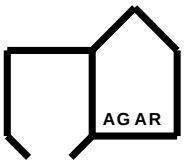

The Australian Group on Antimicrobial Resistance

Australian Staphylococcal Sepsis Outcome Program (ASSOP) 2017

FINAL REPORT

AGAR is funded by the Australian Commission of Safety and Quality in Health Care as part of the Antimicrobial Use and Resistance in Australia (AURA) Surveillance System.

Prof Geoffrey Coombs and Ms Denise Daley on behalf of the Australian Group on Antimicrobial Resistance

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Summary

- In the 2017 survey 2,515 *Staphylococcus aureus* bacteraemia (SAB) episodes were reported.
- 19.0% of SABs were caused by MRSA (In 2013 – 19.1%; 2014 – 18.8%; 2015 18.6%, 2016 19.7%).
    - MRSA rates ranged from 44.4% in the Northern Territory to 9.5% in the Australian Capital Territory
- Onset
    - 77.0% of SABs were community-onset.
    - 78.7% of MSSA were community-onset
    - 69.9% of MRSA were community-onset
- Age/Gender
    - The majority of episodes were in males (66.5%)
    - Only 21.4% of episodes occurred in patients <40 years of age.
- Mortality
    - The overall SAB thirty day mortality was 14.8% (In 2013 - 14.4%; 2014 – 16.1%; 2015 – 15.8%, 2016 – 16.7%)).
    - There was a significant difference in the 30 day all-cause mortality between MSSA (13.9%) and MRSA (18.9%) episodes (p=0.02).
    - In community-onset SAB the mortality rate was 13.8% (14.6% in MRSA and 13.2% in MSSA).
    - In hospital-onset SAB the mortality rate was 18.3% (23.4% in MRSA and 16.5% in MSSA).
- Clinical Manifestations
    - In community–onset SAB osteomyelitis/septic arthritis infections were the most common principle clinical manifestations.
    - In hospital–onset SAB device-related infection without metastatic focus was the most common clinical manifestation
- Length of Stay (LOS)
    - 26.1% of patients had a LOS greater than 30 days.

    - There was **no** significant difference in mean LOS between MRSA and MSSA episodes
    - There was a significant difference in mean LOS between community- and hospital-onset MSSA (p=0.002)
    - There was a significant difference in mean LOS between community- and hospital-onset MRSA (p=0.006)
- MRSA Health-care Associated Clones (HA)
    - Three HA clones were identified. No HA clones harboured the Panton Valentine Leucocidin (PVL)-associated genes.
    - The dominant healthcare associated clone was ST22-IV (EMRSA-15).
- MRSA Community-associated Clones (CA)
    - Thirty nine CA clones were identified of which 49.7% of isolates harboured the PVL-associated genes.
    - The dominant CA clone was ST93-IV (QLD Clone)

Background and Objectives

Globally *Staphylococcus aureus* is one of the most frequent causes of hospital-acquired and community-acquired blood stream infections.[1] Although there are a wide variety of manifestations of serious invasive infection caused by *S. aureus*, in the great majority of these cases the organism can be detected in blood cultures. Therefore, *S. aureus* bacteraemia (SAB) is considered a very useful marker for serious invasive infection.[2]

Although prolonged antimicrobial therapy and prompt source control are used to treat SAB[3], mortality ranges from as low as 2.5% to as high as 40%.[4-6] Mortality rates however are known to vary significantly with patient age, clinical manifestation, co-morbidities and methicillin resistance.[7, 8] A prospective study of SAB conducted by 27 laboratories in Australia and New Zealand found a 30-day all-cause mortality of 20.6%.[9] On univariate analysis increased mortality was significantly associated with older age, European ethnicity, methicillin resistance, infections not originating from a medical device, sepsis syndrome, pneumonia/empyema and treatment with a glycopeptide or other non-β-lactam antibiotic.

The Australian Group on Antimicrobial Resistance (AGAR), a network of laboratories located across Australia, commenced surveillance of antimicrobial resistance in *S. aureus* in 1986.[10] In 2013 AGAR commenced the Australian Staphylococcal Sepsis Outcome Programme (ASSOP).[11]

The primary objective of ASSOP 2017 was to determine the proportion of SAB isolates demonstrating antimicrobial resistance with particular emphasis on:

1. Assessing susceptibility to methicillin
2. Molecular epidemiology of methicillin-resistant *S. aureus* (MRSA)

Results

From the 1st January 2017 to the 31st December 2017, 2,515 SAB episodes from 36 laboratories were included in ASSOP 2017. Isolates were collected from all states and territories. A new *S. aureus* 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. Each episode of bacteraemia was designated hospital onset (HO) if the first positive blood culture(s) in an episode was collected >48 hours after admission.

Almost all SAB patients were admitted to hospital: 2,470/2,515 (98.2%).

Methicillin Sensitive *Staphylococcus aureus* (MSSA) and Methicillin Resistant *Staphylococcus aureus* (MRSA) Episodes by Region

19.0% of SABs were methicillin resistant (95%CI 17.5-20.6), ranging from 9.5% (95%CI 4.4-17.3) in the Australian Capital Territory (ACT) to 44.4% (95%CI: 34.4-54.7) in the Northern Territory (Table 1).

Table 1: **Methicillin Sensitive *Staphylococcus aureus* (MSSA) and Methicillin Resistant *Staphylococcus aureus* (MRSA) Episodes by region**

Region	MSSA	MRSA	Total	%MRSA[a]
ACT	86	9	95	9.5
NSW	540	139	679	20.5
NT	55	44	99	44.4
Qld	470	83	553	15.0
SA**	133	34	167	20.4
Tas	81	10	91	11.0
Vic	301	64	365	17.5
WA	371	95	466	20.4
Australia	**2,037**	**478**	**2,515**	**19.0**

[a] Percentage of *S. aureus* identified as MRSA
ACT = Australian Capital Territory, NSW = New South Wales, NT = Northern Territory, Qld = Queensland, SA = South Australia, Tas = Tasmania, Vic = Victoria, WA = Western Australia
MSSA = Methicillin sensitive *S. aureus*; MRSA = Methicillin resistant *S. aureus*
** One hospital in SA only provided data for the first 6 months of 2017

Place of Onset of Bacteraemia

Data on the place of onset of bacteraemia was available for 2,515 (100%) episodes (Table 2).

There was a significant difference between community and hospital-onset *S. aureus*, MRSA and MSSA bacteraemia with the majority being community-onset (blood taken on or before admission or <48hrs after hospital admission): 1,935/2,515 (76.8%; 95%CI 75.1-78.4).

Table 2: **Methicillin Susceptible *Staphylococcus aureus* (MSSA) and Methicillin Resistant *Staphylococcus aureus* (MRSA) Episodes by Place of Onset.**

Species	Community-onset (%)	Hospital-onset (%)	Total	p
MSSA	1,602 (78.7)	435 (21.4)	2,037	<0.0001
MRSA	334 (69.9)	144 (30.1)	478	<0.0001
All *S. aureus*	**1,936 (77.0)**	**579 (23.0)**	**2,515**	

MRSA = Methicillin resistant *Staphylococcus aureus*; MSSA = Methicillin sensitive *Staphylococcus aureus*

MRSA Place of Onset by Region

Overall MRSA bacteraemia was predominantly community-onset 69.8% (95%CI 65.5-73.9) although place of onset varied between regions. Hospital-onset bacteraemia ranged from 13.7% in Western Australia to 55.6% in the ACT (Table 3).

Table 3: **Methicillin Resistant *Staphylococcus aureus* (MRSA) Episodes by Region and Place of Onset.**

Region	Total SAB	Total MRSA	MRSA - CO	%CO	MRSA - HO	%HO
ACT	95	9	5	55.6	4	44.4
NSW	679	139	88	63.3	51	36.7
NT	99	44	32	72.7	12	27.3
Qld	553	83	56	67.5	27	32.5
SA	167	34	19	55.9	15	44.1
Tas	91	10	7	70.0	3	30.0
Vic	365	64	45	70.3	19	29.7
WA	466	95	82	86.3	13	13.7
Australia	**2,515**	**478**	**334**	**69.9**	**144**	**30.1**

MRSA-CO = MRSA community-onset; %CO = % of MRSA community-onset; MRSA-HO = MRSA hospital-onset; %HO = % hospital-onset

Thirty Day All- Cause Mortality

Thirty day all-cause mortality data was available for 1,996 (79.4%) episodes of SAB (Table 4).

The 30 day all-cause mortality for SAB was 14.8%.

There was a significant difference in the 30 day all-cause mortality between MSSA (13.9%) and MRSA (18.9%) episodes (p=0.02) and community (13.7%) and hospital-onset (18.3) *S. aureus* (p=0.02),

There was no significant difference in mortality between MRSA (p=0.15) and MSSA hospital or community-onset episodes (p=0.13).

Table 4: **Methicillin Susceptible *Staphylococcus aureus* (MSSA) and Methicillin Resistant *Staphylococcus aureus* (MRSA) episodes 30 day all-cause mortality by place of onset.**

	Community-onset		Hospital-onset		Total	
	N	**Mortality (%)**	**N**	**Mortality (%)**	**N**	**Mortality (%)**
MSSA	1,279	169 (13.2)	352	58 (16.5)	1,631	227 (13.9)
MRSA	241	40 (16.6)	124	29 (23.4)	365	69 (18.9)
All *S. aureus*	**1,520**	**209 (13.8)**	**476**	**87 (18.3)**	**1,996**	**296 (14.8)**

MRSA = Methicillin resistant *Staphylococcus aureus*; MSSA = Methicillin sensitive *Staphylococcus aureus;*

Patient Demographics

Age and Gender

Age and gender were available for 2,515 SAB patients (100%) (Table 5 and Figures 1-3).

Increasing age was a risk factor for SAB with only 559/2,515 (21.4%, 95%CI 19.8-23.1) of episodes in patients aged 40 years and younger.

The majority of episodes were in male patients: 1,673/2,515 (66.5%, 95%CI 64.6-68.3).

Table 5: ***Staphylococcus aureus*** **bacteraemia by Decade of Life and Gender.**

Decade	Female	Male	Total	M/100F
1	64	89	153	139
2	31	73	104	235
3	31	64	95	206
4	71	116	187	163
5	110	164	274	149
6	122	236	358	193
7	110	317	427	288
8	123	300	423	244
9	133	250	383	188
10	45	64	109	142
11	2		2	0
Total	**842**	**1,673**	**2,515**	**199**

M/100F = males per 100 females

Figure 1: *Staphylococcus aureus* bacteraemia by Decade of Life and Gender

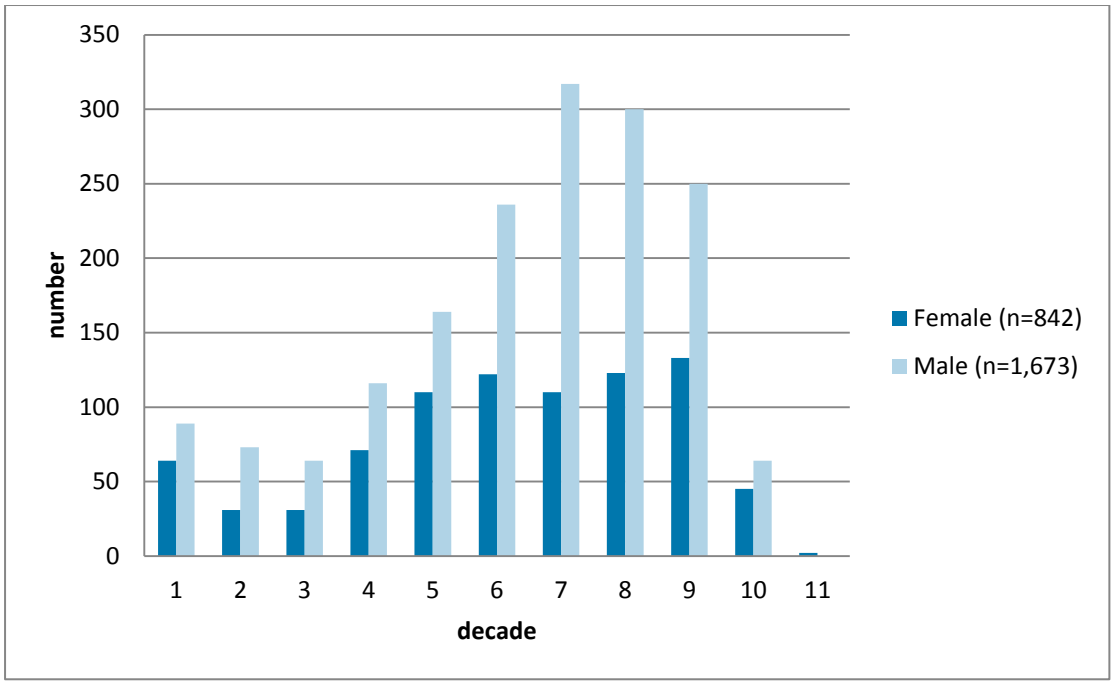


Figure 2: Methicillin Sensitive *Staphylococcus aureus* (MSSA) bacteraemia by Decade of Life and Gender

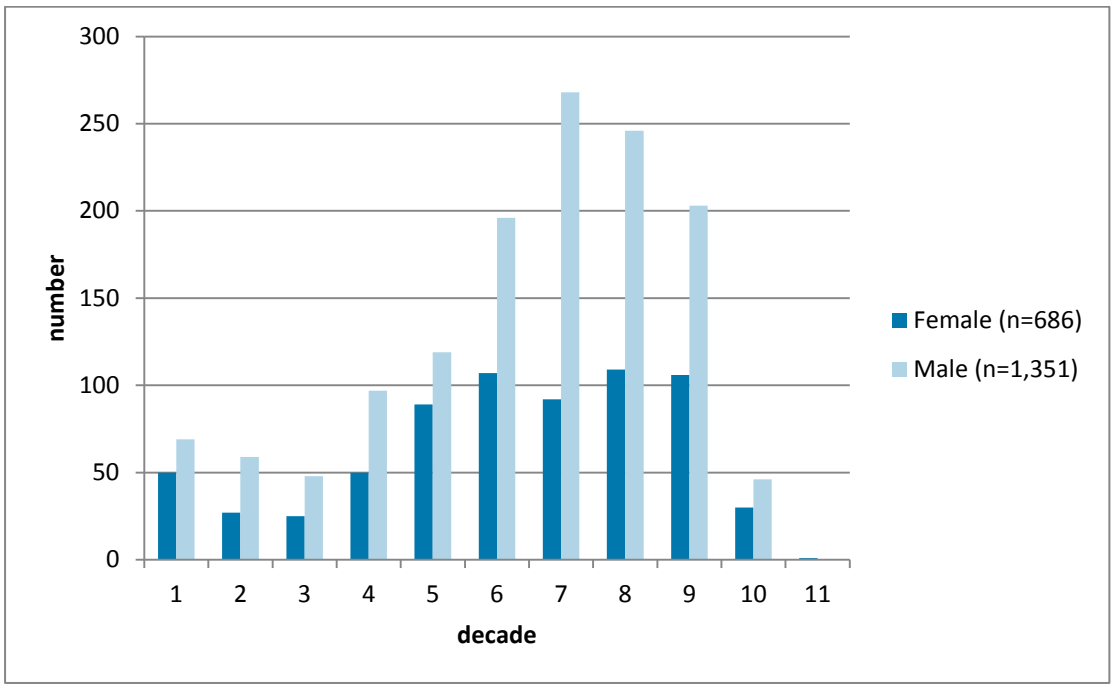
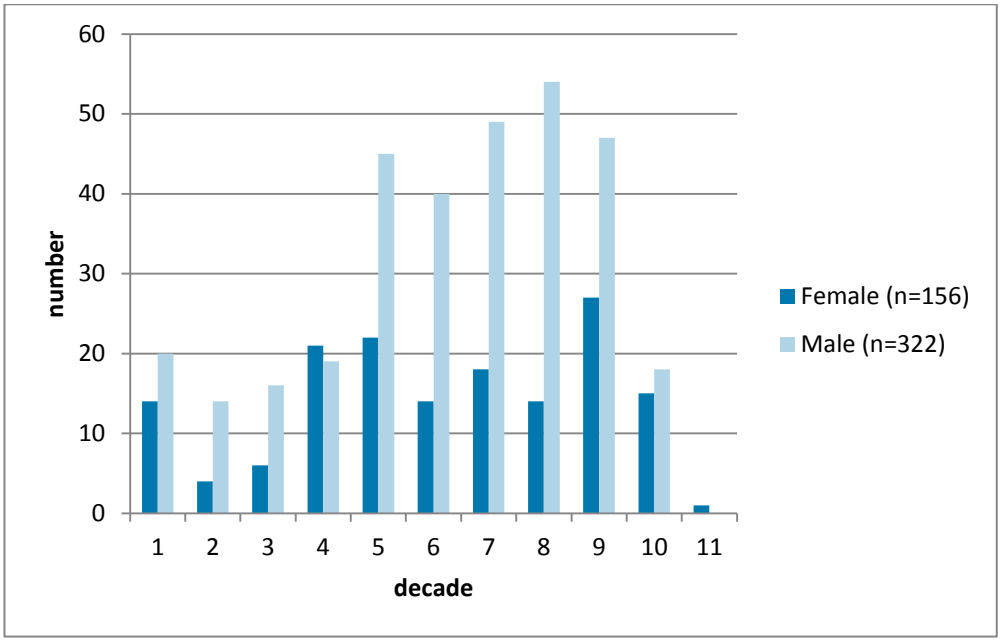


Figure 3: Methicillin Resistant *Staphylococcus aureus* (MRSA) bacteraemia by Decade of Life and Gender



Principle Clinical Manifestation

Principle clinical manifestation was known for 2,205 (87.7%) SAB episodes (Table 6).

Overall the most common principle clinical manifestation was osteomyelitis/septic arthritis (19.0%), followed by skin and skin structure (18.6%), and device-related infection (16.4%). Of the hospital onset SABs, where data was known, the most common principle clinical manifestation was device-related infection (27.3%). Of the community-onset SABs, where data was known, the most common principle clinical manifestation was osteomyelitis/septic arthritis (19.0%).

Table 6: *Staphylococcus aureus* by Principle Clinical Manifestation and Gender

Principle Clinical Manifestation	Female	%	Male	%	Total	%
Osteomyelitis/Septic Arthritis	125	17.1%	294	19.9%	419	19.0%
Skin and Skin Structure	131	17.9%	279	18.9%	410	18.6%
Device-related infection without metastatic focus	136	18.6%	225	15.3%	361	16.4%
No focus	105	14.4%	192	13.0%	297	13.5%
Other clinical syndrome	54	7.4%	118	8.0%	172	7.8%
Endocarditis L-sided	48	6.6%	106	7.2%	154	7.0%
Pneumonia/Empyema	35	4.8%	77	5.2%	112	5.1%
Deep abscess(es) excluding those in the CNS[a]	32	4.4%	59	4.0%	91	4.1%
Endocarditis R-sided	21	2.9%	34	2.3%	55	2.5%
CNS infection (meningitis, abscess(es)	13	1.8%	26	1.8%	39	1.8%
Device-related infection with metastatic focus	16	2.2%	24	1.6%	40	1.8%
Febrile neutropenia	11	1.5%	25	1.7%	36	1.6%
Urinary tract infection	3	0.4%	11	0.7%	14	0.6%
Intra-abdominal infection other than biliary tract	1	0.1%	3	0.2%	4	0.2%
Biliary tract infection (including cholangitis)		0.0%	1	0.1%	1	<0.1%
Total	**731**	**100.0%**	**1,474**	**100.0%**	**2,205**	**100.0%**

[a] CNS = central nervous system

Length of Stay Post Bacteraemic Episode

Length of stay (LOS) post SAB was known for 2,291 (91.8%) episodes.

24.1% of patients had a LOS post SAB greater than 30 days (Table 7).

There was no significant difference in mean LOS between MRSA and MSSA episodes.

Table 7: Methicillin Susceptible *Staphylococcus aureus* (MSSA) and Methicillin Resistant *Staphylococcus aureus* (MRSA) Episodes by Length of Stay

Length of Stay (days)	MSSA	%	MRSA	%	Total	%
<7	335	18.0	94	21.9	429	18.7
7-14	481	25.8	105	24.5	586	25.6
15-30	561	30.1	116	27.0	677	29.6
>30	485	26.0	114	26.6	599	26.1
Total	1,862		436		2,291	
Mean LOS	20		20			

MRSA = Methicillin resistant *Staphylococcus aureus*; MSSA = Methicillin sensitive *Staphylococcus aureus*

Length of Stay Post *S. aureus* Bacteraemic Episode versus Place of Onset

There was a significant difference in mean LOS between community- and hospital-onset SAB (p=0.0002).

There was a significant difference in mean LOS between community- and hospital-onset methicillin sensitive SAB (p=0.002) (Table 8).

Table 8: Methicillin Susceptible *Staphylococcus aureus* (MSSA) Episodes: Length of Stay versus Place of Onset

Length of Stay (Days)	Community-onset	%	Hospital-onset	%	Total	%
<7	279	19.1	56	14.1	355	18.0
7-14	387	26.4	94	23.6	481	25.8
15-30	436	29.8	125	31.4	561	30.1
>30	362	24.7	123	30.9	485	26.0
Total	1,464		398		1,862	
Mean LOS	19		23		p=0.002	

There was a significant difference in mean LOS between community- and hospital-onset methicillin resistant SAB (p=0.0062) (Table 9).

Table 9: Methicillin Resistant *Staphylococcus aureus* (MRSA) Episodes: Length of Stay versus Place of Onset

Length of Stay (Days)	Community-onset	%	Hospital-onset	%	Total	%
<7	72	24.6	22	16.2	94	21.9
7-14	78	26.6	27	19.9	105	24.5
15-30	74	25.3	42	30.9	116	27.0
>30	69	23.5	45	33.1	114	26.6
	293		136		429	
Mean LOS	18		24		p=0.006	

Susceptibility Testing Results

The number and proportion of MSSA isolates non-susceptible to penicillin and the non-β-lactam antimicrobials by region is shown in Table 10.

Table 10: The number tested and proportion of methicillin sensitive *Staphylococcus aureus* (MSSA) isolates non-susceptible to penicillin and the non-β-lactam antimicrobials, by region. Results using CLSI (C) and EUCAST (E) breakpoints are shown where the breakpoints differ.

Antimicrobial (Breakpoint mg/L)		ACT	NSW	NT	QLD	SA*	Tas	Vic	WA	Australia
Penicillin (>0.12)	Tested	86	539	55	470	132	81	301	370	2,034
	Non-susceptible	61	415	45	356	107	56	236	295	1571
	% non-susceptible	70.8%	77.0%	81.8%	75.7%	81.1%	69.1%	78.4%	79.7%	77.2%
Penicillin	Tested	86	539	55	469	133	81	301	371	2,035
(ß-lactamase adjusted)	Non-susceptible	62	429	48	376	111	59	245	304	1,634
	% non-susceptible	72.1%	79.6%	87.3%	80.2%	83.5%	72.8%	81.4%	81.9%	80.3%
Ciprofloxacin (>1)	Tested	86	534	55	470	132	81	301	370	2,029
	Non-susceptible	2	19		8	3	2	7	12	53
	% non-susceptible	2.3%	3.6%	0.0%	1.7%	2.3%	2.5%	2.3%	3.2%	2.6%
Clindamycin (>0.5)	Tested	86	539	55	470	132	81	301	370	2,034
	Non-susceptible	1	13	1	5	1		3	8	32
	% non-susceptible	1.2%	2.4%	1.8%	1.1%	0.8%	0.0%	1.0%	2.2%	1.6%
Daptomycin (>1)	Tested	86	540	55	470	133	81	301	371	2,037
	Non-susceptible		4					1		5
	% non-susceptible	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.2%

Erythromycin (>0.5 C) (>2 E)	Tested	86	539	55	470	132	81	301	370	2,034
	Non-susceptible (C)	8	72	10	56	15	6	37	49	253
	% non-susceptible	9.3%	13.4%	18.2%	11.9%	11.4%	7.4%	12.3%	13.2%	12.4%
	Non-susceptible (E)	5	62	10	42	14	4	32	47	216
	% non-susceptible	5.8%	11.5%	18.2%	8.9%	10.6%	4.9%	10.6%	12.7%	10.6%
Fusidic Acid (>1 E)	Tested	86	539	55	470	132	81	301	370	2,034
	Non-susceptible	3	18	2	30	4	1	3	4	65
	% non-susceptible	3.5%	3.3%	3.6%	6.4%	3.0%	1.2%	1.0%	1.1%	3.2%
Gentamicin (>4 C) (>1 E)	Tested	86	539	55	470	132	81	301	370	2,034
	Non-susceptible (C)	1	7	1	2			2	2	15
	% non-susceptible	1.2%	1.3%	1.8%	0.4%	0.0%	0.0%	0.7%	0.5%	0.7%
	Non-susceptible (E)	1	13	2	3			2	2	23
	% non-susceptible	1.2%	2.4%	3.6%	0.6%	0.0%	0.0%	0.7%	0.5%	1.1%
Mupirocin – High Level	Tested	86	539	55	470	131	81	301	371	2,034
	Non-susceptible	1	3	1	21		2	1	1	30
	% non-susceptible	1.2%	0.6%	1.8%	4.5%	0.0%	2.5%	0.3%	0.3%	1.5%
Nitrofurantoin (>32 C)	Tested	86	471	55	470	132	37	301	370	1,922
	Non-susceptible (C)	1	1		1			1		4
	% non-susceptible	1.2%	0.2%	0.0%	0.2%	0.0%	0.0%	0.3%	0.0%	0.2%
Rifampicin (>1 C) (>0.5 E)	Tested	86	539	55	470	132	37	301	370	1,990
	Non-susceptible (C)		2		4			2		8
	% non-susceptible	0.0%	0.4%	0.0%	0.8%	0.0%	0.0%	0.7%	0.0%	0.4%

Non-susceptible (E)		3		4			2		9
% non-susceptible	0.0%	0.6%	0.0%	0.8%	0.0%	0.0%	0.7%	0.0%	0.5%
Teicoplanin (>8 C) (>2 E) Tested	86	539	55	470	132	81	301	370	2,034
Non-susceptible (C)									
% non-susceptible	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-susceptible (E)		1		1				2	4
% non-susceptible	0.0%	0.2%	0.0%	0.2%	0.0%	0.0%	0.0%	0.5%	0.2%
Tetracycline/Doxycycline (>4 C) (>2 E)									
Tested	86	534	55	470	132	81	301	370	2,029
Non-susceptible (C)	2	28		7	4	2	7	15	65
% non-susceptible	2.3%	5.2%	0.0%	1.5%	3.0%	2.5%	2.3%	4.1%	3.2%
Non-susceptible (E)	2	29		7	4	2	7	15	66
% non-susceptible	2.3%	5.4%	0.0%	1.5%	3.0%	2.5%	2.3%	4.1%	3.3%
Trimethoprim-Sulfamethoxazole (>2/38)									
Tested	86	539	55	470	131	81	301	370	2,033
Non-susceptible	2	11	1	12	2		5	11	44
% non-susceptible	2.3%	2.0%	1.8%	2.6%	1.5%	0.0%	1.7%	3.0%	2.2%

*One SA hospital only submitted 6 months data

All MSSA isolates were susceptible to vancomycin and linezolid.

The number and proportion of MRSA isolates non-susceptible to penicillin and the non-β-lactam antimicrobials by region is shown in Table 11.

Table 11: The number tested and proportion of methicillin resistant *Staphylococcus aureus* (MRSA) isolates non-susceptible to penicillin and the non-β-lactam antimicrobials by region. Results using CLSI (C) and EUCAST (E) breakpoints are shown where the breakpoints differ.

Antimicrobial (Breakpoint mg/L)		ACT	NSW	NT	QLD	SA*	Tas	Vic	WA	Australia
Ciprofloxacin (>1)	Tested	9	137	44	83	34	10	64	95	476
	Non-susceptible	4	93	4	18	19	6	36	18	198
	%Non-susceptible	44.4%	67.9%	9.1%	21.7%	55.9%	60.0%	56.3%	18.9%	41.6%
Clindamycin (>0.5)	Tested	9	137	44	83	34	10	63	95	475
	Non-susceptible		32	2	12	6	2	9	4	67
	% non-susceptible	0.0%	23.4%	4.5%	14.5%	17.6%	20.0%	14.3%	4.2%	14.1%
Daptomycin (>1)	Tested	9	139	44	83	34	10	64	95	478
	Non-susceptible		1						1	2
	% non-susceptible	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%	0.4%
Erythromycin (>0.5 C) (>2 E)	Tested	9	139	44	83	34	10	64	95	477
	Non-susceptible (C)	2	68	20	22	21	6	28	32	199
	% non-susceptible	22.2%	49.3%	45.5%	26.5%	61.8%	60.0%	43.8%	33.7%	41.7%
	Non-susceptible (E)	2	68	20	22	21	6	28	30	197
	% non-susceptible	22.2%	49.3%	45.5%	26.5%	61.8%	60.0%	43.8%	31.6%	41.3%

Fusidic Acid (>1 E)	Tested	9	138	44	83	34	10	64	95	477
	Non-susceptible		5	4	5			3	2	19
	% non-susceptible	0.0%	3.6%	9.1%	6.0%	0.0%	0.0%	4.7%	2.1%	4.0%
Gentamicin (>4 C) (>1 E)	Tested	9	138	44	83	34	10	64	95	477
	Non-susceptible (C)	1	42	6	8	4	1	8	3	73
	% non-susceptible	11.1%	30.4%	13.6%	9.6%	11.8%	10.0%	12.5%	3.2%	15.3%
	Non-susceptible (E)	2	46	6	8	6	1	9	3	79
	% non-susceptible	22.2%	33.3%	13.6%	9.6%	16.7%	10.0%	14.1%	3.2%	16.6%
Mupirocin – High Level	Tested	9	139	44	83	34	10	64	95	477
	Non-susceptible		3		6				1	10
	% non-susceptible	0.0%	2.2%	0.0%	7.2%	0.0%	0.0%	0.0%	1.1%	2.1%
Nitrofurantoin (>32 C) (>64 E)	Tested	9	114	44	83	34	7	64	95	450
	Non-susceptible (C)		1		1			3		5
	% non-susceptible	0.0%	0.9%	0.0%	1.2%	0.0%	0.0%	4.7%	0.0%	1.1%
	Non-susceptible (E)									
	% non-susceptible	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rifampicin (>1 C) (>0.5 E)	Tested	9	138	44	83	34	7	64	95	474
	Non-susceptible (C)		1	1	3	1		3		9
	% non-susceptible	0.0%	0.7%	2.3%	3.6%	2.9%	0.0%	4.7%	0.0%	1.9%
	Non-susceptible (E)		1	1	3	1		3		9
	% non-susceptible	0.0%	0.7%	2.3%	3.6%	2.9%	0.0%	4.7%	1.0%	1.9%

Teicoplanin (>8 C) (>2 E)	Tested	9	138	44	83	34	10	64	95	477
	Non-susceptible (C)									
	% non-susceptible	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Non-susceptible (E)							1		1
	% non-susceptible	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	0.0%	0.2%
Tetracycline/Doxycycline (>4 C) (>2 E)	Tested	9	137	44	83	34	10	64	95	476
	Non-susceptible (C)	1	37	3	9	4	1	9	3	67
	% non-susceptible	11.1%	27.0%	6.8%	10.8%	11.8%	10.0%	14.1%	3.2%	14.1%
	Non-susceptible (E)	1	42	3	9	5	1	10	3	74
	% non-susceptible	11.1%	30.7%	6.8%	10.8%	14.7%	10.0%	15.6%	3.2%	15.5%
Trimethoprim-Sulfamethoxazole (>2/38)		9	137	44	83	33	10	64	95	475
			15	5	12	6	1	8	14	61
		0.0%	10.9%	11.4%	14.5%	18.2%	10.0%	12.5%	14.7%	12.8%

*One SA hospital only submitted 6 months data

All MRSA were susceptible to linezolid and vancomycin.

Antimicrobial Resistance Versus Place of Onset – Methicillin Sensitive *S. aureus*

The antimicrobial resistance results for community-onset and hospital-onset MSSA episodes are shown in Table 12. The only significant difference in susceptibilities between community-onset and hospital-onset MSSA was in erythromycin using EUCAST breakpoints.

Table 12: The number tested and proportion of methicillin sensitive (MSSA) *Staphylococcus aureus* isolates non-susceptible to penicillin and the non-β-lactam antimicrobials by place of onset. Results using CLSI (C) and EUCAST (E) breakpoints are shown where the breakpoints differ.

Antimicrobial	Number tested	Community-onset	Hospital-onset	P*
		%I/R	%I/R	
Penicillin	2,035	77.1%	77.6%	ns
Penicillin β-lac adjusted	2,035	80.0%	81.2%	ns
Ciprofloxacin	2,029	2.6%	2.5%	ns
Clindamycin	2,034	1.7%	1.2%	ns
Daptomycin	2,037	0.2%	0.2%	ns
Erythromycin (C)	2,034	10.9%	10.8%	ns
Erythromycin (E)	2,034	11.4%	7.9%	0.04
Fusidic Acid	2,034	3.0%	3.9%	ns
Gentamicin (C)	2,034	0.7%	0.7%	ns
Gentamicin (E)	2,034	1.2%	0.9%	ns
Mupirocin High-Level	2,034	1.6%	1.2%	ns
Nitrofurantoin (C)	1,922	0.3%	0.0%	ns
Rifampicin (C)	1,989	0.3%	0.2%	ns
Rifampicin (E)	1,990	0.4%	0.5%	ns
Tetracycline/Doxycycline (C)	2,029	3.0%	3.9%	ns
Tetracycline/Doxycycline (E)	2,029	3.1%	3.9%	ns
Trimethoprim-Sulfamethoxazole	2,033	2.1%	2.5%	ns

* Test of significance between %I/R CO and HO

All MSSA isolates were susceptible to linezolid, teicoplanin and vancomycin

Antimicrobial Resistance Versus Place of Onset – Methicillin Resistant *S. aureus*

The antimicrobial resistance results for community-onset and hospital-onset MRSA are shown in Table 13. There were significant differences in non-susceptibility between community and hospital-onset MRSA.

Table 13: The number tested and proportion of methicillin resistant (MRSA) *Staphylococcus aureus* isolates non-susceptible to penicillin and the non-β-lactam antimicrobials by place of onset. Results using CLSI (C) and EUCAST (E) breakpoints are shown where the breakpoints differ.

Antimicrobial	Number tested	Community-onset	Hospital-onset	p*
		%I/R	%I/R	
Ciprofloxacin	476	34.5%	58.0%	<0.0001
Clindamycin	475	9.6%	24.5%	<0.0001
Daptomycin	478	0.3%	0.7%	ns
Erythromycin (C)	477	35.4%	56.3%	<0.0001
Erythromycin (E)	477	35.1%	55.6%	<0.0001
Fusidic Acid	477	3.6%	4.9%	ns
Gentamicin (C)	477	9.6%	28.5%	<0.0001
Gentamicin (E)	477	10.8%	29.9%	<0.0001
Mupirocin High-Level	477	1.8%	2.8%	ns
Nitrofurantoin (C)	450	0.9%	1.5%	ns
Rifampicin (C)	474	1.8%	2.1%	ns
Rifampicin (E)	474	1.8%	2.1%	ns
Teicoplanin (C)	477	0	0	ns
Teicoplanin (E)	477	0.3%	0.0%	ns
Tetracycline/Doxycycline (C)	476	10.2%	23.1%	<0.0001
Tetracycline/Doxycycline (E)	476	11.4%	25.2%	<0.0001
Trimethoprim-Sulfamethoxazole	475	8.7%	22.4%	<0.0001

* Test of significance between %I/R CO and HO
All MRSA isolates were susceptible to linezolid and vancomycin

Trend Data (2013-2017)

Methicillin Sensitive *Staphylococcus aureus*

The following figures show the trends in antimicrobial non-susceptibility for MSSA by region from 2013 to 2017 (Figures 4 -12).

Figure 4: The Antimicrobial Non-susceptibility Results of Methicillin Sensitive *Staphylococcus aureus* (MSSA) Isolates from the Australian Capital Territory (2013-2017).

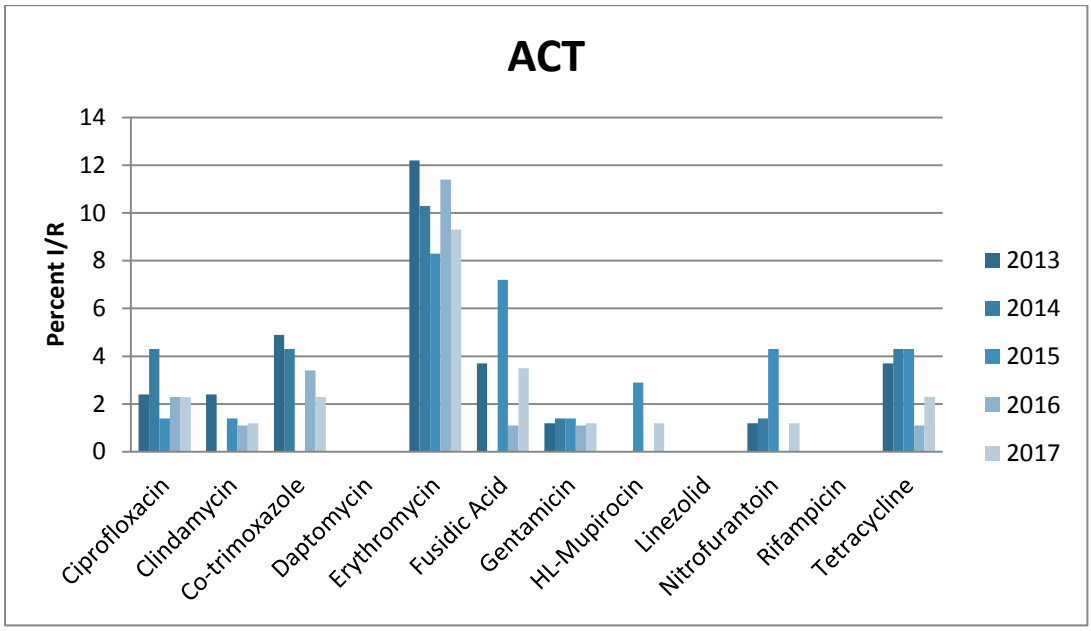


Figure 5: The Antimicrobial Non-susceptibility Results of Methicillin Sensitive *Staphylococcus aureus* (MSSA) Isolates from New South Wales (2013-2017).

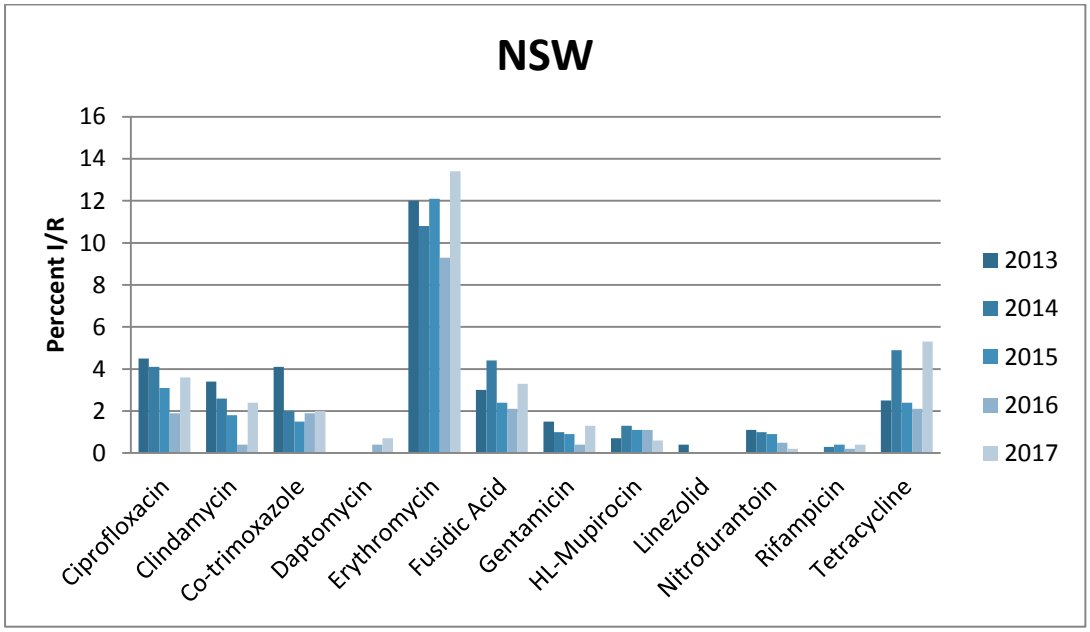


Figure 6: The Antimicrobial Non-susceptibility Results of Methicillin Sensitive *Staphylococcus aureus* (MSSA) Isolates from the Northern Territory (2013-2017).

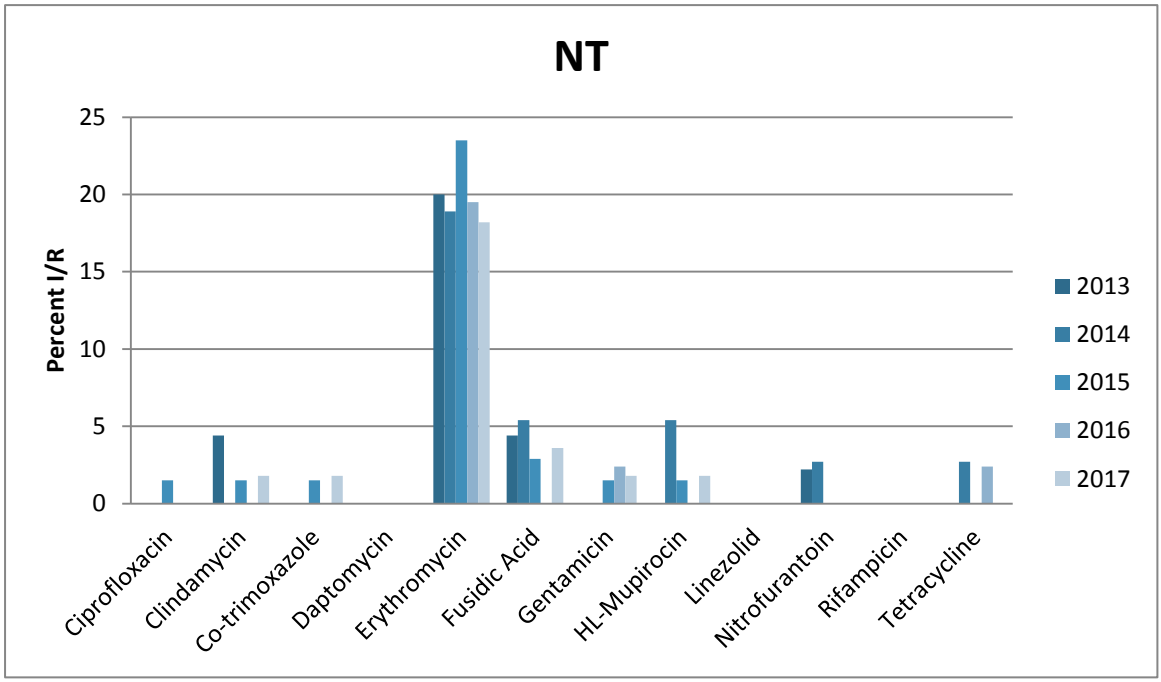


Figure 7: The Antimicrobial Non-susceptibility Results of Methicillin Sensitive *Staphylococcus aureus* (MSSA) Isolates from Queensland (2013-2017).

Note: Decreasing trend in clindamycin (Chi-sq for trend = 3.787, p=0.05), nitrofurantoin (Chi-sq for trend = 17.732, p<0.0001), and gentamicin resistance (Chi-sq for trend = 4.577, p=0.03),

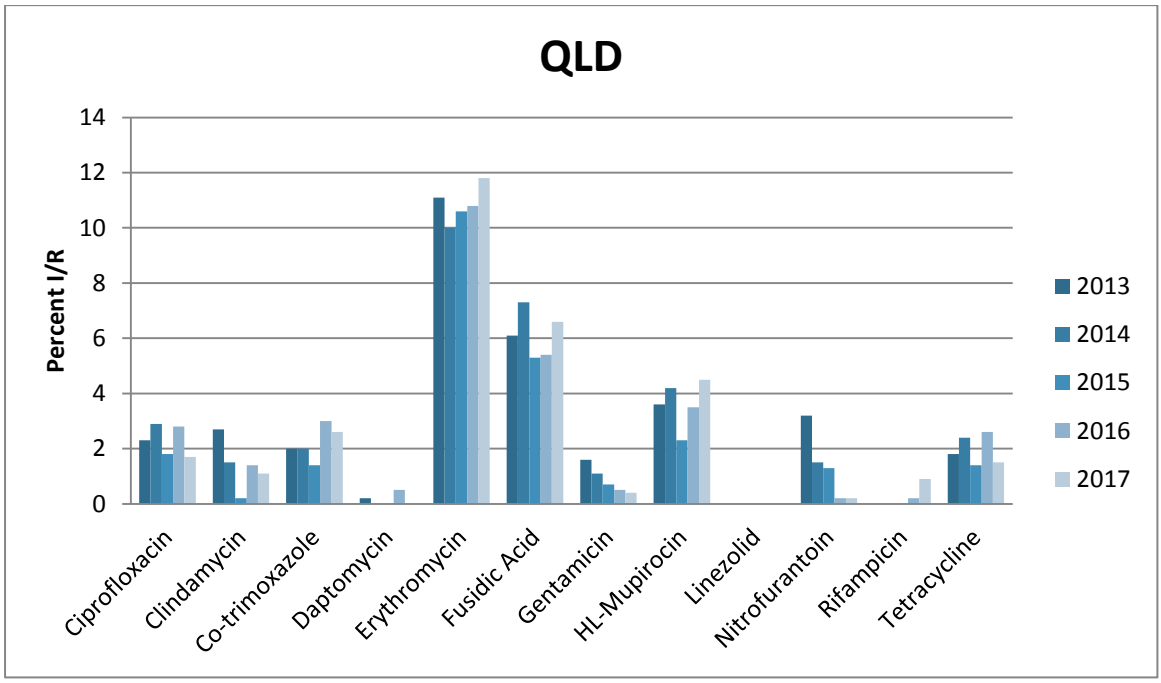


Figure 8: The Antimicrobial Non-susceptibility Results of Methicillin Sensitive *Staphylococcus aureus* (MSSA) Isolates from South Australia (2013-2017).

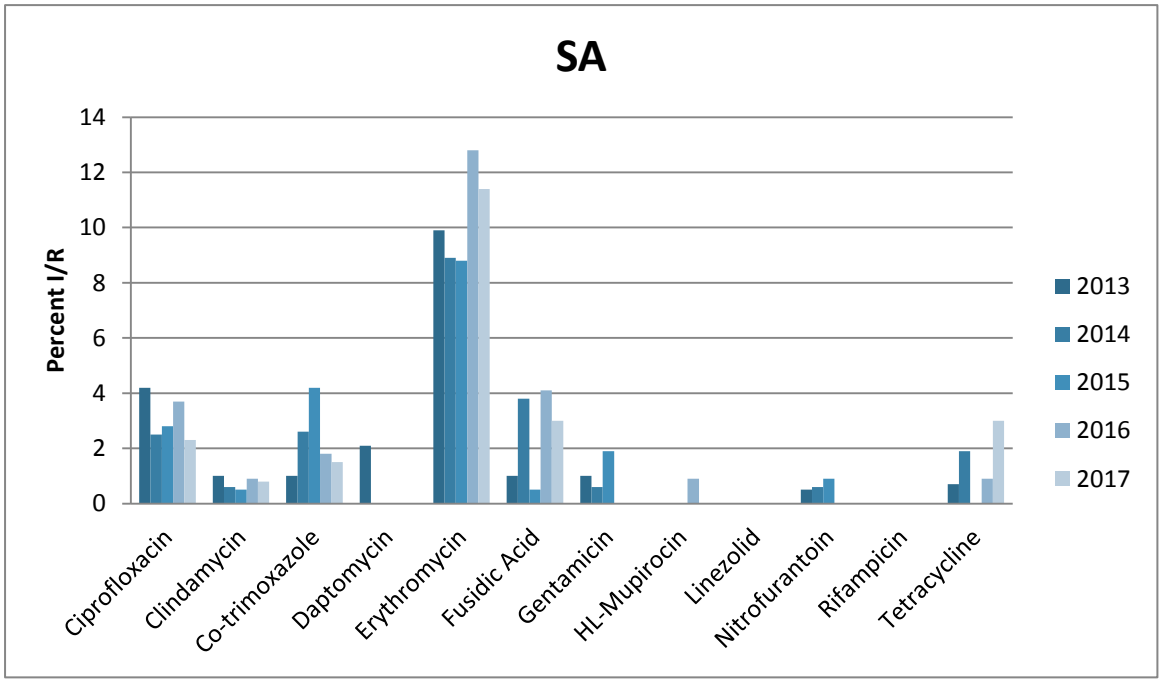


Figure 9: The Antimicrobial Non-susceptibility Results of Methicillin Sensitive *Staphylococcus aureus* (MSSA) Isolates from Tasmania (2013-2017).

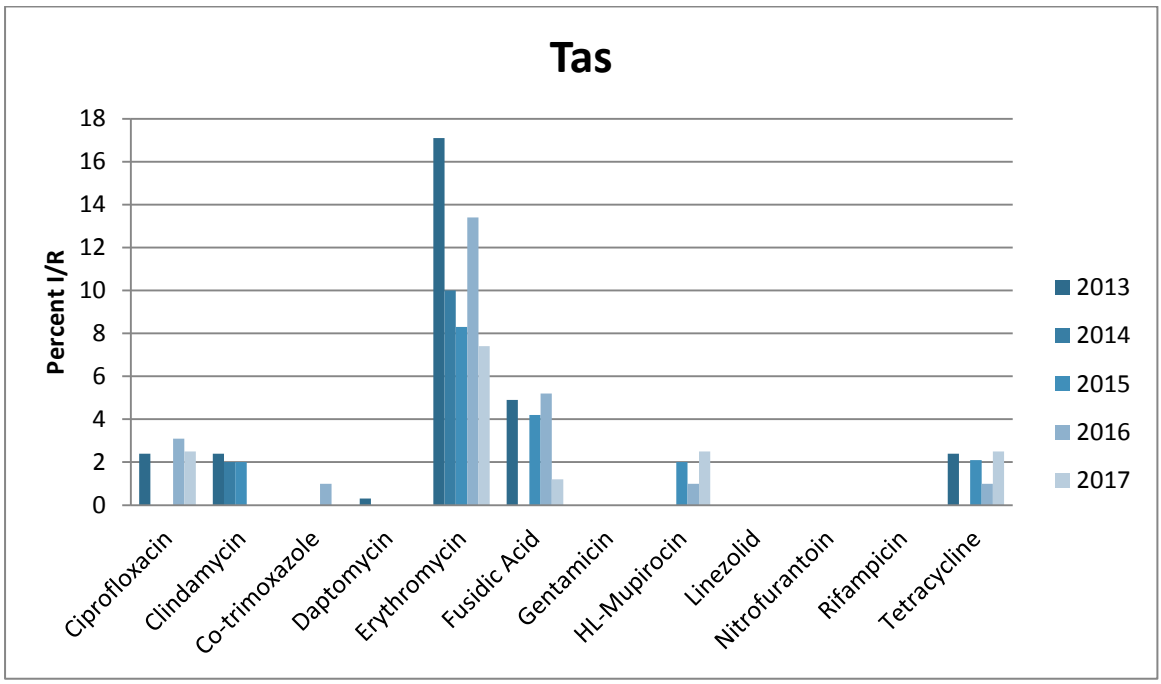


Figure 10: The Antimicrobial Non-susceptibility Results of Methicillin Sensitive Staphylococcus aureus (MSSA) Isolates from Victoria (2013-2017).

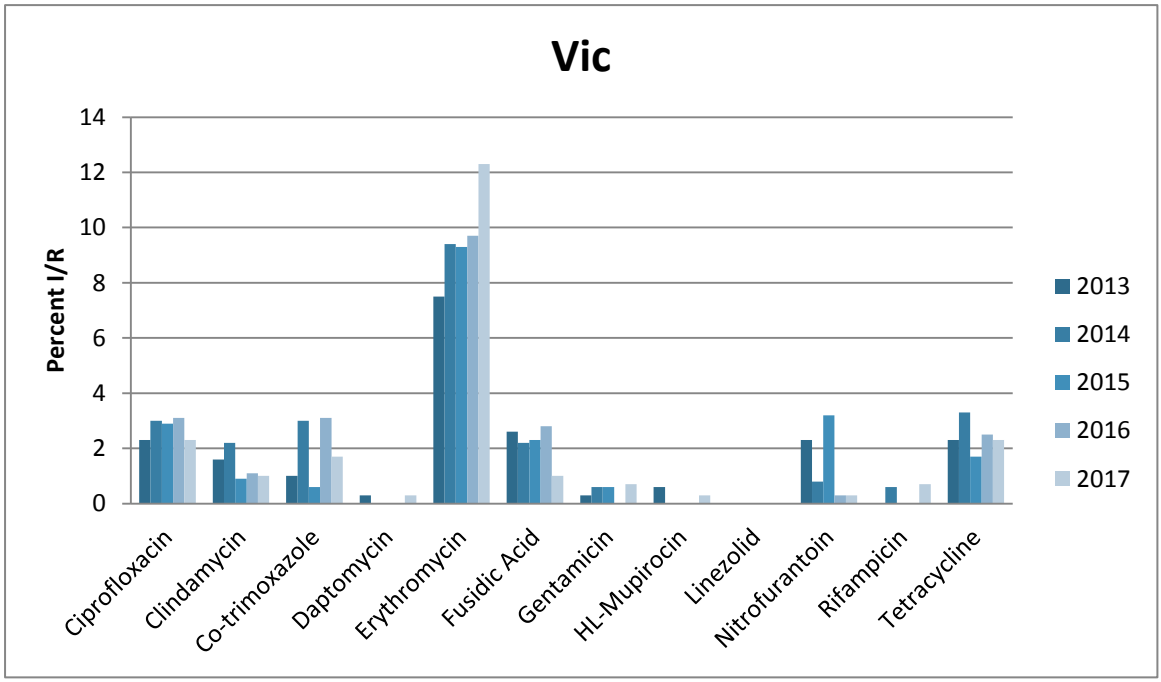


Figure 11: The Antimicrobial Non-susceptibility Results of Methicillin Sensitive *Staphylococcus aureus* (MSSA) Isolates from Western Australia (2013-2017).

Note: Decreasing trend in fusidic acid resistance (Chi-sq for trend = 8.104, p=0.004)

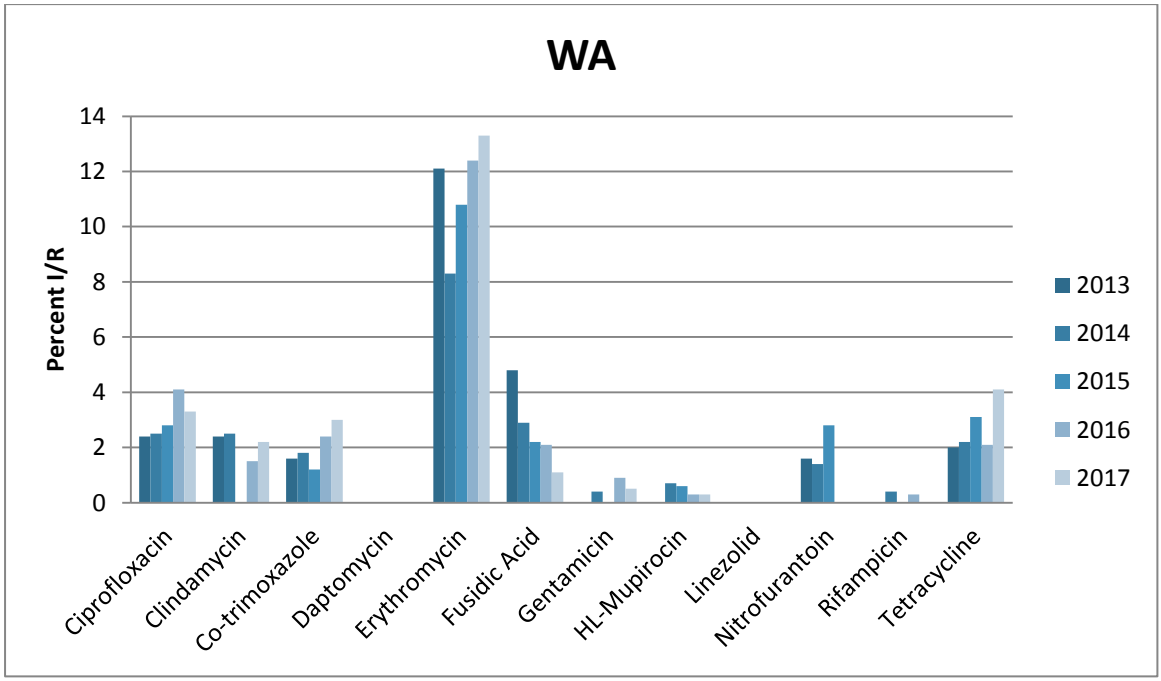
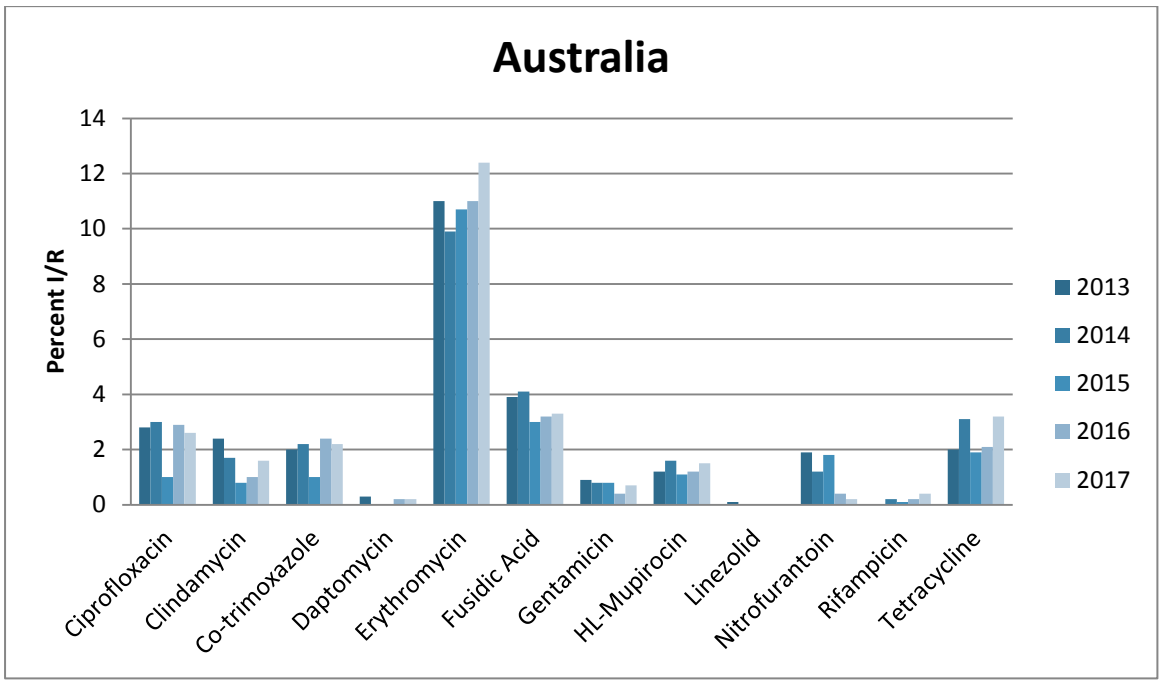


Figure 12: The Antimicrobial Non-susceptibility Results of Methicillin Sensitive *Staphylococcus aureus* (MSSA) Isolates from Australia (2013-2017).

Note: Decreasing trend in nitrofurantoin resistance (Chi-sq for trend = 31.014, p<0.0001), an increasing trend in rifampicin resistance (Chi-sq for trend = 5.195, p=0.02)



Methicillin Resistant *Staphylococcus aureus*

The following figures show the trends in antimicrobial non-susceptibility for MRSA by region from 2013 to 2017 (Figures 13 -22).

Figure 13: Methicillin Resistant *Staphylococcus aureus* (MRSA) for Australia (2013-2017) by Region.

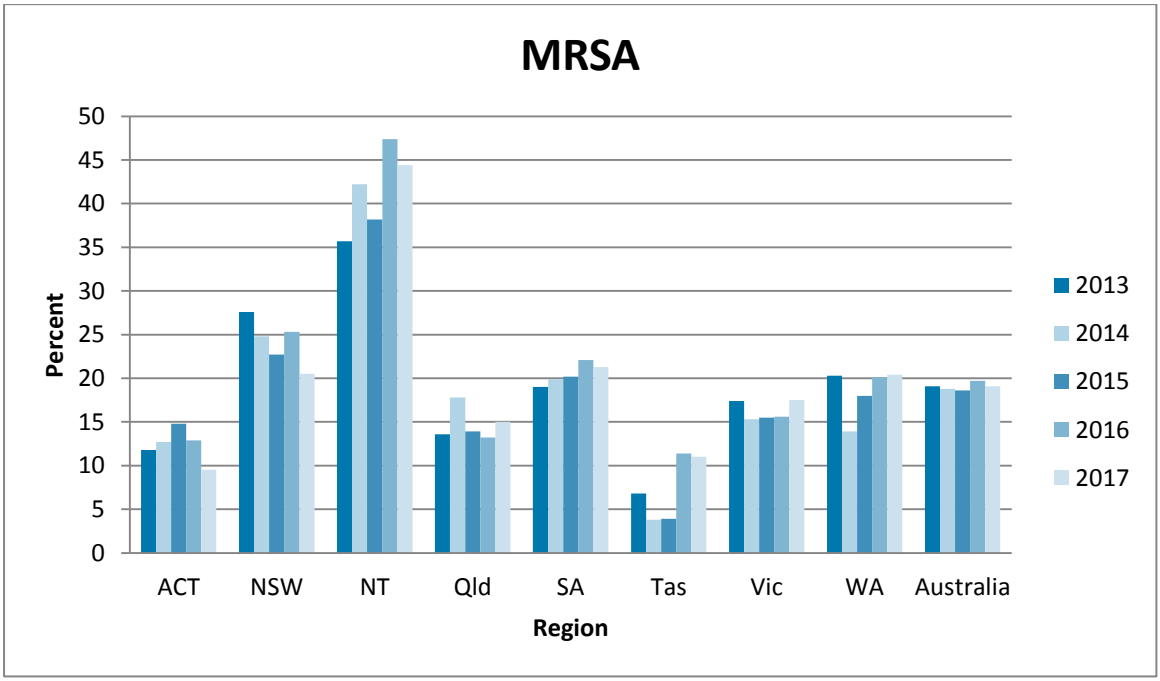


Figure 14: The Antimicrobial Non-susceptibility Results of Methicillin Resistant *Staphylococcus aureus* (MRSA) Isolates from the Australian Capital Territory (2013-2017)

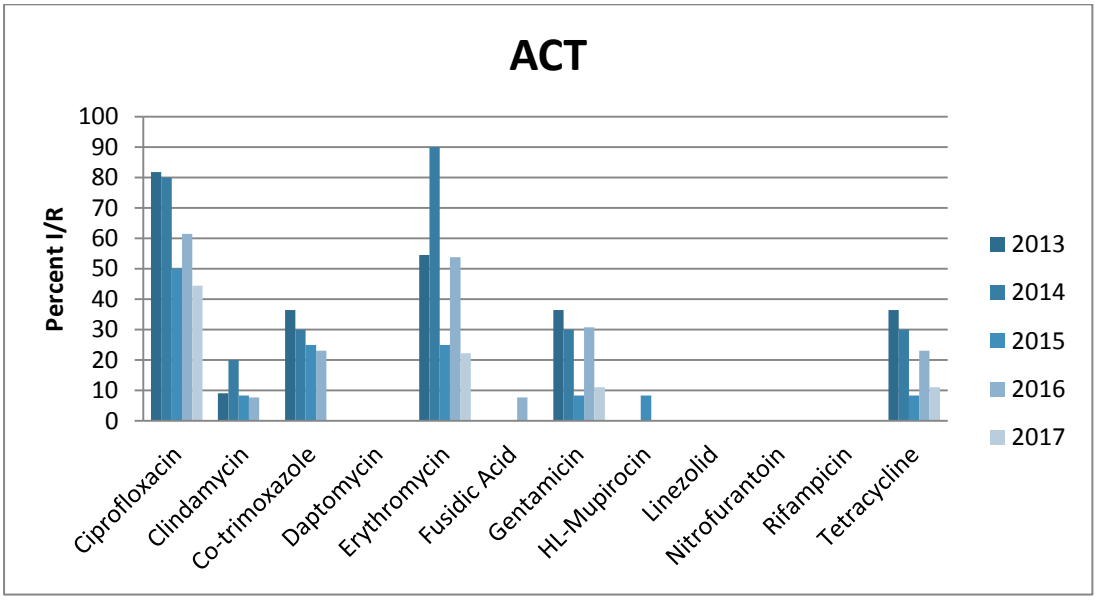


Figure 15: The Antimicrobial Non-susceptibility Results of Methicillin Resistant *Staphylococcus aureus* (MRSA) Isolates from New South Wales (2013-2017)

Note: Decreasing trend in co-trimoxazole resistance (Chi-sq for trend =8.685, p=0.003).

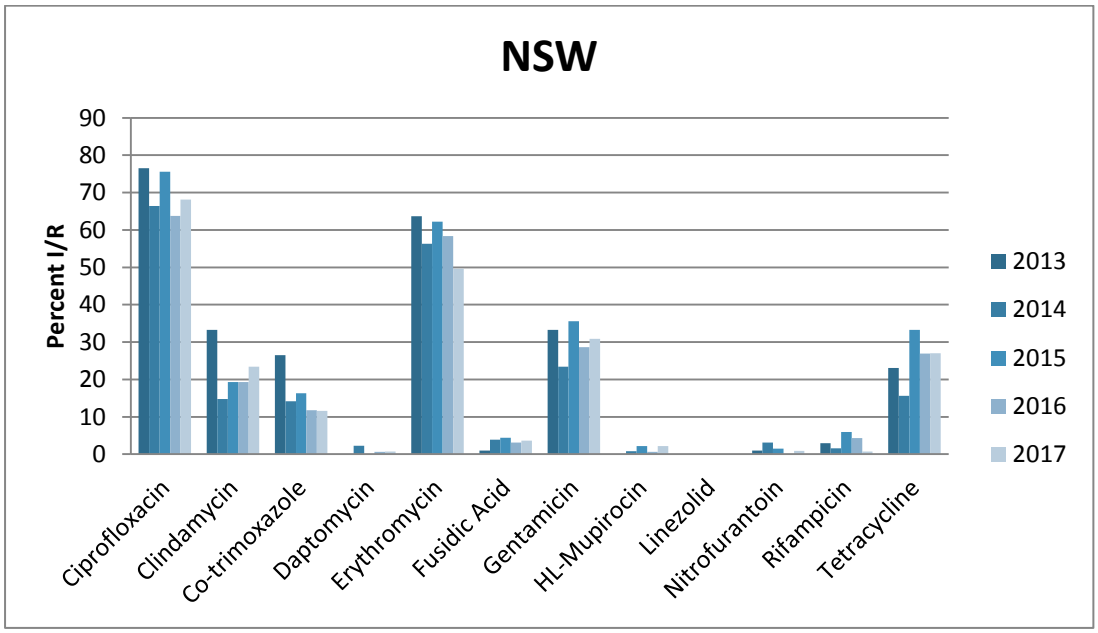


Figure 16: The Antimicrobial Non-susceptibility Results of Methicillin Resistant *Staphylococcus aureus* (MRSA) Isolates from the Northern Territory (2013-2017)

Note: Decreasing trend for tetracycline (Chi-sq for trend = 7.544, p=0.006) and cotrimoxazole resistance (Chi-sq for trend = 4.84, p=0.03)

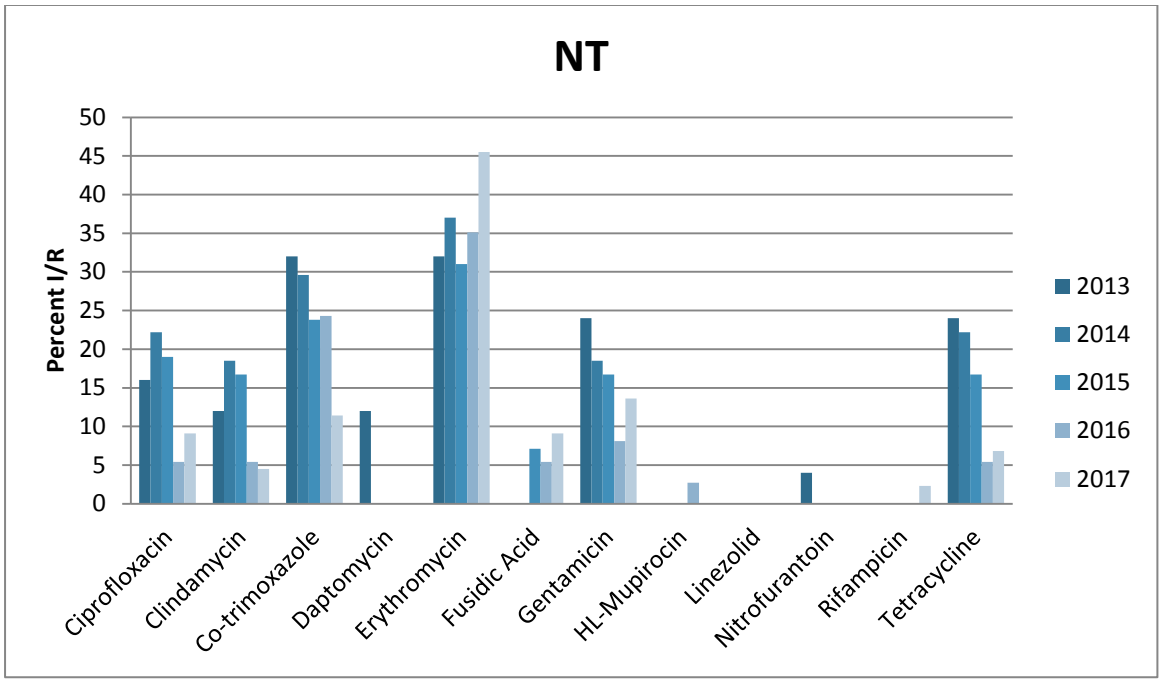


Figure 17: The Antimicrobial Non-susceptibility Results of Methicillin Resistant *Staphylococcus aureus* (MRSA) Isolates from Queensland (2013-2017)

Note: Decreasing trend for ciprofloxacin (Chi-sq for trend = 11.58, p=0.0007) and erythromycin resistance (Chi-sq for trend = 10.521, p=0.001).

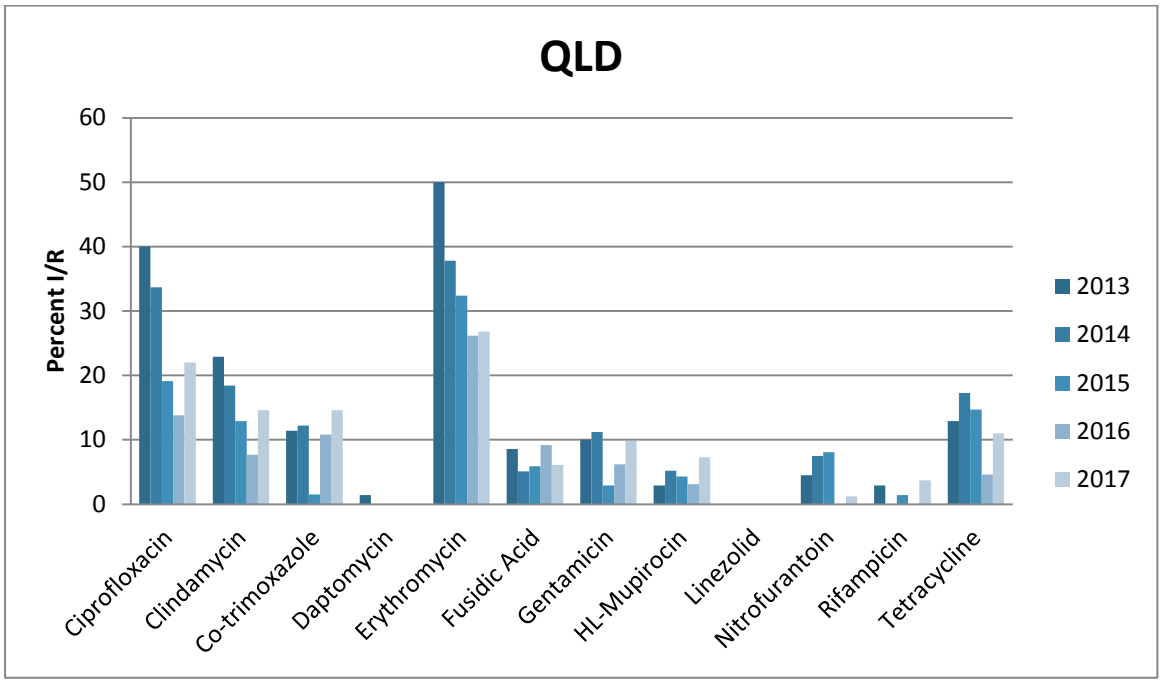


Figure 18: The Antimicrobial Non-susceptibility Results of Methicillin Resistant *Staphylococcus aureus* (MRSA) Isolates from South Australia (2013-2017)

Note: Increasing trend in clindamycin resistance (Chi-sq for trend = 4.169, p=0.04)

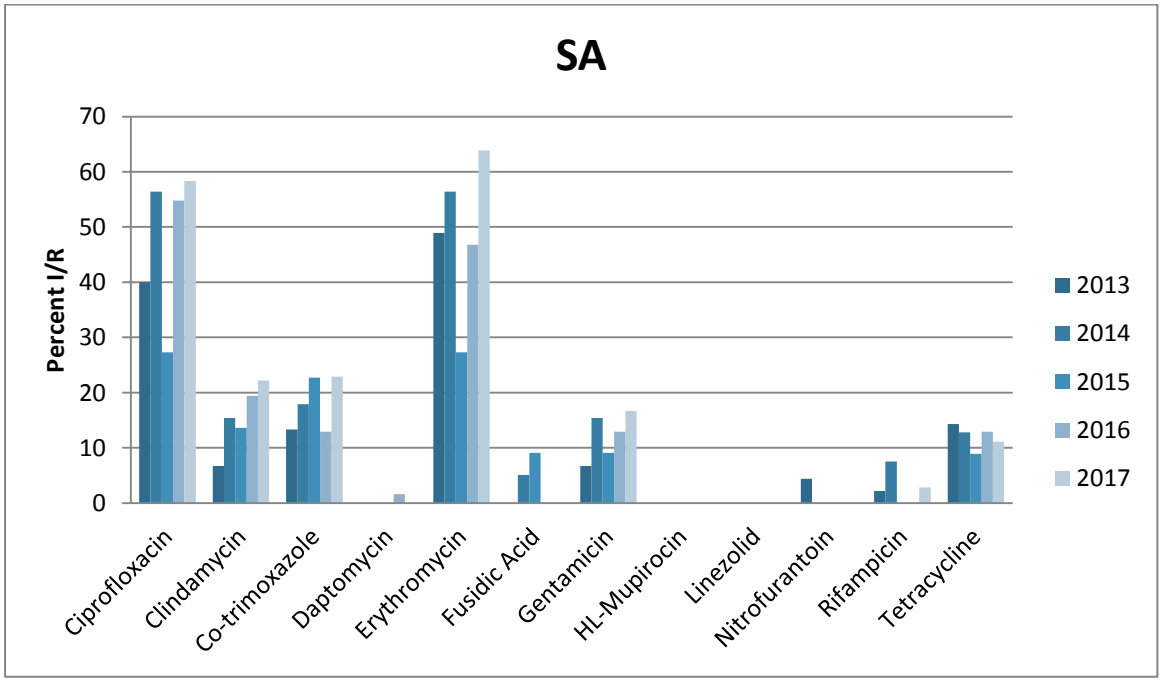


Figure 19: The Antimicrobial Non-susceptibility Results of Methicillin Resistant *Staphylococcus aureus* (MRSA) Isolates from Tasmania (2013-2017)

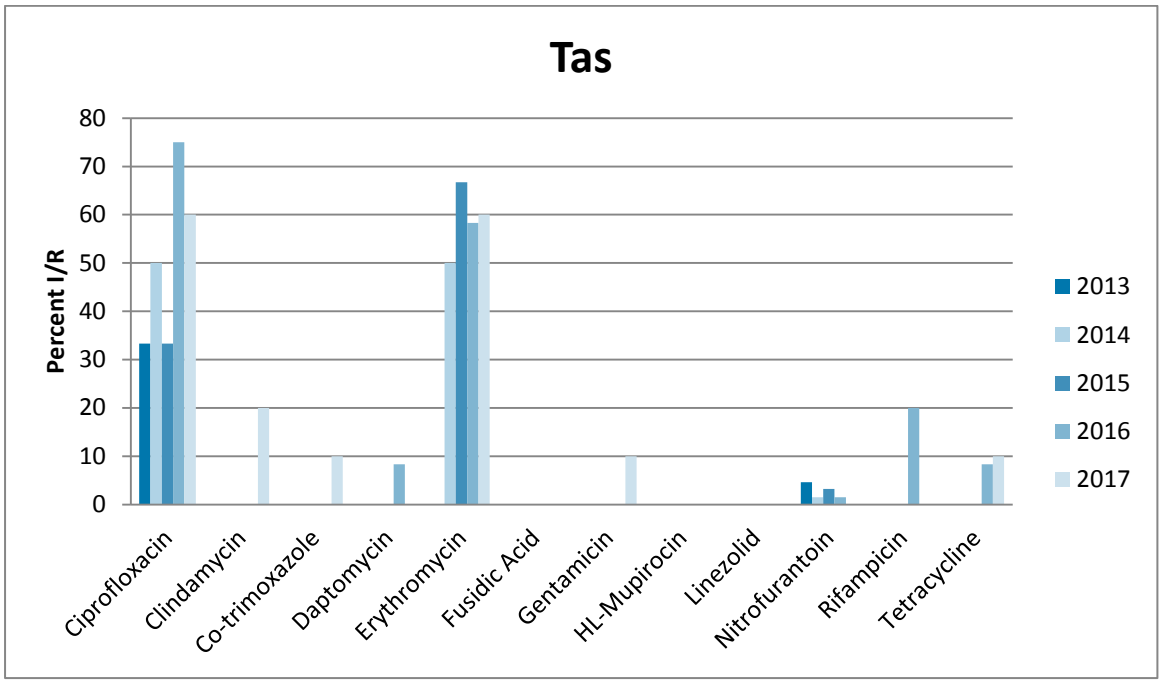


Figure 20: The Antimicrobial Non-susceptibility Results of Methicillin Resistant *Staphylococcus aureus* (MRSA) Isolates from Victoria (2013-2017)

Note: Decreasing trend in ciprofloxacin resistance (Chi-sq for trend = 4.331, p=0.04) clindamycin (Chi-sq for trend = 13.428, p=0.0002), tetracycline (Chi-sq for trend = 5.529, p=0.02) and co-trimoxazole resistance (Chi-sq for trend = 12.717, p=0.0004).

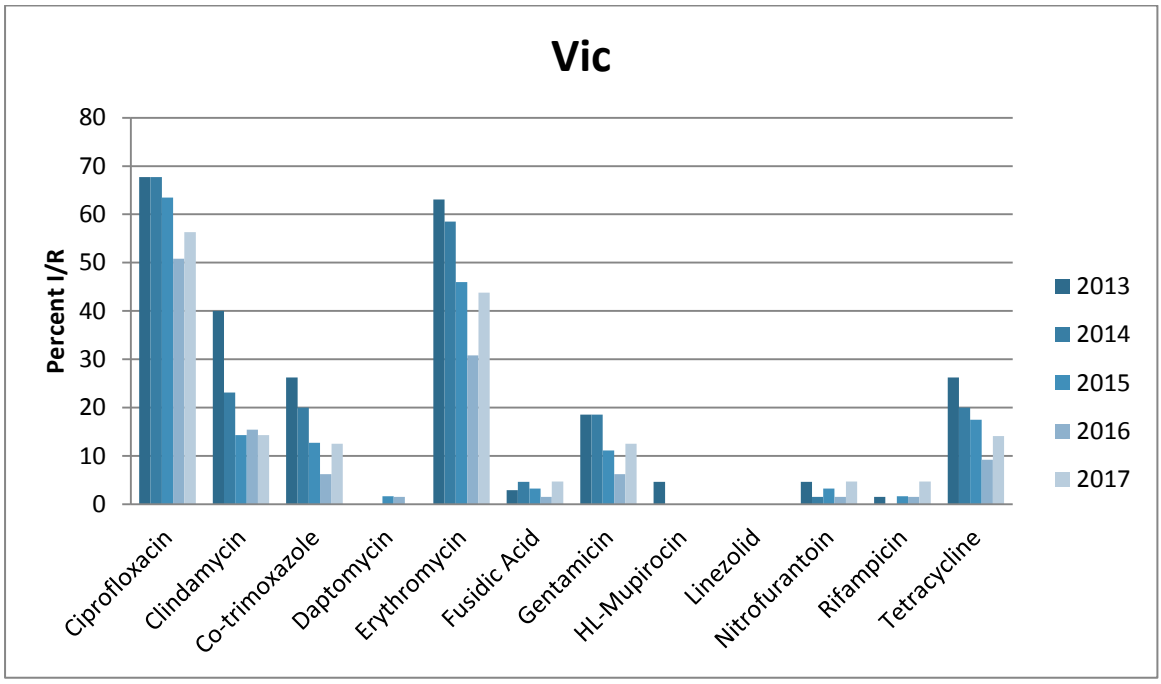


Figure 21: The Antimicrobial Non-susceptibility Results of Methicillin Resistant *Staphylococcus aureus* (MRSA) Isolates from Western Australia (2013-2017)

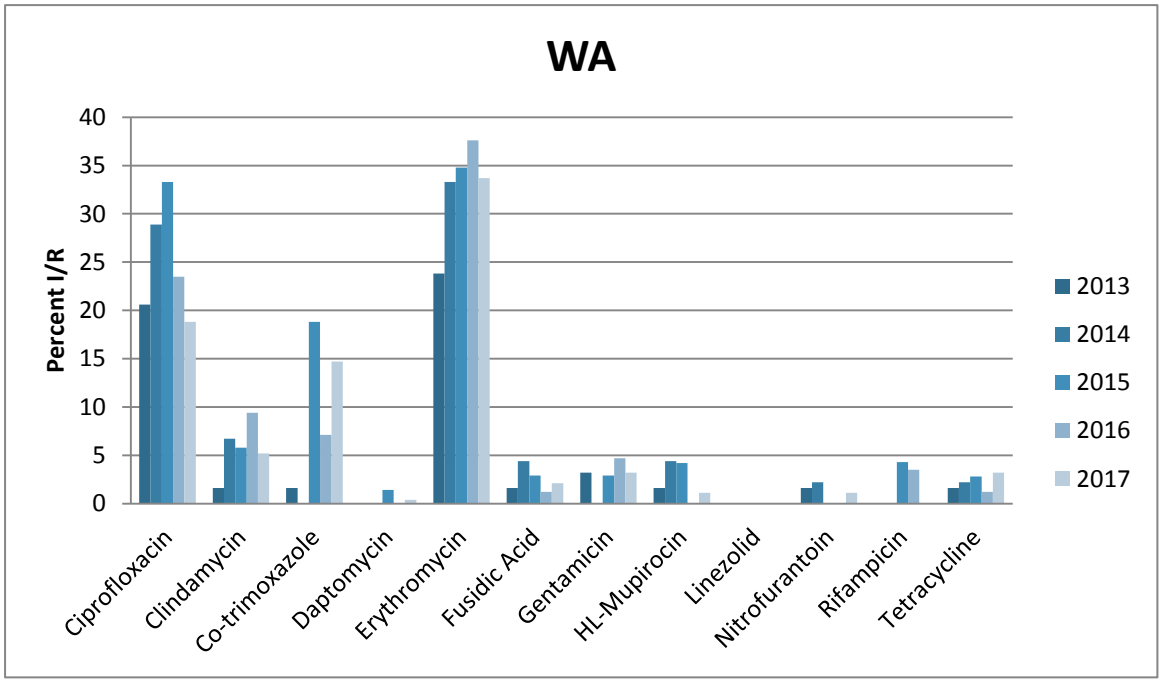
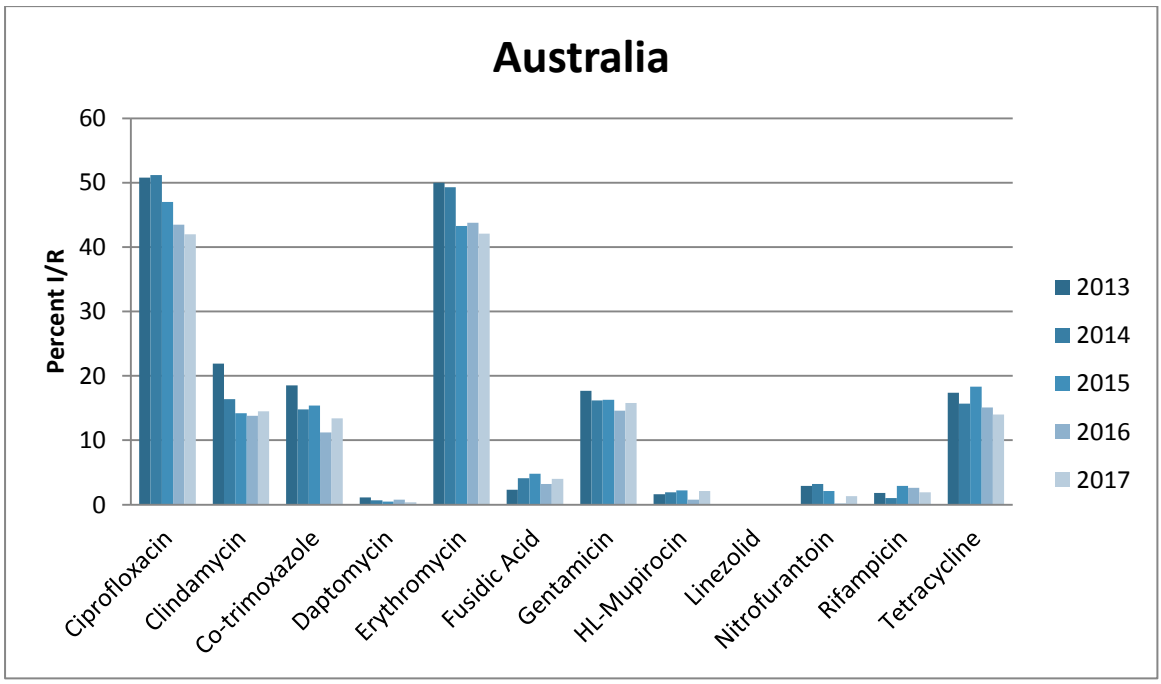


Figure 22: The Antimicrobial Non-susceptibility Results of Methicillin Resistant *Staphylococcus aureus* (MRSA) Isolates from Australia (2013-2017)

Note: Decreasing trend in ciprofloxacin (Chi-sq for trend = 11.444, p=0.0007) clindamycin (Chi-sq for trend = 8.548, p=0.004), erythromycin (Chi-sq for trend = 7.759, p=0.005) and co-trimoxazole resistance (Chi-sq for trend = 7.617, p=0.006).



The Molecular Epidemiology of Methicillin Resistant *Staphylococcus aureus*

Molecular typing of the MRSA was performed by the Antimicrobial Resistance and Infectious Disease Laboratory at the School of Veterinary Life Science, Murdoch University, WA.

Typing was performed by Whole Genome Sequencing (WGS) using the Illumina MiSeq platform.

Of the 480 MRSA bacteraemic episodes reported, 462 MRSA isolates (96.3%) were available for typing by whole genome sequencing (WGS).

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Healthcare-associated MRSA

Based on the multilocus sequence type (MLST) and SCC*mec* type three healthcare-associated MRSA (HA-MRSA) clones were identified: ST22-IV (EMRSA-15); ST239-III (Aus 2/3 EMRSA) and ST5-II (NY/Japan EMRSA or USA100) (Table14).

Panton-Valentine leucocidin (PVL) associated genes were not identified.

The most frequently isolated HA-MRSA clone, ST22-IV, was identified in all regions. ST239-III was isolated in all regions except Western Australia and the Australian Capital Territory. ST5-II was isolated in New South Wales and Queensland (Table 15).

Table 14: The Number and Proportion of Healthcare-associated MRSA by Clone, Place of Onset and Panton-Valentine leucocidin Carriage

Clone	Clonal Complex	Total %[a]	%HA MRSA[b]	Onset		PVL positive %[c]
				Hospital %[c]	Community %[c]	
ST22-IV (EMRSA15)	22	90 (19.5)	76.3	37 (41.4)	53 (58.9)	0
ST239-III (Aus2/3 EMRSA)	8	25 (5.4)	21.2	17 (68.0)	8 (32.0)	0
ST5-II (NY/Japan/USA100)	5	3 (0.6)	2.5		3 (100)	0
Total		118 (25.5)		54 (45.8)	64 (54.2)	0

,[a] Percentage of all MRSA ;[b] Percentage of HA MRSA; [c] Percentage of the clone

Table 15: The Number and Proportion of Healthcare-associated MRSA Clones by Region.

Clone	ACT	NSW	NT	QLD	SA	Tas	Vic	WA	AUS
ST22-IV (EMRSA15)	2 (100)	42 (71.2)	1 (33.3)	4 (50.0)	14 (82.4)	5 (83.3)	13 (92.9)	9 (100)	90 (76.3)
ST239-III (Aus2/3 EMRSA)		16 (27.1)	2 (66.7)	2 (25.0)	3 (17.6)	1 (17.6)	1 (7.1)		25 (21.2)
ST5-II (NY/Japan/USA100)		1 (1.7)		2 (25.0)					3 (0.6)
Total	**2**	**59**	**3**	**8**	**17**	**6**	**14**	**9**	**118**

Table 16 shows the number and proportion of healthcare-associated MRSA clones by region and place of onset of bacteraemia.

Table 16: Healthcare-associated MRSA Clones by Region and Place of Onset

Region	Community-onset (CO)	%CO	Hospital-onset (HO)	%HO	Total
ACT	1	50.0	1	50.0	2
NSW	29	49.2	30	50.8	59
NT	2	66.7	1	33.3	3
QLD	6	75.0	2	25.0	8
SA	6	35.3	11	64.7	17
TAS	3	50.0	3	50.0	6
VIC	10	71.4	4	28.6	14
WA	7	77.8	2	22.2	9
Australia	**64**	**54.2**	**54**	**45.8**	**118**

Community-Associated Methicillin Resistant *S. aureus*

Based on the MLST and SCC*mec* 48 Community-associated MRSA (CA-MRSA) clones were identified. PVL was detected in 14 CA-MRSA clones. Overall 49.1% of CA MRSA were PVL-positive (Table 17).

The most frequently isolated CA-MRSA clone, ST93-IV (Qld CA-MRSA), was isolated in all states except Tasmania (Table 18).

Table 17: Number and Proportion of Community Associated MRSA by Clone, Place of Onset and Panton-Valentine leucocidin Carriage.

Clone	Clonal Complex	Total %[a]	%CA MRSA[b]	Onset		
				Hospital %[c]	Community %[c]	PVL positive %[c]
ST93-IV	Singleton	113 (24.5)	32.8%	17 (15.0)	96 (85.0)	106 (93.8)
ST45-V	45	44 (9.5)	12.8%	17 (38.6)	27 (61.4)	15 (34.1)
ST5-IV	5	39 (8.4)	11.3%	13 (33.3)	26 (66.7)	9 (23.1)
ST1-IV	1	34 (7.4)	9.9%	8 (23.5)	26 (76.5)	1 (2.9)
ST78-IV	78	16 (3.5)	4.7%	3 (18.8)	13 (81.3)	2 (12.5)
ST30-IV	30	10 (2.2)	2.9%	1 (10.0)	9 (90.0)	7 (70.0)
ST8-IV	8	10 (2.2)	2.9%	2 (20.0)	8 (80.0)	10 (100.0)
ST5-V	5	8 (1.7)	2.3%	2 (25.0)	6 (75.0)	
ST97-IV	97	8 (1.7)	2.3%	2 (25.0)	6 (75.0)	
ST8-IV	8	8 (1.7)	2.4%	2 (25.0)	6 (75.0)	8 (100.0)
ST6-IV	5	7 (1.5)	2.0%	2 (28.6)	5 (71.4)	4 (57.1)
ST953-IV	97	6 (1.3)	1.7%	2 (33.3)	4 (66.7)	
ST22-IV PVL positive	22	4 (0.9)	1.2%	1 (25.0)	3 (75.0)	4 (100.0)
ST762-IV	1	4 (0.9)	1.2%	1 (25.0)	3 (75.0)	
ST59-V		4 (0.9)	1.2%	1 (25.0)	3 (75.0)	4 (100.0)
ST188-IV	188	4 (0.9)	1.2%	3 (75.0)	1 (25.0)	
ST872-IV		3 (0.6)	0.9%	1 (33.3)	2 (66.7)	
ST45-IV	45	3 (0.6)	0.9%	2 (66.7)	1 (33.3)	2 (66.7)
ST72-IV	72	3 (0.6)	0.9%		3 (100.0)	3 (100.0)
ST835-no ccr genes	5	2 (0.4)	0.6%		2 (100.0)	
ST8slv-IV		2 (0.4)	0.6%		2 (100.0)	2 (100.0)
ST6slv-V		2 (0.4)	0.6%		2 (100.0)	
ST73-IV	5	2 (0.4)	0.6%		2 (100.0)	

Clone	Clonal Complex	Total %[a]	%CA MRSA[b]	Onset		
				Hospital %[c]	Community %[c]	PVL positive %[c]
ST1232-V		1 (0.2)	0.3%		1 (100.0)	1 (100.0)
ST1568-VI		1 (0.2)	0.3%		1 (100.0)	
ST1649-IV		1 (0.2)	0.3%		1 (100.0)	
ST1850-IV	75	1 (0.2)	0.3%		1 (100.0)	
ST1-V	1	1 (0.2)	0.3%	1 (100.0)		
ST218-IV		1 (0.2)	0.3%		1 (100.0)	
ST2250-IV		1 (0.2)	0.3%	1 (100.0)		
ST2371-IV		1 (0.2)	0.3%	1 (100.0)		1 (100.0)
ST3349-III		1 (0.2)	0.3%	1 (100.0)		
ST398-V		1 (0.2)	0.3%		1 (100.0)	
ST573-V		1 (0.2)	0.3%		1 (100.0)	
ST59-IV	59	1 (0.2)	0.3%		1 (100.0)	1 (100.0)
ST72-V		1 (0.2)	0.3%	1 (100.0)		
ST772-V	1	1 (0.2)	0.3%	1 (100.0)		1 (100.0)
ST834-IV	9	1 (0.2)	0.3%		1 (100.0)	
ST835-I		1 (0.2)	0.3%		1 (100.0)	
ST835-V		1 (0.2)	0.3%	1 (100.0)		
ST88-IV	188	1 (0.2)	0.3%		1 (100.0)	
Total		344 (74.5)	100.0	84 (24.4)	260 (75.6)	171 (49.7)

,[a] Percentage of all MRSA ;[b] Percentage of CA MRSA; [c] Percentage of the clone

Table 18: The Number and Proportion of the Major Community-associated MRSA Clones (>10 isolates) by Region and Panton-Valentine leucocidin Carriage.

Clone	ACT		NSW		NT		QLD		SA		Tas		Vic		WA		AUS	
	n	PVL+ (%)	n	PVL+ (%)	n	PVL+ (%)	n	PVL+ (%)	n	PVL+ (%)	n	PVL+ (%)	n	PVL+ (%)	n	PVL+ (%)	n	PVL+ (%)
ST93-IV	2	50.0%	15	93.3%	29	89.7%	27	100.0%	3	100.0%			9	77.8%	28	100.0%	113	93.8%
ST45-V	1	0.0%	29	34.5%			1	0.0%	1	0.0%			11	36.4%	1	100.0%	44	34.1%
ST5-IV			5	0.0%	4	25.0%	13	0.0%	3	33.3%			4	0.0%	10	70.0%	39	23.1%
ST1-IV	2	0.0%	1	100.0%	3	0.0%	8	0.0%	3	0.0%	3		2	0.0%	12	0.0%	34	2.9%
ST78-IV			1	0.0%			1	100.0%	2	0.0%			1	0.0%	11	9.1%	16	12.5%
ST30-IV			3	66.7%			3	66.7%	1	100.0%			1	0.0%	2	100.0%	10	70.0%
Other	2	30.8%	19	63.2%	3	0.0%	19	26.3%	4	50.0%			19	47.4%	22	9.1%	88	35.2%
Total	7	28.6%	73	53.4%	39	69.2%	72	48.6%	17	41.2%	3		47	42.6%	86	47.7%	344	49.7%

Table 19 shows the number and proportion of community-associated MRSA clones by region and place of onset of bacteraemia.

Table 19`: Community-associated MRSA Clones by Region and Place of Onset

Region	Community-onset (CO)	%CO	Hospital-onset (HO)	%HO	Total
ACT	4	57.1%	3	42.9%	7
NSW	55	75.3%	18	24.7%	73
NT	29	74.4%	10	25.6%	39
QLD	48	66.7%	24	33.3%	72
SA	13	76.5%	4	23.5%	17
TAS	3	100.0%			3
VIC	33	70.2%	14	29.8%	47
WA	75	87.2%	11	12.8%	86
Australia	260	75.6%	84	24.4%	344

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