Australian Group on Antimicrobial Resistance (AGAR) Australian Enterococcal Sepsis Outcome Programme (AESOP) Annual Report 2020

Geoffrey W Coombs, Denise A Daley, Nicholas W T Yee, Princy Shoby, Shakeel Mowlaboccus, on behalf of the Australian Group on Antimicrobial Resistance
Communicable Diseases Intelligence
ISSN: 2209-6051 Online

This journal is indexed by Index Medicus and Medline.

Creative Commons Licence - Attribution-NonCommercial-NoDerivatives CC BY-NC-ND

© 2022 Commonwealth of Australia as represented by the Department of Health

This publication is licensed under a Creative Commons Attribution-Non-Commercial-NoDerivatives 4.0 International Licence from https://creativecommons.org/licenses/by-nc-nd/4.0/legalcode (Licence). You must read and understand the Licence before using any material from this publication.

Restrictions
The Licence does not cover, and there is no permission given for, use of any of the following material found in this publication (if any):

- the Commonwealth Coat of Arms (by way of information, the terms under which the Coat of Arms may be used can be found at www.itsanhonour.gov.au);
- any logos (including the Department of Health's logo) and trademarks;
- any photographs and images;
- any signatures; and
- any material belonging to third parties.

Disclaimer
Opinions expressed in Communicable Diseases Intelligence are those of the authors and not necessarily those of the Australian Government Department of Health or the Communicable Diseases Network Australia. Data may be subject to revision.

Enquiries
Enquiries regarding any other use of this publication should be addressed to the Communication Branch, Department of Health, GPO Box 9848, Canberra ACT 2601, or via e-mail to: copyright@health.gov.au

Communicable Diseases Network Australia
Communicable Diseases Intelligence contributes to the work of the Communicable Diseases Network Australia. http://www.health.gov.au/cdna

Communicable Diseases Intelligence (CDI) is a peer-reviewed scientific journal published by the Office of Health Protection and Response, Department of Health. The journal aims to disseminate information on the epidemiology, surveillance, prevention and control of communicable diseases of relevance to Australia.

Editor
Jennie Hood and Noel Lally

Deputy Editor
Simon Petrie

Design and Production
Kasra Yousefi

Editorial Advisory Board
David Durrheim, Mark Ferson, John Kaldor, Martyn Kirk and Linda Selvey

Website
http://www.health.gov.au/cdi

Contacts
CDI is produced by the Office of Health Protection and Response, Australian Government Department of Health, GPO Box 9848, (MDP 6) CANBERRA ACT 2601

Email:
cdi.editor@health.gov.au

Submit an Article
You are invited to submit your next communicable disease related article to the Communicable Diseases Intelligence (CDI) for consideration. More information regarding CDI can be found at: http://health.gov.au/cdi.

Further enquiries should be directed to:
cdi.editor@health.gov.au.
Annual report

Australian Group on Antimicrobial Resistance (AGAR) Australian Enterococcal Sepsis Outcome Programme (AESOP) Annual Report 2020

Geoffrey W Coombs, Denise A Daley, Nicholas W T Yee, Princy Shoby, Shakeel Mowlaboccus, on behalf of the Australian Group on Antimicrobial Resistance

Abstract

From 1 January to 31 December 2020, forty-nine institutions around Australia participated in the Australian Enterococcal Sepsis Outcome Programme (AESOP). The aims of AESOP 2020 were to determine the proportion of enterococcal bacteraemia isolates in Australia that were antimicrobial-resistant, and to characterise the molecular epidemiology of the \( E. faecium \) isolates. Of the 1,230 unique episodes of enterococcal bacteraemia investigated, 93.9% were caused by either \( E. faecalis \) (54.2%) or \( E. faecium \) (39.7%). Ampicillin resistance was not detected in \( E. faecalis \) but was detected in 88.2% of \( E. faecium \). Vancomycin non-susceptibility was detected in 0.2% of \( E. faecalis \) and 32.6% of \( E. faecium \). Overall, 35.2% of \( E. faecium \) harboured \( \text{vanA} \) and/or \( \text{vanB} \) genes. For the \( \text{vanA/B} \) positive \( E. faecium \) isolates, 38.8% harboured the \( \text{vanA} \) gene, 60.6% the \( \text{vanB} \) gene, and 0.6% harboured both \( \text{vanA} \) and \( \text{vanB} \). Although the percentage of \( E. faecium \) bacteraemia isolates was significantly lower than that detected in the 2019 AESOP (presumably due to the COVID-19 elective surgery restrictions placed on hospitals), it remains substantially higher than that recorded in most European countries. The \( E. faecium \) isolates detected consisted of 71 multilocus sequence types (STs), with 81.7% of these isolates classified into eight major STs each containing ten or more isolates. All major STs belonged to clonal cluster 17 (CC17), a major hospital-adapted polyclonal \( E. faecium \) cluster. The major STs (ST17, ST1424, ST80, ST796, ST78, ST1421, ST555 and ST117) were found across most regions of Australia. The predominant clone was ST17, which was identified in all regions except the Northern Territory. Overall, 40.9% of isolates belonging to the eight major STs harboured the \( \text{vanA} \) or \( \text{vanB} \) gene. The AESOP 2020 has shown enterococcal bacteraemia episodes in Australia are frequently caused by polyclonal ampicillin-resistant high-level gentamicin-resistant \( \text{vanA} \)- or \( \text{vanB} \)-positive \( E. faecium \) which have limited treatment options.

Keywords: Australian Group on Antimicrobial Resistance (AGAR); antimicrobial resistance surveillance; \( \text{Enterococcus faecium}, \) \( \text{Enterococcus faecalis} \), vancomycin-resistant enterococci (VRE), bacteraemia

Background

Globally, enterococcus is believed to account for approximately 10% of all bacteraemia cases; it is the fourth and fifth leading cause of sepsis in North America and Europe respectively.\(^1\,2\) Although, in the 1970s, healthcare-associated enterococcal infections were primarily due to \( \text{Enterococcus faecalis} \), there has been a steady increasing prevalence of \( E. faecium \) nosocomial infections.\(^3\,5\) Worldwide, the increase in nosocomial \( E. faecium \) infections has primarily been due to the expansion of polyclonal hospital-adapted clonal complex 17 (CC17) strains. While innately resistant to many classes of antibiotics, \( E. faecium \) has further demonstrated a remarkable capacity to evolve new antimicrobial resistances. In 2009, the Infectious Diseases
Society of America highlighted *E. faecium* as one of the key problem bacteria or ESKAPE (*Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa, and Enterobacter species*) pathogens requiring new therapies.6

The Australian Group on Antimicrobial Resistance (AGAR) is a network of laboratories located across Australia that commenced surveillance of antimicrobial resistance in *Enterococcus* species in 1995.7 In 2011, AGAR commenced the Australian Enterococcal Sepsis Outcome Programme (AESOP).8,9 The objective of AESOP 2020 was to determine the proportion of *E. faecalis* and *E. faecium* bacteraemia isolates demonstrating antimicrobial resistance, with particular emphasis on:

1. assessing susceptibility to ampicillin;
2. assessing susceptibility to glycopeptides; and
3. the molecular epidemiology of *E. faecium*.

**Methodology**

**Participants**

Thirty laboratories servicing 49 institutions from all Australian states and mainland territories.

**Collection period**

From 1 January to 31 December 2020, the 39 laboratories collected all enterococcal species isolated from blood cultures. Enterococci of the same species and antimicrobial susceptibility profiles isolated from a patient’s blood culture within 14 days of the first positive culture were excluded. A new enterococcal sepsis episode in the same patient was recorded if it was confirmed by a further culture of blood taken more than 14 days after the initial positive culture. Data were collected on age, sex, date of admission and discharge (if admitted), and mortality at seven and 30 days from date of blood culture collection. To avoid interpretive bias, no attempt was made to assign attributable mortality. Each episode of bacteraemia was designated as “hospital-onset” if the first positive blood culture(s) in an episode was collected > 48 hours after admission.

**Laboratory testing**

Enterococcal isolates were identified to the species level by the participating laboratories using matrix-assisted laser desorption ionization (MALDI)—MALDI Biotyper (Bruker Daltonics, USA) or Vitek-MS (bioMérieux, France)—or Vitek2® (bioMérieux). Antimicrobial susceptibility testing was performed using the Vitek2® (bioMérieux) or BD Phoenix™ (Becton Dickinson, USA) automated microbiology systems according to the manufacturer’s instructions. Minimum inhibitory concentration (MIC) data and isolates were referred to the Antimicrobial Resistance and Infectious Diseases (AMRID) Research Laboratory at Murdoch University. Clinical and Laboratory Standards Institute (CLSI)10 and European Committee on Antimicrobial Susceptibility Testing (EUCAST)11 breakpoints were utilised for interpretation. Linezolid and daptomycin non-susceptible isolates and vancomycin-susceptible isolates which harboured the *vanA* or *vanB* genes were retested by Etest® (bioMérieux, France), using the Mueller-Hinton agar recommended by the manufacturer. The control strain used was *E. faecalis* ATCC® 29212. Genotyping was performed by whole genome sequencing (WGS) using the NextSeq® 500 platform (Illumina, USA). Sequencing results were analysed using the Nullarbor pipeline.12

Confidence intervals (CI) for proportions, Fisher’s exact test for categorical variables, and chi-square test for trend, were calculated as appropriate, using MedCalc for Windows, version 12.7 (MedCalc Software, Belgium).

Approval to conduct the prospective data collection was given by the research ethics committee associated with each participating laboratory.
Results

From 1 January to 31 December 2020, there were 1,230 unique episodes of enterococcal bacteraemia identified. Although nine Enterococcus species were identified, E. faecalis and E. faecium predominated: 667 isolates (54.2%) were E. faecalis and 488 isolates (39.7%) were E. faecium. Seventy-five enterococci were identified either as E. gallinarum (20 isolates), E. casseliflavus (19 isolates), E. raffinosus (12 isolates), E. avium (12 isolates), E. hirae (8 isolates), E. durans (2 isolates), E. cecorum (1 isolate) or Enterococcus sp. [not speciated] (1 isolate).

A significant difference was observed in patient sex (p < 0.0001), with 801 (65.1%) being male (95% CI: 62.4–67.8). The average age of patients was 63 years, ranging from 0 to 100 years, with a median age of 69 years. The majority of episodes, 688/1,230 (55.9%), were community-onset (95% CI: 53.1–58.7); however, a significant difference (p < 0.0001) in place of onset was seen between E. faecium and E. faecalis, with only 33.2% (95% CI: 30.6–36.1) of E. faecium episodes being community-onset compared to 66.8% (95% CI: 64.0–69.5) for E. faecalis. All-cause mortality at 30 days, where outcome was known, was 18.1% (95% CI: 15.7–20.1). There was no significant difference in mortality between E. faecalis and E. faecium episodes (17.4% vs. 19.5% respectively, p = 0.4), or between vancomycin-susceptible and vancomycin non-susceptible E. faecium episodes (19.4% vs 19.8% respectively, p = 0.9).

E. faecalis phenotypic susceptibility results

Apart from erythromycin, tetracycline, ciprofloxacin and high-level gentamicin, acquired resistance was rare amongst E. faecalis isolates (Table 1). One isolate was resistant to vancomycin (MIC ≥ 32 mg/L). Twenty-four E. faecalis isolates (3.6%) were initially reported as linezolid non-susceptible (CLSI breakpoint > 2 mg/L). By Etest, 17 of the 24 isolates had a linezolid MIC of ≤ 2 mg/L and were therefore considered linezolid susceptible. The remaining seven isolates, with MICs of 4 mg/L—although intermediate by CLSI criteria—were considered susceptible by EUCAST criteria. Of the seven isolates, only one isolate harboured the optrA gene. The G2576T 23S rRNA mutation was detected in two isolates and the G2576T and G2505A 23S rRNA mutations were detected in one isolate. The remaining three isolates did not possess any known mutations in 23S rRNA. The cfr, cfrB and poxtA genes were not detected in the seven linezolid non-susceptible isolates.

Twelve isolates were initially reported as daptomycin non-susceptible (> 2 mg/L) by CLSI criteria. By Etest, 11 of the 12 isolates had a daptomycin MIC < 2 mg/L. The remaining isolate with an MIC of 8.0 mg/L was confirmed as daptomycin resistant. Polymorphisms in the liaF, liaS, liaR, cls and gdpD genes were investigated and the N237D mutation in Cls was detected.

E. faecium phenotypic susceptibility results

The majority of E. faecium isolates were non-susceptible to multiple antimicrobials including ampicillin, erythromycin, tetracycline, ciprofloxacin, nitrofurantoin and high-level gentamicin (Table 2). Overall, 158 isolates (32.6%) were phenotypically vancomycin non-susceptible (MIC > 4 mg/L). Fifty-seven (11.7%) and fifty-nine (12.1%) isolates were teicoplanin non-susceptible by CLSI and EUCAST criteria respectively. Nine isolates (1.9%) were initially reported as linezolid non-susceptible (CLSI breakpoint > 2 mg/L). By Etest, eight of the nine isolates had a linezolid MIC of ≤ 2 mg/L and therefore were considered susceptible. One isolate with an MIC of 4.0 mg/L by Etest, although intermediate by CLSI criteria, was considered susceptible by EUCAST criteria. The isolate did not have any known mutations in 23S rRNA and did not harbour optrA, cfr, cfrB or poxtA.

Five isolates were initially reported as daptomycin non-susceptible (MIC > 4 mg/L). By Etest, two of the five isolates had a daptomycin MIC of 4.0 mg/L and were considered susceptible. The
Table 1: The number and proportion of *E. faecalis* non-susceptible to ampicillin, penicillin and the non-β-lactam antimicrobials, Australia, 2020

| Antimicrobial       | Tested (N) | Breakpoint guideline | Breakpoint (mg/L) | Susceptible | Intermediate | Resistant |
|---------------------|------------|----------------------|-------------------|-------------|--------------|-----------|
|                     |            |                      | S     | I      | R      | % (n) | % (n) | % (n) |
| Ampicillin          | 666        | CLSI                 | ≤ 8   | ≥ 16   | 100 (666) | 0 (0) |
|                     |            | EUCAST               | ≤ 4   | 8     | 100 (666) | 0 (0) |
| Benzylpenicillin    | 608        | CLSI                 | ≤ 8   | ≥ 16   | 98.7 (600) | 1.3 (8) |
| Ciprofloxacin       | 406        | CLSI                 | ≤ 1   | 2      | 88.2 (358) | 4.9 (20) |
|                     |            | EUCAST               | ≤ 1   | 2      | 6.9 (28) |
| Daptomycin          | 650        | CLSI                 | ≤ 2   | 4      | 56.9 (370) | 42.9 (279) |
| Erythromycin        | 523        | CLSI                 | ≤ 0.5 | 1–4    | 10.9 (57) | 49.0 (256) |
| Gentamicin (high-level) | 469    | CLSI                 | < 256 | ≥ 256  | 82.1 (385) | 17.9 (84) |
| Linezolid           | 663        | CLSI                 | ≤ 2   | 4      | 98.5 (656) | 1.1 (7) |
|                     |            | EUCAST               | ≤ 4   | 4      | 100 (666) | 0 (0) |
| Nitrofurantoin      | 664        | CLSI                 | ≤ 32  | 64     | 98.3 (653) | 1.5 (10) |
| Teicoplanin         | 666        | CLSI                 | ≤ 8   | 16     | 99.8 (665) | 0 (0) |
|                     |            | EUCAST               | ≤ 2   | > 2    | 99.8 (665) | 0.2 (1) |
| Tetracycline/doxycycline | 505   | CLSI                 | ≤ 8   | ≥ 16   | 29.3 (148) | 10.5 (53) |
| Vancomycin          | 666        | CLSI                 | ≤ 4   | 8–16   | 99.8 (665) | 0 (0) |
|                     |            | EUCAST               | ≤ 4   | ≥ 4    | 99.8 (665) | 0.2 (1) |

a S: susceptible; I: intermediate; R: resistant.
b No category defined.
c The calling range of the Phoenix susceptibility cards only allows a susceptible or non-susceptible result.

The presence of *vanA/B* genes was determined by PCR and/or WGS on 483 (99.0%) of the 488 *E. faecium* isolates. Overall, 170 of the 483 isolates (35.2%) harboured a *vanA* and/or *vanB* gene. Of the vancomycin non-susceptible *E. faecium* isolates (Vitek2® vancomycin MIC > 4 mg/L), 57 harboured *vanA* and 99 harboured *vanB*. One isolate harboured both *vanA* and *vanB* genes. The *vanA* or *vanB* gene was detected in twelve vancomycin-susceptible *E. faecium* isolates. Nine isolates harboured *vanA*. The nine *vanA*-positive isolates had vancomycin MIC values of 4.0 mg/L [3 isolates], 2.0 mg/L [2 isolates], 1.0 mg/L [2 isolates] and ≤ 0.5 mg/L [2 isolates]; all had teicoplanin MIC ≤ 1 mg/L. Three isolates harboured *vanB* with vancomycin MIC values of 4.0 mg/L [1 isolate] and 1.0 mg/L [2 isolates].

Other three isolates were confirmed as resistant by CLSI criteria. Polymorphisms in the *liaF*, *liaS*, *liaR*, *cls* and *gdpD* genes were investigated. The following mutations were detected: L39N in LiaF (isolate 1: MIC 6.0 mg/L; isolate 3: MIC 32.0 mg/L), T120N in LiaS and W73C in LiaR (isolate 2: MIC 6.0 mg/L).

Genotypic vancomycin susceptibility results

For 348 of the 667 *E. faecalis* isolates (52.2%), *vanA/VanB* polymerase chain reaction (PCR) results were available. One isolate, which had a vancomycin and teicoplanin MIC of ≥ 32 mg/L, harboured *vanA*. The *vanB* gene was not detected.
Table 2: The number and proportion of *E. faecium* non-susceptible to ampicillin, penicillin and the non-β-lactam antimicrobials, Australia, 2020

| Antimicrobial          | Tested (N) | Breakpoint guideline | Breakpoint (mg/L)* | Susceptible | Intermediate | Resistant |
|------------------------|------------|----------------------|--------------------|-------------|--------------|----------|
|                        |            |                      |                    | S   | I  | R  | % (n) | % (n) | % (n)     |
| Ampicillin             | 485        | CLSI                 | ≤ 8                | 11.8 (57) | —  | 88.2 (428) |
|                        |            | EUCAST               | ≤ 4                | 11.8 (57) | 0  | 88.2 (428) |
| Benzylpenicillin       | 441        | CLSI                 | ≤ 8                | 11.1(49)  | —  | 88.9 (392) |
|                        |            | ≥ 16                 | 11.1(49)           | —  | 88.9 (392) |
| Ciprofloxacin          | 319        | CLSI                 | ≤ 1                | 9.1 (29)  | 0.8 (9) | 88.1 (281) |
| Daptomycin             | 62         | CLSI                 | ≤ 4                | 95.2 (59) | 0  | 4.8 (3)   |
| Erythromycin           | 379        | CLSI                 | ≤ 0.5              | 7.9 (30)  | 48 (12.7)| 79.4 (301)|
| Gentamicin (high-level)| 340        | CLSI                 | < 256              | 58.8 (200)| —  | 41.2 (140)|
| Linezolid              | 487        | CLSI                 | ≤ 2                | 99.6 (485)| 0.4 (2) | 0 (0)     |
|                        |            | EUCAST               | ≤ 4                | 100 (487)| —  | 0 (0)     |
| Nitrofurantoin         | 413        | CLSI                 | ≤ 32               | 16.5 (68) | 117 (28.3)| 55.2 (228)|
|                        |            | ≥ 64                 | 16.5 (68)          | 117 (28.3)| 55.2 (228)|
| Teicoplanin            | 485        | CLSI                 | ≤ 8                | 88.3 (429)| 0.6 (3) | 11.1 (54) |
|                        |            | EUCAST               | ≤ 2                | 87.9 (427)| —  | 13.0 (63) |
| Tetracycline/doxycycline | 374      | CLSI                 | ≤ 4                | 30.7 (115)| 5.1 (19) | 64.2 (240)|
| Vancomycin             | 485        | CLSI                 | ≤ 4                | 67.4 (327)| 0.6 (3) | 32.0 (155)|
|                        |            | EUCAST               | ≤ 4                | 67.4 (327)| —  | 32.6 (158)|

a  S: susceptible; I: intermediate; R: resistant.  
b  No category defined.  
c  Susceptible dose dependent.  
d  The calling range of the Phoenix susceptibility cards only allows a susceptible or non-susceptible result.

*E. faecium* molecular epidemiology

Of the 488 episodes, 470 *E. faecium* isolates (96.3%) were available for typing by WGS. The 470 isolates were classified into 71 sequence types (STs) including eight STs with ten or more isolates (Table 3). Of the 63 STs with fewer than ten isolates, 50 STs were each represented by only one isolate. Overall, 384 of the 470 isolates (81.7%) were grouped into the eight major STs. Using eBURST, all major STs were grouped into CC17.

Geographical distribution of the STs varied (Table 3). For the eight major STs, ST17 (116 isolates) was identified in all regions except the Northern Territory; ST1424 (94 isolates) was found in all regions except South Australia and the Northern Territory; ST80 (52 isolates) was found in all regions except Tasmania and the Northern Territory; ST796 (47 isolates) was found only in New South Wales, Victoria and Tasmania; ST78 (34 isolates) was found in all regions except Western Australia, Tasmania and the Northern Territory; ST1421 (20 isolates) was found only in New South Wales and the Australian Capital Territory; ST555 (11 isolates) was found in all regions except Western Australia, Tasmania, and the Australian Capital Territory; and ST117 (10 isolates) was found only in New South Wales and Western Australia.
Table 3: The number and proportion of major *Enterococcus faecium* sequence types (STs), Australia, 2020, by jurisdiction

| ST   | ACT | NSW | NT | Qld | SA | Tas. | Vic. | WA | Australia |
|------|-----|-----|----|-----|----|------|------|----|-----------|
|      | n   | %   | n  | %  | n  | %   | n   | %  | n        |
| ST17 | 1   | 3.2 | 24 | 13.8 | 0 | 0.0 | 19 | 55.9 | 17 | 45.9 | 2 | 25.0 | 15 | 12.5 | 38 | 62.3 | 116 | 24.7 |
| ST1424 | 8   | 25.8 | 63 | 36.2 | 0 | 0.0 | 3 | 8.8 | 0 | 0.0 | 4 | 50.0 | 15 | 12.5 | 1 | 1.6 | 94 | 20.0 |
| ST80 | 13 | 41.9 | 22 | 12.6 | 0 | 0.0 | 2 | 5.9 | 3 | 8.1 | 0 | 0.0 | 7 | 5.8 | 5 | 8.2 | 52 | 11.1 |
| ST796 | 0 | 0.0 | 8 | 4.6 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 12.5 | 38 | 31.7 | 0 | 0.0 | 47 | 10.0 |
| ST78 | 3 | 9.7 | 5 | 2.9 | 0 | 0.0 | 2 | 5.9 | 1 | 2.7 | 0 | 0.0 | 23 | 19.2 | 0 | 0.0 | 34 | 7.2 |
| ST1421 | 1 | 3.2 | 19 | 10.9 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 20 | 4.3 |
| ST555 | 0 | 0.0 | 2 | 1.1 | 3 | 60.0 | 1 | 2.9 | 2 | 5.4 | 0 | 0.0 | 3 | 2.5 | 0 | 0.0 | 11 | 2.3 |
| ST117 | 0 | 0.0 | 3 | 1.7 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 7 | 11.5 | 10 | 2.1 |
| Other | 5 | 16.1 | 28 | 16.1 | 2 | 40.0 | 7 | 20.6 | 14 | 37.8 | 1 | 12.5 | 19 | 15.8 | 10 | 16.4 | 86 | 18.3 |
| Total | 31 | 174 | 5 | 34 | 37 | 8 | 120 | 61 | 470 |

a  ACT: Australian Capital Territory; NSW: New South Wales; NT: Northern Territory; Qld: Queensland; SA: South Australia; Tas: Tasmania; Vic: Victoria; WA: Western Australia.
The vanA gene was detected in four major STs (61 isolates: ST1424, ST80, ST1421 and ST117) (Table 4). The vanB gene was detected in six major STs (95 isolates: ST17, ST1424, ST80, ST796, ST78 and ST555). One ST796 isolate harboured both vanA and vanB genes. Three minor STs (each represented by one isolate) harboured vanA and five minor STs (each represented by one isolate) harboured vanB.

Discussion

Enterococci are intrinsically resistant to a broad range of antimicrobials including the cephalosporins and sulphonamides. By their ability to acquire additional resistance through the transfer of plasmids and transposons, and to disseminate easily in the hospital environment, enterococci have become difficult to treat and provide major infection control challenges.

As the AGAR programs are similar to those conducted in Europe, comparison of Australian antimicrobial resistance data with other countries is possible.

In the 2019 European Centre for Disease Prevention and Control (ECDC) enterococci surveillance program, the European Union/European Economic Area (EU/EEA) population-weighted mean percentage of E. faecium resistant to vancomycin was 18.3% (95% CI: 15.0–22.0), which represents a significant increase from 2015 when the percentage was 10.5%. The 2019 national percentages ranged from 0.0% in Iceland, Finland, and Malta to 50.0% in Cyprus.13

In AESOP 2020, a total of 39.7% of enterococcal bacteraemia episodes were due to E. faecium of which 32.6% (95% CI: 28.5–37.0) were phenotypically vancomycin non-susceptible by Vitek2® or BD Phoenix™. However 35.2% of E. faecium isolates tested (170/483) harboured a vanA/vanB gene, of which 38.8% were vanA-positive. Overall, 66 E. faecium isolates (13.7%) harboured the vanA gene. Prior to the 2020 AESOP we have reported a significant increase in vanA-positive E. faecium in Australia, from 6% in 2013 to 22.3% in 2019.14–20 The decrease in vanA-positive E. faecium in 2020 was primarily due to a decrease in ST1421 and ST1424 isolates. The majority of E. faecium isolates were non-susceptible to multiple antimicrobials including ampicillin, erythromycin, tetracycline, ciprofloxacin and high level gentamicin. The 2020 AESOP survey confirms that the incidence of vancomycin-resistant E. faecium bacteraemia in Australia continues to be a substantial problem.

Table 4: The number and proportion of major Enterococcus faecium sequence types (STs) harbouring vanA/vanB genes, Australia, 2020

| ST     | Not detected | vanA | vanA/vanB | vanB | Total |
|--------|--------------|------|-----------|------|-------|
|        | n            | %    | n         | %    |       |       |
| ST17   | 113          | 97.4 | 0         | 0.0  | 0     | 2.6   | 116   |
| ST1424 | 46           | 48.9 | 46        | 48.9 | 0     | 0.0   | 94    |
| ST80   | 49           | 94.2 | 1         | 1.9  | 0     | 0.0   | 52    |
| ST796  | 0            | 0.0  | 0         | 0.0  | 1     | 2.1   | 46    |
| ST78   | 0            | 0.0  | 0         | 0.0  | 0     | 0.0   | 34    |
| ST1421 | 11           | 55.0 | 9         | 45.0 | 0     | 0.0   | 20    |
| ST555  | 3            | 27.3 | 0         | 0.0  | 0     | 0.0   | 8     |
| ST117  | 5            | 50.0 | 5         | 50.0 | 0     | 0.0   | 10    |
| Other  | 78           | 90.7 | 3         | 3.5  | 0     | 0.0   | 86    |
| Total  | 305          | 64.9 | 64        | 13.6 | 1     | 0.2   | 100   | 21.3 | 470   |
Three (2.9%) of the 103 vanB-positive *E. faecium* and nine (14.1%) of the 64 vanA-positive *E. faecium* isolates had a vancomycin MIC at or below the CLSI and the EUCAST susceptible breakpoint (≤ 4 mg/L) and therefore would not have been identified using routine phenotypic antimicrobial susceptibility methods.

By WGS, *E. faecium* was shown to be very polyclonal, consistent with the known plasticity of the enterococcal genome. The eight major *E. faecium* STs form part of CC17, a global hospital-derived lineage that has successfully adapted to hospital environments. The CC17 lineage is characteristically ampicillin- and quinolone-resistant and subsequent acquisition of *vanA*- or *vanB*-containing transposons by horizontal transfer in CC17 clones has resulted in multi-resistant enterococci with pandemic potential.

In AESOP 2020, eight *E. faecium* STs predominated: ST17 (of which 0% of isolates harboured *vanA*, 2.6% *vanB* genes); ST1424 (48.9% *vanA*, 2.1% *vanB*); ST80 (1.9% *vanA*, 3.8% *vanB*); ST796 (0% *vanA*, 97.9% *vanB*, 2.1% *vanA* and *vanB*), ST78 (0% *vanA*, 100% *vanB*); ST1421 (45.0% *vanA*, 0% *vanB*); ST555 (0% *vanA*, 72.7% *vanB* ) and ST117 (50.0% *vanA*, 0% *vanB*).

**Conclusions**

The AESOP 2020 study has shown that, although predominately caused by *E. faecalis*, enterococcal bacteraemia in Australia is frequently caused by ampicillin-resistant, high-level gentamicin-resistant vancomycin-resistant *E. faecium*. Furthermore, the percentage of *E. faecium* bacteraemia isolates resistant to vancomycin in Australia—although significantly lower than reported in the 2019 AESOP (p < 0.002)—remains significantly higher than that seen in most European countries. In addition to being a significant cause of healthcare-associated sepsis, the emergence of multiple multi-resistant hospital-adapted *E. faecium* strains has become a major infection control issue in Australian hospitals. Ongoing studies on the enterococcal genome will contribute to our understanding of the rapid and ongoing evolution of enterococci in the hospital environment and assist in preventing their nosocomial transmission.

**Acknowledgments**

This study was funded by the Australian Commission on Safety and Quality in Health Care and the Australian Government Department of Health.

Members of the AGAR in 2020 were:

**Australian Capital Territory**

Peter Collignon and Susan Bradbury, Canberra Hospital

**New South Wales**

Thomas Gottlieb and John Huynh, Concord Hospital

James Branley and Linda Douglass, Nepean Hospital

Angela Wong, Royal North Shore Hospital

Sebastiaan van Hal and Alicia Beukers, Royal Prince Alfred Hospital

Jon Iredell and Andrew Ginn, Westmead Hospital

Bree Harris, John Hunter Hospital

Peter Newton and Melissa Hoddle, Wollongong Hospital

Jock Harkness and David Lorenz, St Vincent’s Hospital

Monica Lahra and Peter Huntington, Sydney Children’s Hospital

Michael Maley and Helen Ziochos, Liverpool Hospital
Alison Kesson and Anne Reddacliff, Children's Hospital at Westmead

Northern Territory

Rob Baird and Jann Hennessy, Royal Darwin Hospital

James McLeod, Alice Springs Hospital

Queensland

Graeme Nimmo and Narelle George, Pathology Queensland Central Laboratory, Royal Brisbane and Women's Hospital

Petra Derrington and Cheryl Curtis, Pathology Queensland Gold Coast Hospital

Robert Horvath and Laura Martin, Pathology Queensland Prince Charles Hospital

Naomi Runnegar and Joel Douglas, Pathology Queensland Princess Alexandra Hospital

Jennifer Robson and Marianne Allen, Sullivan Nicolaides Pathology, Greenslopes Hospital

Clare Nourse, Queensland Children's Hospital

South Australia

Kelly Papanaoum and Xiao Ming Chen, SA Pathology (Flinders Medical Centre)

Morgyn Warner and Kija Smith, SA Pathology (Royal Adelaide Hospital and Women's and Children's Hospital)

Tasmania

Louise Cooley and David Jones, Royal Hobart Hospital

Pankaja Kalukottege and Kathy Wilcox, Launceston General Hospital

Victoria

Denis Spelman and Jacqueline Williams, The Alfred Hospital

Marcel Leroi and Elizabeth Grabsch, Austin Health

Tony Korman and Despina Kotsanas, Monash Medical Centre, Monash Children's Hospital and Dandenong Hospital

Andrew Daley and Gena Gonis, Royal Women's and Children's Hospital

Mary Jo Waters and Lisa Brenton, St Vincent’s Hospital

Western Australia

Denise Daley, PathWest Laboratory Medicine – WA Fiona Stanley Hospital

Ronan Murray and Jacinta Bowman, PathWest Laboratory Medicine – WA Sir Charles Gairdner Hospital

Michael Leung, PathWest Laboratory Medicine – Northwest WA

Owen Robinson and Geoffrey Coombs, PathWest Laboratory Medicine – WA Royal Perth Hospital

Sudha Pottumarthy-Boddu and Jacqueline Foster, Australian Clinical Laboratories, St John of God Hospital, Murdoch

Shalinie Perera and Ian Meyer, Western Diagnostic Pathology, Joondalup Hospital

Christopher Blyth, Perth Children’s Hospital
Author details

Prof. Geoffrey W Coombs,1,2,3

Ms Denise A Daley,2,3

Mr Nicholas W T Yee,1

Ms Princy Shoby,1

Dr Shakeel Mowlaboccus,1,2

on behalf of the Australian Group on Antimicrobial Resistance

1. Antimicrobial Resistance and Infectious Diseases (AMRID) Research Laboratory, Murdoch University, Murdoch, Western Australia, Australia

2. Department of Microbiology, PathWest Laboratory Medicine-WA, Fiona Stanley Hospital, Murdoch, Western Australia, Australia

3. Australian Group on Antimicrobial Resistance, Fiona Stanley Hospital, Murdoch, Western Australia, Australia

Corresponding author

Prof. Geoffrey Coombs

Antimicrobial Resistance and Infectious Diseases (AMRID) Research Laboratory, Murdoch University, Murdoch, Western Australia, Australia

Telephone: +61 8 6152 2397

Email: g.coombs@murdoch.edu.au
References

1. Pinholt M, Ostergaard C, Arpi M, Bruun NE, Schönheyder HC, Gradel KO et al. Incidence, clinical characteristics and 30-day mortality of enterococcal bacteraemia in Denmark 2006–2009: a population-based cohort study. *Clin Microbiol Infect.* 2014;20(2):145–51.

2. Deshpande LM, Fritsche TR, Moet GJ, Biedenbach DJ, Jones RN. Antimicrobial resistance and molecular epidemiology of vancomycin-resistant enterococci from North America and Europe: a report from the SENTRY antimicrobial surveillance program. *Diagn Microbiol Infect Dis.* 2007;58(2):163–70.

3. Murray BE. The life and times of the Enterococcus. *Clin Microbiol Rev.* 1990;3(1):46–65.

4. Simonsen CS, Småbrekke L, Monnet DL, Sørensen TL, Møller JK, Kristinsson KG et al. Prevalence of resistance to ampicillin, gentamicin and vancomycin in *Enterococcus faecalis* and *Enterococcus faecium* isolates from clinical specimens and use of antimicrobials in five Nordic hospitals. *J Antimicrob Chemother.* 2003;51(2):323–31.

5. Treitman AN, Yarnold PR, Warren J, Noskin GA. Emerging incidence of *Enterococcus faecium* among hospital isolates (1993 to 2002). *J Clin Microbiol.* 2005;43(1):462–3.

6. Boucher HW, Talbot GH, Bradley JS, Edwards JE, Gilbert D, Rice LB et al. Bad bugs, no drugs: no ESKAPE! An update from the Infectious Diseases Society of America. *Clin Infect Dis.* 2009;48(1):1–12.

7. Christiansen KJ, Turnidge JD, Bell JM, George NM, Pearson JC, Australian Group on Antimicrobial Resistance. Prevalence of antimicrobial resistance in *Enterococcus* isolates in Australia, 2005: report from the Australian Group on Antimicrobial Resistance. *Commun Dis Intell Q Rep.* 2007;31(4):392–7.

8. Coombs GW, Daley D, Pearson JC, Ingram PR. A change in the molecular epidemiology of vancomycin resistant enterococci in Western Australia. *Pathology.* 2014;46(1):73–5.

9. Coombs GW, Pearson JC, Daley DA, Le T, Robinson OJ, Gottlieb T et al. Molecular epidemiology of enterococcal bacteremia in Australia. *J Clin Microbiol.* 2014;52(3):897–905.

10. Clinical and Laboratory Standards Institute (CLSI). *Performance standards for antimicrobial susceptibility testing.* 31st ed. CLSI supplement M100. Wayne, PA: CLSI; 2021.

11. The European Committee on Antimicrobial Susceptibility Testing (EUCAST). *Breakpoint tables for interpretation of MICs and zone diameters. Version 11.0.* Basel: EUCAST; 2021. Available from: https://www.eucast.org/fileadmin/src/media/PDFs/EUCAST_files/Breakpoint_tables/v_11.0_Breakpoint_Tables.pdf.

12. Seemann T, Goncalves da Silva A, Bulach DM, Schultz MB, Kwong JC, Howden BP. *Nullarbor.* San Francisco; Github. [Accessed on 3 Jun 2016.] Available from: https://github.com/tseemann/nullarbor.

13. European Centre for Disease Prevention and Control (ECDC). Surveillance Atlas of Infectious
Diseases. [Webpage.] Solna: ECDC. Available from: http://atlas.ecdc.europa.eu/public/index.aspx.

14. Coombs GW, Pearson JC, Daly DA, Le TT, Robinson JO, Gottlieb T et al. Australian Enterococcal Sepsis Outcome Programme annual report, 2013. Commun Dis Intell Q Rep. 2014;38(4):E320–6.

15. Coombs GW, Daley DA, Lee YT, Pang S, Pearson JC, Robinson JO et al. Australian Group on Antimicrobial Resistance Australian Enterococcal Sepsis Outcome Programme annual report, 2014. Commun Dis Intell Q Rep. 2016;40(2):E236–43.

16. Coombs GW, Daley DA, Lee YT, Pang S, Bell JM, Turnidge JD et al. Australian Group on Antimicrobial Resistance (AGAR) Australian Enterococcal Sepsis Outcome Programme (AESOP) Annual Report 2015. Commun Dis Intell (2018). 2018;42. pii: S2209-6051(18)00015-5.

17. Coombs GW, Daley DA, Lee YT, Pang S, Australian Group on Antimicrobial Resistance. Australian Group on Antimicrobial Resistance (AGAR) Australian Enterococcal Sepsis Outcome Programme (AESOP) Annual Report 2016. Commun Dis Intell (2018). 2018;42. pii: S2209-6051(18)00020-9.

18. Geoffrey W Coombs, Denise A Daley, Yung Thin Lee, Dr Stanley Pang. Australian Group on Antimicrobial Resistance (AGAR) Australian Enterococcal Sepsis Outcome Programme (AESOP) Annual Report 2017. Commun Dis Intell (2018). 2019;43. doi: https://doi.org/10.33321/cdi.2019.43.42.

19. Coombs GW, Daley DA, Mowlaboccus S, Lee YT, Pang S, Australian Group on Antimicrobial Resistance. Australian Group on Antimicrobial Resistance (AGAR) Australian Enterococcal Sepsis Outcome Programme (AESOP) Annual Report 2018. Commun Dis Intell (2018). 2020;44. doi: https://doi.org/10.33321/cdi.2020.44.19.

20. Coombs GW, Daley DA, Mowlaboccus S, Pang S, Australian Group on Antimicrobial Resistance. Australian Group on Antimicrobial Resistance (AGAR) Australian Enterococcal Sepsis Outcome Programme (AESOP) Annual Report 2019. Commun Dis Intell (2018). 2020;44. doi: https://doi.org/10.33321/cdi.2020.44.72.