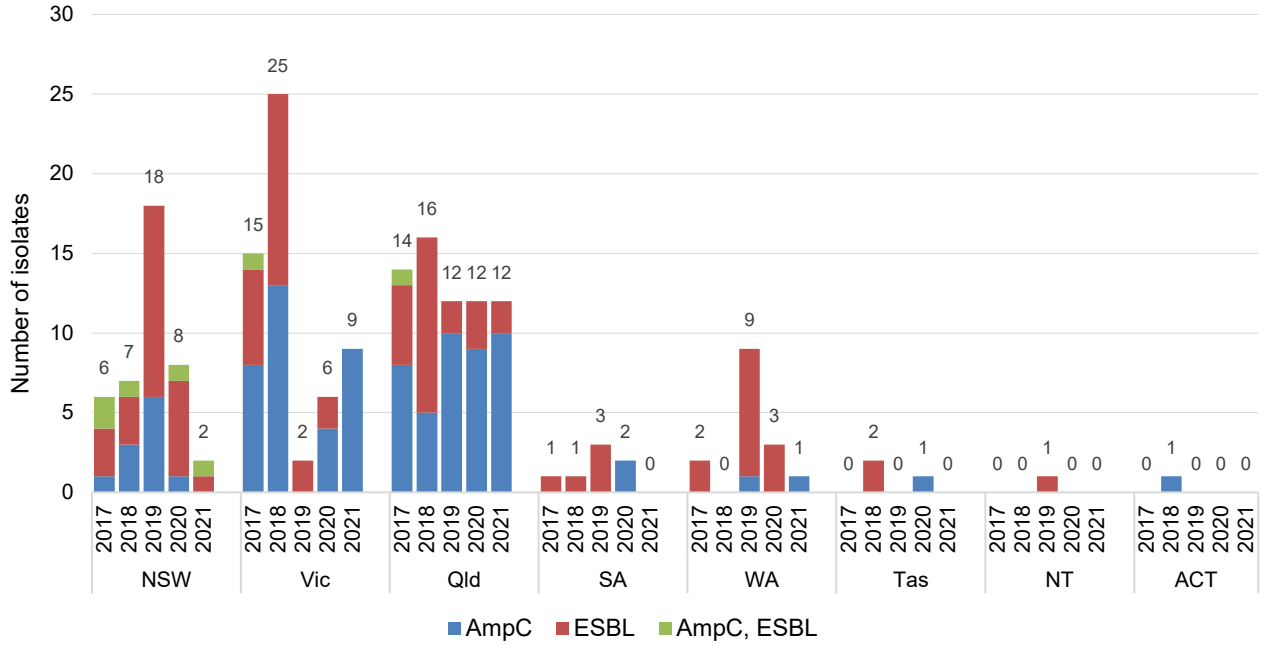


Table 6: Ceftriaxone-nonsusceptible *Salmonella* species, number reported to CARAlert by setting, state and territory, 2021

	State or territory								
Setting	**NSW**	**Vic**	**Qld**	**SA**	**WA**	**Tas**	**NT**	**ACT**	**Total**
Total	**2**	**9**	**12**	**0**	**1**	**0**	**0**	**0**	**24**
Public hospital	2	5	5	0	0	0	0	0	12
Private hospital	0	0	1	0	0	0	0	0	1
Aged care home	0	0	0	0	0	0	0	0	0
Community	0	2	6	0	1	0	0	0	9
Unknown	0	2	0	0	0	0	0	0	2

Shigella species

Shigella species infections are commonly food-borne or sexually transmitted. In 2021, there was a ten-fold decrease in the number of MDR *Shigella* species reports compared to 2020 (*n* = 30 in 2021; *n* = 298 in 2020). The reports were predominantly from Victoria (9/30, 30%), Western Australia (8/30, 27%) and New South Wales (7/30, 23%) (Figure 24 and 25). Reports from New South Wales declined rapidly in 2021 compared to 2020 (*n* = 7 in 2021; *n* = 169 in 2020, down 96%).

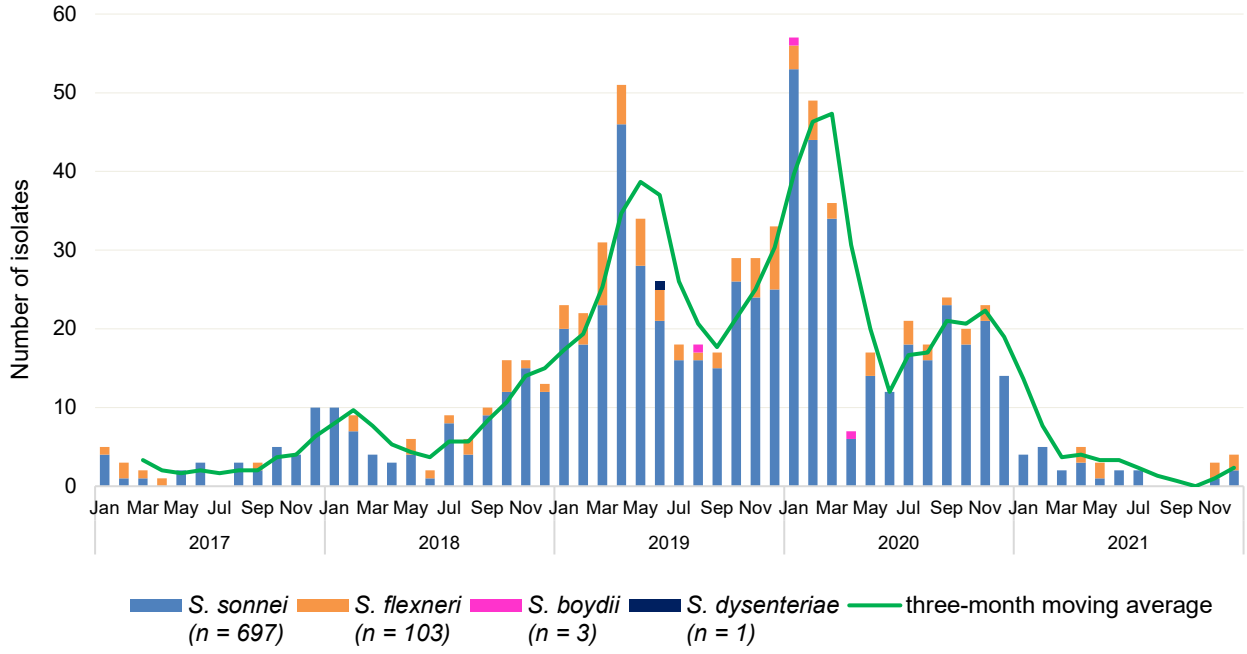
Shigella sonnei was the predominant species (20/25, 80%) in all jurisdictions except Queensland where *S. flexneri* comprised a little over one-half (3/5, 60%) of the reports. There were no reports from Tasmania, the Northern Territory, or the Australian Capital Territory in 2021.

The proportion of shigellosis notifications that were MDR decreased from 18.6% (298/1,600) nationally in 2020 to 6.6% in 2021 (30/455: range, 1.4% [1/69] in South Australia to 29.0% [9/31] in Queensland) (Figure 26).

Almost all (23/24, 96%) of the MDR *Shigella* species were reported from hospital (*n* = 12) or community (*n* = 11) settings (Table 7).

National data

Figure 24: Multidrug-resistant *Shigella* species, number reported to CARAlert by month, 2017 – 2021



State and territory data

Figure 25: Multidrug-resistant *Shigella* species, number reported to CARAlert by state and territory, 2017–2021

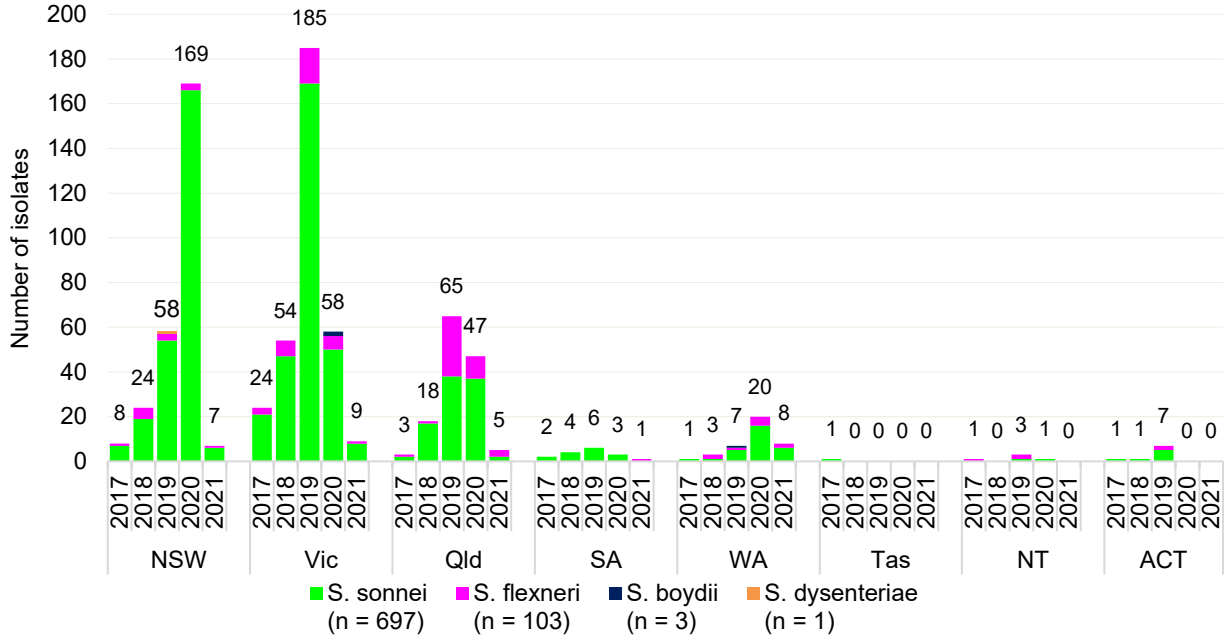
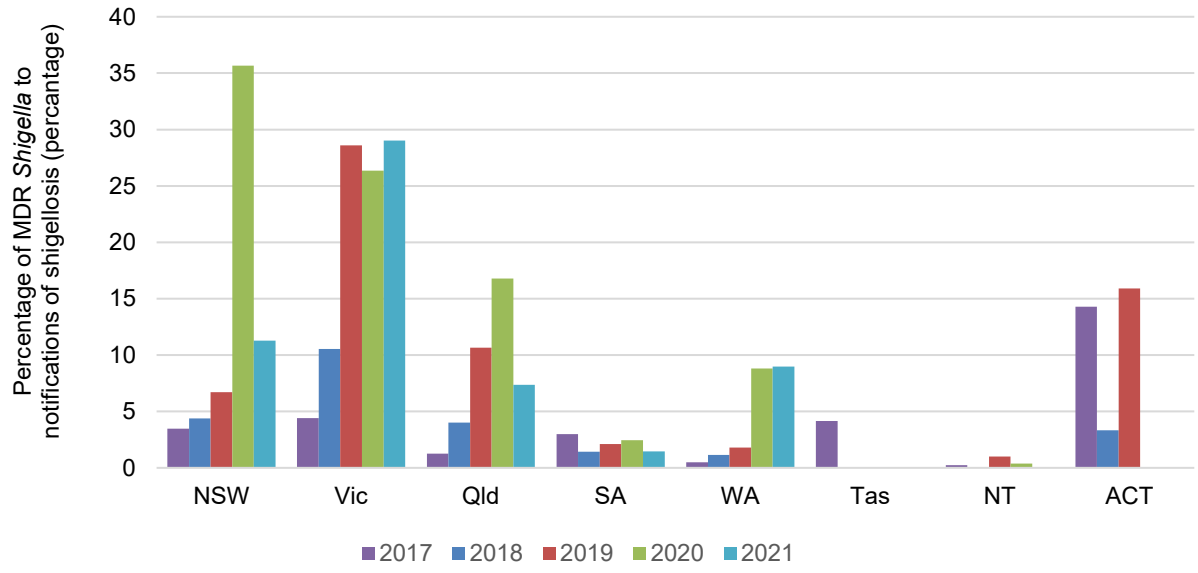


Table 7: Multidrug-resistant *Shigella* species, number reported to CARAlert by setting, state and territory, 2021

Setting	State or territory								Total
	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	
Total	**7**	**9**	**5**	**1**	**8**	**0**	**0**	**0**	**30**
Public hospitals	3	3	1	0	4	0	0	0	11
Private hospitals	0	1	0	0	0	0	0	0	1
Aged care homes	0	0	0	0	0	0	0	0	0
Community	4	1	3	1	3	0	0	0	12
Unknown	0	4	1	0	1	0	0	0	6

Figure 26: Multidrug-resistant *Shigella* species and notifications of shigellosis, proportion reported to CARAlert by state and territory, 2017–2021



Note: Notifications of shigellosis may include diagnosis by PCR only.

Source: National Notifiable Diseases Surveillance System[12]

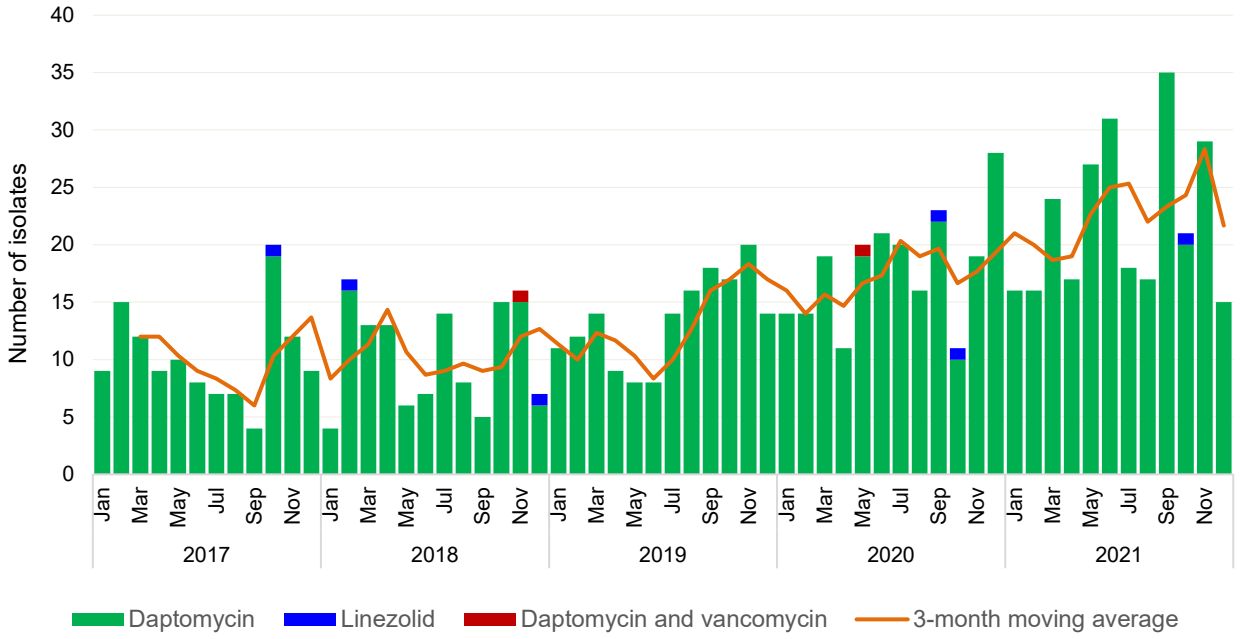
Staphylococcus aureus

Staphylococcus aureus is a common pathogen causing a wide variety of infections of varying severity. The number of vancomycin-, linezolid- or daptomycin-nonsusceptible *S. aureus* reports has increased two-fold from 2018 (*n* = 266 in 2021; *n* = 125 in 2018) (Figure 27). In 2021, 50% (134/266) of all reports were from Queensland (Figure 28). Almost all were DNSA, with only one linezolid-nonsusceptible *S. aureus* reported from Queensland.

The total number of reports of DNSA increased in 2021 (*n* = 265 in 2021; *n* = 213 in 2020, up 24%). There was an increase in the numbers reported from Queensland (*n* = 133 in 2021; *n* = 106 in 2020), Western Australia (*n* = 39 in 2021; *n* = 35 in 2020), and the Australian Capital Territory (*n* = 6 in 2021; *n* = 2 in 2020) compared to 2020; however, reports from Victoria decreased (*n* = 24 in 2021; *n* = 27 in 2020, down 11%). In 2021, where the setting was known, reports were predominantly from hospitals (111/248, 45%) and the community (109/248, 44%); and 11% (28/248) were from aged care homes (Table 8). Differences in testing and reporting practices by originating laboratories for this CAR may contribute to disproportionate state and territory numbers.

National data

Figure 27: Vancomycin, linezolid or daptomycin-nonsusceptible *Staphylococcus aureus,* number reported to CARAlert by month, 2017–2021



Notes:

1. For CARAlert, *S. aureus* complex includes *S. argenteus* and *S. schweitzeri*
2. No *S. argenteus* and *S. schweitzeri* were reported from 2017 to 2021
3. No vancomycin-nonsusceptible *S. aureus* were reported from 2017 to 2021.

State and territory data

Figure 28: Vancomycin-, linezolid- or daptomycin-nonsusceptible *Staphylococcus aureus,* number reported to CARAlert, 2017–2021

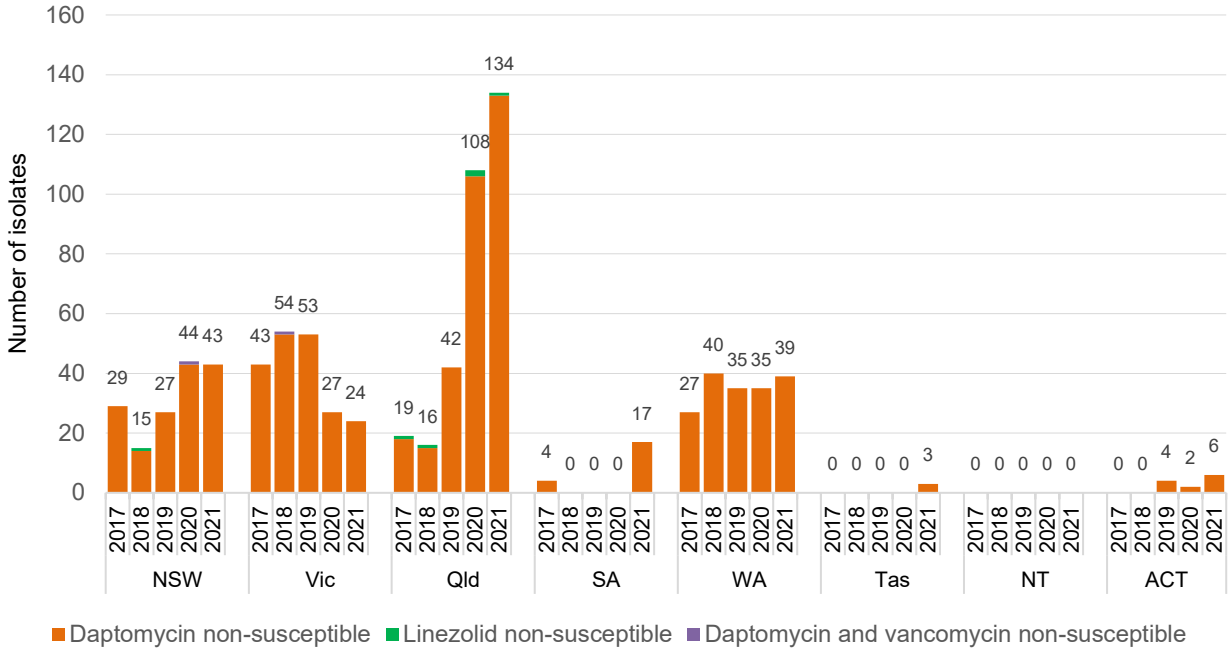


Table 8. Daptomycin-nonsusceptible *Staphylococcus aureus,* number reported to CARAlert by setting and state and territory, 2021

	State or territory								
Setting	**NSW**	**Vic**	**Qld**	**SA**	**WA**	**Tas**	**NT**	**ACT**	**Total**
Total	**43**	**24**	**133**	**17**	**39**	**3**	**0**	**6**	**265**
Public hospital	19	14	4	10	33	3	0	3	86
Private hospital	1	1	23	0	0	0	0	0	25
Aged care home	4	0	22	0	1	0	0	1	28
Community	17	2	78	7	3	0	0	2	109
Unknown	2	7	6	0	2	0	0	0	17

Streptococcus pyogenes

Streptococcus pyogenes most commonly causes skin and soft tissue infections, and acute pharyngitis, but may cause serious and life-threatening infections such as scarlet fever, septicaemia, bone and joint infections, toxic shock syndrome, necrotising fasciitis and pneumonia.

There have been no reports of *S. pyogenes* with reduced susceptibility to penicillin between 2017 and 2021.

Discussion

Carbapenemase-producing *Enterobacterales*

Carbapenemase-producing *Enterobacterales* continue to be dominated by those of the IMP type, found most often in the *E. cloacae* complex. CPE were reported from 130 public and private hospitals throughout Australia in both 2020 and 2021. This is compared to 132 hospitals in 2019, and 120 in 2018. Despite 20% (26/130) of Australian hospitals reporting CPE for the first time in 2021, there has been a general decline in reports of this CAR since 2019.

NDM-producing *Enterobacterales* were reported from all states and territories. Reports have continued to decrease in 2020 and 2021, after increasing during 2019. Although NDM types are generally thought to be acquired overseas, identification of local transmission and appropriate control action are important priorities. A reduction in reports may reflect the closure of international borders following the onset of the coronavirus 2019 (COVID-19) pandemic.

The differences between states and territories in the proportion of screening isolates may indicate local variations in surveillance, infection prevention and control, and screening practices. The impact of outbreaks on other aspects of hospital work and patient flows may be substantial in the absence of timely prevention and control action. The variation between states and territories in reports of CPE as a proportion of all CARs, and the frequency of reporting of CPE, indicates the need for local decisions about containment priorities.

A total of 7.7% of all CPE reports (46/600) occurred in the 0–4-year age group. The mode of acquisition of these CARs is not known; however, CPE outbreaks can occur in the neonatal intensive care unit setting. The long-term impact of this type of resistance on neonates is unknown. Education of clinicians on the risks of neonatal acquisition of antimicrobial-resistant organisms, and review of the appropriateness of antimicrobial use and infection control in the neonatal care setting are encouraged.

Patients are likely to be affected by CPE if they: are hospitalised for a prolonged period; have been hospitalised or had surgery overseas; have had multiple, or recent exposure to different antimicrobial agents, especially cephalosporins, fluoroquinolones and carbapenems; have diabetes mellitus; are on mechanical ventilation; are admitted to the intensive care unit; or have an indwelling medical device (such as a central venous catheter, urinary catheter or biliary catheter).

Ongoing reports of CPE albeit at low levels, highlight, the value of active surveillance and the importance of compliance with the *Australian Guidelines for the Prevention and Control of Infection in Healthcare*[7], and use of guidance for specific organisms, such as *Recommendations for the control of carbapenemase-producing* Enterobacterales*: A guide for acute health service organisations*.[8]

Arrangements for specialist oversight of and access to restricted antimicrobials, such as carbapenems, should continue to be a priority all Australian hospitals along with implementation of systems that meet the antimicrobial stewardship (AMS) actions of the National Safety and Quality Health Service (NSQHS) Standards.[13]

Critical antimicrobial resistances in aged care homes

The number of CARs reported from aged care homes has increased since 2019 (*n* = 56 in 2021; *n* = 49 in 2020; *n* = 41 in 2019). The majority of these were daptomycin-nonsusceptible *S. aureus* (28/56, 50% in 2021; 35/49, 71.4% in 2020; 22/41, 53.7% in 2019). The utility of continuing to monitor this CAR is currently under review due to changes in laboratory testing and reporting practices that may have contributed to disproportionate results between states and territories. The next most commonly reported CAR was CPE (*n* = 26 in 2021; *n* = 13 in 2020; *n* = 17 in 2019). Almost 89% (50/56) of all CARs reported from aged care homes in 2021 were from clinical isolates.

In aged care homes, skin and soft tissue infections are the most common reason for antimicrobial prescriptions.[14] Skin and soft tissue infections are commonly caused by *S. aureus*, which is spread by contact with contaminated surfaces and hands of care workers, visitors and residents; this is why environmental cleaning and hand hygiene are so important. In group living situations, *S. aureus* may also be inadvertently spread by sharing personal items such as bed linen, towels or clothing.

In Queensland, the number of reports of this CAR in *S. aureus* from aged care homes (*n* = 22) was similar to reports from hospitals (*n* = 27). These results may reflect variation between laboratories in the testing for, and reporting of, this CAR.

There is a risk of transmission of these CARs in aged care homes and in hospitals due to the frequent movement of aged care home residents between these two settings. Control of CPE requires specific infection prevention and control measures in all care settings. To support capacity to prevent and control transmission of CPE, aged care homes should comply with the infection prevention and control requirements of the Aged Care Quality Standards, which includes compliance with national guidelines.[7]

Critical antimicrobial resistances in young Australians

The 0–4-year age group accounted for 25% (6/24) of all reports of ceftriaxone-nonsusceptible *Salmonella* species and 7.7% of all CPE (46/600).

The long-term impacts of antimicrobial-resistant pathogens in children are unknown; expert opinion suggests that clearance of many CARs cannot be assured.[15] In addition, antimicrobial exposure in early childhood has been associated with a variety of health risks.[16-18]

Multidrug-resistant *Shigella* species

Reports of multidrug-resistant (MDR) *Shigella* species decreased ten-fold in 2021 after declining in 2020 from 2019 (*n* = 30 in 2021; *n* = 298 in 2020; *n* = 331 in 2019). A sharp decrease occurred in April 2020, which corresponded with the introduction of COVID-19 restrictions in Australia. In 2021, reports of this CAR were predominantly from Victoria (9/30, 30%), Western Australia (8/30, 27%) and New South Wales (7/30, 23%). In 2019, the majority of reports were from Victoria (38/51; 75%), and in 2020, most were from New South Wales (35/57; 61%).

Whilst reports of MDR *Shigella* species have declined since 2020, it is reasonable to anticipate an increase in reporting in 2022 and beyond following the easing of COVID-19 restrictions in Australia. Therefore, ongoing surveillance will be important. Past increases in reports suggest that empirical antimicrobial therapy recommendations for shigellosis may need to be reconsidered. Increases also require ongoing close review by states and territories as there are limited oral antimicrobial options, and intravenous antimicrobials may be required to treat MDR infections. There may also be resource implications for the health system because of increased testing, hospital admissions and transmission in the community. Public health messaging should continue to highlight the risk of sexual transmission of *Shigella* species, particularly in men who have sex with men, and provide guidance on ways to reduce the risk of transmission.

Neisseria gonorrhoeae

There was one report of *Neisseria gonorrhoeae* with ceftriaxone-nonsusceptibility in 2021 compared to three in 2020, four in 2019 and six in 2018. A number of reports from other countries of ceftriaxone-resistant *N. gonorrhoeae* strains raised global concerns about the effectiveness of current recommended treatments.[19-21] In Australia, the recommended treatment for *N. gonorrhoeae* is ceftriaxone in conjunction with azithromycin. This regimen was introduced in Australia in 2014 to

limit further development of resistance to ceftriaxone.[22] The low background rate of azithromycin-nonsusceptible *N. gonorrhoeae* (low-level resistance) in Australia is well established. Reports of this CAR have declined since 2019 in the context of 34,244 notifications of gonococcal infection nationally in 2019, 29,517 notifications in 2020, and 26,045 notifications in 2021.[12] The clinical implications of this low-level resistance are not clear. Continuing low numbers of reports of ceftriaxone-nonsusceptibility, and the resumption of usual social interaction and international travel following easing of COVID-19 restrictions from late 2021, indicate that ongoing monitoring of azithromycin- and ceftriaxone-nonsusceptibility is required because of the importance of emerging changes in susceptibility for treatment guidelines.

Enterococcus species

Reports of linezolid-nonsusceptible *Enterococcus* species declined in 2021 (*n* = 13 in 2021; *n* = 19 in 2020, down 32%). This was after an increased number of reports from 2018 (*n* = 14) to 2019 (n = 22). There were only four reports of this CAR in 2017. Although numbers are low, this CAR has potential for emerging resistance in the future.[23]

Other CARs reported to CARAlert

Other CARs reported to CARAlert remain at very low levels; however, ongoing prevention and control strategies, and monitoring are essential to ensure that levels of these CARs remain low in Australia.

The Commission's Antimicrobial Use and Resistance in Australia (AURA) team will also continue to prepare analyses of antimicrobial resistance data for, and liaise with, Therapeutic Guidelines Limited, the organisation that develops guidance on antimicrobial prescribing in Australia.

Emerging critical antimicrobial resistances

There were no reports of *mcr-1* in 2021. Colistin resistance is concerning because it limits the effectiveness of a last-line antimicrobial. This means it is an urgent priority for continued surveillance and rapid prevention and control action when detected.

Developments and future plans

The Commission's AURA team will continue to collaborate with relevant experts to enhance CARAlert as new resistances are identified. The next review of CARs reported to CARAlert will occur in 2022. The AURA team will also continue to maintain the CARAlert system, and review reported CARs in collaboration with states, territories, the Australian Government Department of Health and clinical experts to inform potential outbreak responses, infection prevention and control programs, and antimicrobial prescribing.

Data reported to the AURA Surveillance System signal implications for health services as a result of antimicrobial resistance (AMR). Estimates of the impacts of AMR vary by organism, and are not available for the majority of CARs. However, CARs do increase hospital length of stay, deaths and health service resource needs.

The Commission will work with states and territories on strategies to promote consistency of screening and infection control practices to improve CPE containment. The response to emerging CARs in aged care homes will be considered in liaison with the Aged Care Quality and Safety Commission, aged care provider organisations and general practitioners. The importance of infection prevention and control, and AMS in this setting will be promoted, consistent with the

mandatory Aged Care Quality Standards, with specific considerations for the response to CPE and other CARs.

Maintaining effective surveillance of resistance in *N. gonorrhoeae* and *Shigella* species, continuing programs for prevention and control of sexually transmissible infections and implementing outbreak response strategies are all essential to minimise the spread of untreatable gonorrhoea and shigellosis.

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Appendix 1 About CARAlert

The National Alert System for Critical Antimicrobial Resistances (CARAlert) was established by the Australian Commission on Safety and Quality in Health Care (the Commission) in March 2016 as a component of the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System. Participating confirming laboratories submit data to CARAlert on priority organisms with critical resistance to last-line antimicrobial agents (CARs). Isolates collected from patients are reported to CARAlert as either a clinical isolate, that is a specimen (e.g., from blood, urine, wound) taken to guide clinical diagnosis, or as a screen for infection prevention and control purposes. No patient-level data are held in the CARAlert system. Funding for CARAlert is provided by the Australian Government Department of Health, with contributions from the states and territories as part of the analysis and data submission processes.

The CARs reported under CARAlert are listed in Table A1. These CARs were drawn from the list of high-priority organisms and antimicrobials that are the focus of the AURA Surveillance System.

In 2021, 28 confirming laboratories participated in CARAlert (Appendix 3). CARAlert generates a weekly summary email alert to report information on confirmed CARs to state and territory health authorities, the Australian Government Department of Health and confirming laboratories. CARAlert is based on routine processes used by pathology laboratories for identifying and confirming potential CARs.

CARAlert data support timely responses to CARs by hospitals, and state and territory health departments. Some states have made selected CARs, such as carbapenemase-producing *Enterobacterales* (CPE) and *Candida auris*, notifiable either using their public health legislation or by policy. Some states and territories have standalone systems for monitoring selected CARs, which complement CARAlert, but these are not widespread. Over time, CARAlert data will become increasingly useful to inform a broader range of safety and quality improvement programs.

The Commission's AURA team reviewed CARs reported to CARAlert in 2018, in conjunction with relevant experts, and the states and territories. The review identified four new CARs that were reported to CARAlert from July 2019:

- Transferrable resistance to colistin in *Enterobacterales*
- Carbapenemase-producing *Acinetobacter baumannii* complex
- Carbapenemase-producing *Pseudomonas aeruginosa*
- *Candida auris*.

The next review of CARs reported to CARAlert will be in completed by the Commission in 2022.

Information on CARAlert processes and considerations for interpreting CARAlert data is in Appendix 2.

Table A1: List of critical antimicrobial resistances reported to CARAlert

Species	Critical Resistance
Acinetobacter baumannii complex	Carbapenemase-producing*
*Candida auris**	–
Enterobacterales	Carbapenemase-producing, and/or ribosomal methyltransferase-producing
Enterobacterales	Transmissible colistin resistance*
Enterococcus species	Linezolid-resistant
Mycobacterium tuberculosis	Multidrug-resistant – resistant to at least rifampicin and isoniazid
Neisseria gonorrhoeae	Ceftriaxone-nonsusceptible or azithromycin§-nonsusceptible
Salmonella species	Ceftriaxone-nonsusceptible
Shigella species	Multidrug-resistant
Staphylococcus aureus†	Vancomycin-, linezolid- or daptomycin-nonsusceptible
Streptococcus pyogenes	Penicillin reduced susceptibility
Pseudomonas aeruginosa	Carbapenemase-producing*

* Reported from July 2019

† For CARAlert, *S. aureus* includes *S. argenteus* and *S. schweitzeri*

§ Low level-azithromycin-nonsusceptible *N. gonorrhoeae* excluded from the weekly digest following review in 2018

Appendix 2 Methodology

CARAlert reporting processes

All of the following criteria must be met for organisms and resistances to be categorised as a critical antimicrobial resistance (CAR) for reporting to the National Alert System for Critical Antimicrobial Resistances (CARAlert):

- Inclusion as a priority organism for national reporting as part of the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System
- A serious threat to last-line antimicrobial agents
- Strongly associated with resistance to other antimicrobial classes
- At low prevalence in, or currently absent from, Australia and potentially containable
- Data not otherwise collected nationally in a timely way.

Candida auris does not meet the criterion regarding AURA Surveillance System priority organisms. It was added as a CAR for reporting to CARAlert from 2019, in response to feedback from respondents to the 2018 review of CARs reported to CARAlert, and international concerns from 2017, because it is multidrug-resistant and had been associated with outbreaks in healthcare facilities causing invasive infections. The United States Centers for Disease Control posted advice in 2017 about its detection, treatment and infection control measures that should be implemented.

The CARAlert system is based on the following routine processes used by pathology laboratories for identifying and confirming potential CARs:

- Collection and routine testing – the isolate is collected from the patient and sent to the originating laboratory for routine testing
- Confirmation – if the originating laboratory suspects that the isolate is a CAR, it sends the isolate to a confirming laboratory that has the capacity to confirm the CAR
- Reporting to clinicians in accordance with usual laboratory processes – the confirming laboratory reports back to the originating laboratory, which in turn reports to the clinician who initially requested the microbiological testing
- Submission to the CARAlert system – the confirming laboratory advises the originating laboratory of the result of the test, and the originating laboratory reports back to the health service that cared for the patient; the confirming laboratory then submits the details of the resistance and organism to the secure CARAlert web portal.

Information collected in CARAlert includes: the originating and confirmatory laboratory, specimen identifier, specimen collection date, CAR, CAR type or subtype if applicable, organism name, specimen type, facility type, patient age range, patient gender, and state or territory of patient residence and state or territory of record.

No patient-level data are held in the CARAlert system. Authorised officers in each state and territory health department can access the CARAlert web portal directly for further information about their jurisdiction, including the name of the public hospital where a patient with a confirmed CAR was cared for, and to extract reports on their data.

Australian public and private laboratories that have the capacity to confirm CARs were identified through consultation with state and territory health authorities, the Public Health Laboratory Network (PHLN) and the Australian Group on Antimicrobial Resistance (AGAR). In 2021, 28 confirming laboratories participated in CARAlert, and there was at least one confirming laboratory in each state and territory. The CARs that each of the confirming laboratories are able to confirm are regularly reviewed.

All data analyses for this report were performed using Microsoft Excel 365.

Data considerations

The following are important considerations for interpreting CARAlert data:

- The data are based on the date that the isolate with the confirmed CAR was collected.
- States and territories refer to the state or territory within which the hospital is located, or within which the patient resides for isolates from the community. If place of residence is unknown or overseas, the state or territory of the originating laboratory is reported.
- The same CAR/type/species is not submitted where the sample originated from the same patient who had the previous CAR, and the isolate was collected on the same day, or collected in the same admission or within three months.
- Comparison between reports may be influenced by delayed detection or late submissions of CARs.
- Number of CARs reported does not always equal the number of patients, as patients may have more than one CAR, or species, detected in a specimen.
- Cut-off date for data that are included in updates and reports is four weeks after the end of each reporting period.
- National summary data is provided; comparison across states and territories is provided for organisms where there are large numbers reported and a comparison is meaningful.

Appendix 3 CARAlert confirming laboratories, 2021

The Commission thanks all the originating and confirming laboratories for their support for CARAlert and AURA. The following confirming laboratories contributed to CARAlert in 2021:

State or Territory	Institution
Australian Capital Territory	ACT Pathology, Garran
New South Wales	NSW Health Pathology, Concord Hospital, Concord
	NSW Health Pathology, Liverpool Hospital, Liverpool
	NSW Health Pathology, John Hunter Hospital, New Lambton Heights
	NSW Health Pathology, Royal North Shore Hospital, St Leonards
	NSW Health Pathology, Royal Prince Alfred Hospital, Camperdown
	NSW Health Pathology, St George Hospital, Kogarah
	NSW Health Pathology, The Prince of Wales Hospital, Randwick
	NSW Health Pathology, Westmead Hospital, Westmead
	St Vincent's Pathology (SydPath), Darlinghurst
Northern Territory	Territory Pathology, Tiwi
Queensland	Pathology Queensland, Central laboratory, Royal Brisbane and Women's Hospital, Herston
	Pathology Queensland, Forensic & Scientific Services, Coopers Plains
	QML Pathology, Murarrie
	Sullivan Nicolaides Pathology, Bowen Hills
South Australia	SA Pathology, Royal Adelaide Hospital, Adelaide
Tasmania	Royal Hobart Hospital, Hobart
Victoria	Alfred Pathology Service, Melbourne
	Austin Pathology, Heidelberg
	Dorevitch Pathology, Heidelberg
	Microbiological Diagnostic Unit Public Health Laboratory, Melbourne
	Victorian Infectious Diseases Reference Laboratory (VIDRL), Melbourne
	Melbourne Pathology, Collingwood
	Monash Pathology, Clayton
	St Vincent's Hospital, Fitzroy
Western Australia	PathWest Laboratory Medicine WA, Fiona Stanley Hospital, Murdoch
	PathWest Laboratory Medicine WA, QEII Medical Centre, Nedlands
	Australian Clinical Labs, Osborne Park

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