Australian Group on Antimicrobial Resistance Hospital-onset *Staphylococcus aureus* Surveillance Programme annual report, 2011

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Abstract

In 2011, the Australian Group on Antimicrobial Resistance (AGAR) conducted a period-prevalence survey of clinical *Staphylococcus aureus* isolated from hospital inpatients. Twenty-nine microbiology laboratories from all states and mainland territories participated. Specimens were collected more than 48 hours post-admission. Isolates were tested by Vitek2® antimicrobial susceptibility card (AST-P612 card). Nationally, the proportion of *S. aureus* that were methicillin-resistant *S. aureus* (MRSA) was 30.3%; ranging from 19.9% in Western Australia to 36.8% in New South Wales/Australian Capital Territory. Resistance to the non-ß-lactam antimicrobials was common except for rifampicin, fusidic acid, high-level mupirocin and daptomycin. No resistance was detected for vancomycin, teicoplanin or linezolid. Antibiotic resistance in methicillin susceptible *S. aureus* (MSSA) was rare apart from erythromycin (13.2%) and there was no resistance to vancomycin, teicoplanin or linezolid. Inducible clindamycin resistance was the norm for erythromycin resistant, clindamycin intermediate/susceptible *S. aureus* in Australia with 90.6% of MRSA and 83.1% of MSSA with this phenotype having a positive double disc diffusion test (D-test). The proportion of *S. aureus* characterised as being healthcare-associated MRSA (HA-MRSA) was 18.2%, ranging from 4.5% in Western Australia to 28.0% in New South Wales/Australian Capital Territory. Four HA-MRSA clones were characterised and 98.8% of HA-MRSA isolates were classified as either ST22-IV [2B] (EMRSA-15) or ST239-III [3A] (Aus-2/3 EMRSA). Multiclonal community-associated MRSA (CA-MRSA) accounted for 11.7% of all *S. aureus*. In Australia, regional variation in resistance is due to the differential distribution of MRSA clones between regions, particularly for the major HA-MRSA clone, ST239-III [3A] (Aus-2/3 EMRSA), which is resistant to multiple non-ß-lactam antimicrobials. *Commun Dis Intell* 2013;37(3):E210–E218.

Keywords: antimicrobial resistance surveillance; *Staphylococcus aureus;* hospital-onset infections; methicillin susceptible, methicillin resistant

Introduction

Staphylococcus aureus is a major pathogen in the hospital environment, causing a wide variety of infections that are associated with considerable mortality. Several studies have indicated that mortality is higher for patients infected with methicillin-resistant *S. aureus* (MRSA) than methicillin-susceptible *S. aureus* (MSSA)[1–4] and that MRSA infections are associated with increased costs due to longer hospital stays and the need for treatment with costly antimicrobials.[5–7]

The Australian Group on Antimicrobial Resistance (AGAR) has undertaken antimicrobial resistance period-prevalence surveys in Australia since 1986.[8] Hospital inpatient surveys have been conducted biennially since 2005.[9] The objectives of the hospital inpatient survey was to determine the prevalence of antimicrobial resistance in clinical isolates of *S. aureus* throughout Australia in hospital inpatients admitted for 48 hours or more and to describe the molecular epidemiology of the MRSA isolates.

The findings of the 2011 AGAR hospital inpatients survey are presented in this report.

Methods

Twenty-nine laboratories from all states and territories participated in the 2011 *S. aureus* AGAR survey. In the Northern Territory and the Australian Capital Territory only 1 laboratory participated in each region and in Tasmania only 2 laboratories participated. To ensure institutional anonymity data were combined as follows: New South Wales with the Australian Capital Territory, Victoria with Tasmania, and Queensland with the Northern Territory.

From 1 July to 30 November 2011 each laboratory collected up to 100 consecutive *S. aureus* isolates from hospital inpatients (hospital stay greater than 48 hours at the time of specimen collection). Only 1 isolate per patient was tested. Each *S. aureus* isolate was judged to come from a potentially infected

site. Each hospital laboratory only collected from one institution. The three private laboratories collected from the multiple institutions that they serviced.

Susceptibility methodology

All isolates were tested using the Vitek2® antimicrobial susceptibility card (AST-P612). All isolates with a penicillin minimum inhibitory concentration of ≤0.125 mg/L were screened for the presence of ß-lactamase using nitrocefin discs. To detect inducible clindamycin resistance a double disc diffusion test (D-test) was performed on all erythromycin resistant and clindamycin intermediate or susceptible *S. aureus* isolates. Clinical and Laboratory Standards Institute breakpoints[10] were utilised for all antimicrobials excluding fusidic acid (http://www.eucast.org/clinical_breakpoints/). Isolates with an MIC in the intermediate resistance category have been called resistant in this report.

Epidemiological typing of methicillin-resistant *Staphylococcus aureus*

Of the 713 MRSA identified, 703 (98.6%) were referred to the Australian Collaborating Centre for *Enterococcus* and *Staphylococcus* Species (ACCESS) Typing and Research for epidemiological typing.

Electrophoresis of chromosomal DNA using a contour-clamped homogeneous electric field DRIII System (Bio-Rad Laboratories Pty Ltd) was performed as previously described[11] on all MRSA isolates. Multilocus sequence typing (MLST) and SCC*mec* typing was performed as previously described[12–14] on selected MRSA isolates.

PCR for the detection of Panton–Valentine leucocidin (PVL) determinants was performed as previously described[15] on all MRSA isolates.

Methicillin-resistant *Staphylococcus aureus* nomenclature

MRSA clones were defined by the combination of the MLST and the SCC*mec* type.[16] Clones were reported with their ST and SCC*mec* type followed by their colloquial name in parenthesis; e.g. ST22-IV [2B] (EMRSA-15). Clones were classified into 2 groups on the basis of previously published evidence; those implicated in healthcare-associated infection (HA-MRSA) and those implicated in community-associated infection (CA-MRSA).

Clones that diverged at no more than one of the 7 MLST loci were considered to belong to the same clonal complex. Double locus variants were included in the same clonal complex if the linking single locus variant was present in the MLST database (http://www.mlst.net/).

Statistical analysis

Differences between proportions were tested using a Chi-square test with alpha set at 5% and Fisher's exact test for 95% confidence limits (GraphPad® Prism Software). Relative risk and 95% confidence intervals were calculated using VassarStats (http://vassarstats.net).

Results

There were 2,357 isolates included in the survey (Table 1). Skin and soft tissue infection specimens contributed the majority of isolates (70.5%) followed by respiratory specimens (17.1%). Blood culture isolates contributed 6.5% of the total. Significantly ($P<0.0001$) more isolates caused non-invasive (91.3%) than invasive (8.7%) infections (Table 2).

Table 1: *Staphylococcus aureus* isolates, Australia, 2011, by region

Region	Number of institutions	Number of isolates	Per cent of total
NSW/ACT	8	639	27.1
Qld/NT	7	591	25.1
SA	3	254	10.8
Vic/Tas	7	541	22.9
WA	4	332	14.1
Total	29	2,357	100.0

Table 2: Site of *Staphylococcus aureus* isolates, Australia, 2011

Specimen site	Number of isolates	Per cent of total	95%CI
Skin and soft tissue	1,661	70.5	68.6–72.3
Respiratory	404	17.1	15.6–18.7
Blood	153	6.5	5.5–7.6
Urine	88	3.7	3.0–4.6
Sterile body cavity	49	2.1	1.5–2.7
Cerebrospinal fluid	2	0.1	0.01–0.3
Total	2,357	100.0	
Invasive*	204	8.7	7.5–9.9
Non-invasive	2,153	91.3	90.1–92.4

* Blood/cerebrospinal fluid/sterile body cavity

Table 3: Proportion of *Staphylococcus aureus* that were methicillin-resistant, Australia, 2011, by region and source

Region	All isolates			Invasive isolates*			Non-invasive isolates		
	n/N	%	95%CI	n/N	%	95%CI	n/N	%	95%CI
NSW/ACT	235/639	36.8	33.1–40.6	29/65	44.6	33.2–56.7	206/574	35.9	32.1–39.9
Qld/NT	180/591	30.5	26.9–34.3	11/41	26.8	15.7–41.9	169/550	30.7	27.0–34.7
SA	55/254	21.7	17.0–27.1	10/28	35.7	20.7–54.2	45/226	19.9	15.2–25.6
Vic/Tas	177/541	32.7	28.9–36.8	9/42	21.4	11.7–35.9	168/499	33.7	29.7–37.9
WA	66/332	19.9	15.9–24.5	4/28	14.3	5.7–31.5	62/304	20.4	16.2–25.3
Aus	713/2,357	30.3	28.4–32.1	63/204	30.9	24.9–37.5	650/2,153	30.2	28.3–32.2

* Blood/cerebrospinal fluid/sterile body cavity

Methicillin-resistant *Staphylococcus aureus*

The proportion of *S. aureus* isolates that were MRSA was 30.3% nationally (Table 3) with significantly different ($P<0.0001$) proportions across Australia ranging from 19.9% in Western Australia to 36.8% in New South Wales/Australian Capital Territory. The proportion of *S. aureus* isolates that were MRSA at each institution ranged from 7% to 56%. The proportion of invasive *S. aureus* that were MRSA (30.9%) was not significantly higher than for non-invasive isolates (30.2%) ($P=1$). The proportion of MRSA isolated in the 5 sites of infection was similar ($P=0.24$) with MRSA ranging from 29.0% in skin and soft tissue infections to 36.4% in urine (Table 4). MRSA was not isolated from cerebrospinal fluid specimens.

Amongst the MRSA isolates, resistance to the non-ß-lactam antimicrobials was common except for fusidic acid, rifampicin, high-level resistance to mupirocin and daptomycin, where resistance was below 4% nationally (Table 5). Resistance was not detected for vancomycin, teicoplanin or linezolid. Resistance levels varied significantly between regions with Victoria/Tasmania having the highest proportions for the top 6 antimicrobials.

Table 4: Proportion of *Staphylococcus aureus* that were methicillin-resistant, by specimen type

Site of infection	All Isolates		
	n/N	%	95%CI
Skin and soft tissue	482/1,661	29.0	26.8–31.3
Respiratory	136/404	33.7	29.1–38.5
Blood/cerebrospinal fluid	46/155	29.7	22.6–37.5
Urine	32/88	36.4	26.4–46.7
Sterile body cavity	17/49	34.7	17.0–49.6

Table 5: Number and proportion of methicillin-resistant *Staphylococcus aureus* isolates resistant to the non-ß-lactam antimicrobials, Australia, 2011, by region

Drug	NSW/ACT (n=235)		Qld/NT (n=180)		SA (n=55)		Vic/Tas (n=177)		WA (n=66)		Aus (n=713)		Differences across regions	
	n	%	n	%	n	%	n	%	n	%	n	%	X^2	*P*
Erythromycin	164	69.8	103	57.2	28	50.9	131	74.0	30	45.5	456	64.0	28.63	<0.0001
Clindamycin*	89	37.9	43	23.9	10	18.2	68	38.4	2	3.0	212	29.7	42.82	<0.0001
Tetracycline	91	38.7	59	32.8	12	21.8	76	42.9	1	1.5	239	33.5	43.66	<0.0001
Co-trimoxazole	87	37.0	50	27.8	11	20.0	69	39.0	2	3.0	219	30.7	37.54	<0.0001
Ciprofloxacin	188	80.0	85	47.2	34	61.8	150	84.7	20	30.3	477	66.9	115.7	<0.0001
Gentamicin	85	36.2	58	32.2	7	12.7	66	37.3	1	1.5	217	30.4	42.07	<0.0001
Fusidic acid	5	2.1	12	6.7	1	1.8	6	3.4	2	3.0	26	3.6	6.844	0.14
Rifampicin	3	1.3	7	3.9	0	0.0	3	1.7	1	1.5	14	2.0	5.279	0.26
Mupirocin†	4	1.7	5	2.8	0	0.0	0	0.0	0	0.0	9	1.3	7.492	0.11
Daptomycin	0	0.0	2	1.1	0	0.0	0	0.0	0	0.0	2	0.3	5.939	0.20

* Constitutive resistance

† High-level resistance

Methicillin-susceptible *Staphylococcus aureus*

Resistance to non-ß-lactams amongst MSSA was rare apart from resistance to erythromycin (13.2% nationally) (Table 6). Resistance was not detected for vancomycin, teicoplanin or linezolid. Resistance levels between regions varied significantly for penicillin and high-level mupirocin. South Australia had the highest rate of resistance for penicillin and Queensland/Northern Territory was highest for high-level mupirocin. Multi-resistance was uncommon in MSSA (36/1,644 2.2%).

Inducible clinidamycin resistance

Overall, 348 of the 2,357 isolates (14.8%) were erythromycin resistant and clindamycin intermediate/susceptible *S. aureus* isolates. Of these, 306 (87.9%) were D-test positive indicating inducible clindamycin resistance. For MRSA the number that were D-test positive was 203/224 (90.6%) and for MSSA 103/124 (83.1%).

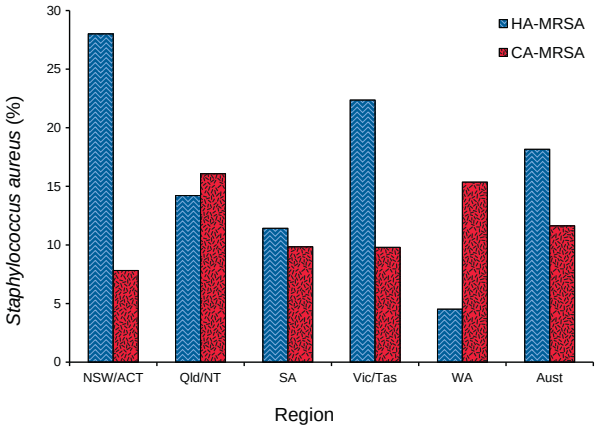
Molecular typing

Based on molecular typing, of the 703 MRSA referred to ACCESS Typing and Research, 428 (60.9%) and 275 (39.1%) were classified as HA-MRSA and CA-MRSA strains respectively.

Healthcare-associated methicillin-resistant *Staphylococcus aureus*

Throughout Australia the percentage of *S. aureus* characterised as HA-MRSA was 18.2% ranging from 4.5% in Western Australia to 28.0% in the New South Wales/Australian Capital Territory region (Figure).

Figure: Percentage of *Staphylococcus aureus* characterised as HA-MRSA and CA-MRSA strains, by region



Four HA-MRSA clones were identified: ST22-IV [2B] (EMRSA-15) (49.5% of HA-MRSA); ST239-III [3A] (Aus-2/3 EMRSA) (49.3%); 3 isolates of ST5-II [2A] (New York Japan MRSA/USA100) and 2 isolates of ST36-II [2A] (EMRSA-16/USA200).

ST22-IV [2B] (EMRSA-15) has become the predominant HA-MRSA clone in Australia accounting for 30.2% of MRSA ranging from 15.6% in Queensland/Northern Territory to 40.2% in

Table 6: Number and proportion of methicillin-susceptible *Staphylococcus aureus* isolates resistant to the non-ß-lactam antimicrobials, Australia, 2011, by state or territory

	NSW/ACT (n=404)		Qld/NT (n=411)		SA (n=199)		Vic./Tas. (n=364)		WA (n=266)		Aus (n=1,644)		Differences across regions	
Drug	n	%	n	%	n	%	n	%	n	%	n	%	X^2	*P*
Penicillin	346	85.6	355	86.4	179	89.9	321	88.2	212	79.7	1,413	85.9	12.8	0.01
Erythromycin	49	12.1	64	15.6	25	12.6	52	14.3	27	10.2	217	13.2	5.0	0.29
Clindamycin*	10	2.5	8	1.9	3	1.5	9	2.5	7	2.6	37	2.3	1.0	0.91
Tetracycline	13	3.2	9	2.2	2	1.0	13	3.6	9	3.4	46	2.8	4.3	0.37
Co-trimoxazole	9	2.2	8	1.9	3	1.5	8	2.2	5	1.9	33	2.0	0.5	0.98
Ciprofloxacin	15	3.7	12	2.9	5	2.5	15	4.1	8	3.0	55	3.3	1.6	0.81
Gentamicin	5	1.2	7	1.7	1	0.5	3	0.8	2	0.8	18	1.1	1.1	0.29
Fusidic Acid	11	2.7	24	5.8	8	4.0	3	0.8	9	3.4	55	3.3	1.8	0.18
Rifampicin	0	0.0	0	0.0	1	0.5	0	0.0	0	0.0	1	0.1	7.3	0.12
Mupirocin†	3	0.7	20	4.9	0	0.0	0	0.0	3	1.1	26	1.6	4.2	0.04
Daptomycin	1	0.2	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	3.1	0.55

* Constitutive resistance

† High-level resistance

New South Wales/Australian Capital Territory (Table 7). ST22-IV [2B] are typically PVL negative, and 99% and 66% of these were resistant to ciprofloxacin and erythromycin respectively.

ST239-III [3A] (Aus-2/3 EMRSA) accounted for 30.0% of MRSA ranging from 0% in Western Australia to 36.2% in Victoria/Tasmania (Table 7). PVL negative ST239-III [3A] (Aus -2/3 EMRSA was typically resistant to tetracycline (100%), erythromycin (97%), ciprofloxacin (96%), cotrimoxazole (94%), and gentamicin (94%).

Community-associated-methicillin-resistant *Staphylococcus aureus*

Throughout Australia the percentage of *S. aureus* characterised as CA-MRSA was 11.7% ranging from 7.8% in New South Wales/Australian Capital Territory to 16.1% in Queensland/Northern Territory. Thirty-two CA-MRSA clones were identified by pulsed field gel electrophoresis, corresponding to 25 MLST/SCC*mec* clones (Table 8). Overall, 79.6% of CA-MRSA were classified into 6 clones.

ST1-IV [2B] (WA1) accounted for 9.0% of MRSA ranging from 3.5% in Victoria/Tasmania to 31.8% in Western Australia (Table 9). Typically PVL negative, 95.2% of isolates were non-multi-resistant. Eighty- nine per cent of isolates were resistant to the ß-lactam antimicrobials only or additionally to erythromycin (16%) or fusidic acid only (6%), or to both (8%). Two isolates were resistant to mupirocin, gentamicin and erythromycin, and a single isolate resistant to mupirocin, gentamicin and fusidic acid.

ST93-IV [2B] (Qld CA-MRSA) accounted for 7.3% of MRSA ranging from 1.7% in Victoria/Tasmania to 14.5% Queensland/Northern Territory (Table 9). PVL positive ST93-IV (Qld CA-MRSA) were typically resistant to the ß-lactams only (41/51) or additionally to erythromycin (10/51).

ST5-IV [2B] (WA3) and ST78-IV [2B] (WA2) although predominantly isolated in Western Australia (9.1% and 18.2% of MRSA respectively), were also isolated in most regions of Australia. ST45-V [5C2] (WA84) and ST30-IV [2B] (SWP MRSA) were predominantly isolated in Victoria/Tasmania (11.5% of MRSA) and Queensland/Northern Territory (8.4% of MRSA) respectively.

Overall, 92.7% of CA-MRSA were non-multi-resistant and 50.9% of isolates were resistant to ß-lactam antimicrobials only. However, 20 isolates (7.3% of CA-MRSA) were multiresistant including 3 PVL positive ST772-V [5C2] (Bengal Bay MRSA) isolates, which in addition to ß-lactam antimicrobials were resistant to gentamicin, erythromycin, ciprofloxacin and cotrimoxazole. One CA-MRSA (ST7-V [5C2]) isolate was resistant to 5 non-ß-lactam antimicrobials; gentamicin, erythromycin, ciprofloxacin, cotrimoxazole and tetracycline.

Panton–Valentine leucocidin

In 2011, 13.5% of MRSA were PVL positive. Eighty-seven (31.6%) CA-MRSA (Table 8) and 8 ST22-IV [2B] were PVL positive. PVL-positive CA-MRSA clones included the international clones ST8-IV [2B] (USA300) and ST772-V [5C2] (Bengal Bay MRSA).

Discussion

This survey demonstrates that MRSA remains a significant burden in Australian hospitals. For 2011, the national proportion of *S. aureus* that were MRSA was 30.3%, which was not significantly different to the proportions seen in past AGAR hospital inpatient surveys (X^2 for trend 0.7527, $P=0.3856$).[9] Differences between regions in the 2011 survey were significant with South Australia and Western Australia having a lower proportion than other regions. Although the proportion of MRSA amongst the different specimen types was similar, the high proportion of MRSA in invasive isolates is of concern as MRSA bacteraemia is associated with increased mortality compared with MSSA.[1–4]

More than 60% of the MRSA in the 2011 study were resistant to erythromycin and ciprofloxacin, and more than 30% were resistant to tetracycline, co-trimoxazole and gentamicin. Regional differences were again common due to different MRSA clones circulating in Australia. Erythromycin and ciprofloxacin resistance was more widespread in

Table 7: Proportion of methicillin-resistant *Staphylococcus aureus* isolates characterised as ST22-IV [2B] (EMRSA-15) and ST239-III [3A], Australia, 2011, by state or territory

	NSW/ACT	Qld/NT	SA	Vic/Tas	WA	Aust
ST22-IV [2B]	40.2%	15.6%	34.5%	33.3%	22.7%	30.2%
ST239-III [3A]	35.8%	31.3%	18.2%	36.2%	0%	30.0%

Table 8: Proportion of community-associated-methicillin-resistant *Staphylococcus aureus*, Australia, 2011, by clone and Panton–Valentine leucocidin carriage

Clone	Clonal complex	Alternative name	n	%	PVL Pos
ST1-IV [2B]	1	WA-1	63	22.9	3 (4.8%)
ST93-IV [2B]	Singleton	Queensland MRSA	51	18.6	51 (100%)
ST5-IV [2B]	5	WA-3	34	12.4	2 (5.9%)
ST78-IV [2B]	88	WA-2	25	9.1	0
ST45-V [5C2]	45	WA-84 (Vic CA-MRSA)	25	9.1	0
ST30-IV [2B]	30	SWP MRSA	21	7.6	18 (85.7%)
ST73-IV [2B]	5	WA-65	10	3.6	0
ST8-IV [2B]	8	USA300	8	2.9	8 (100%)
ST772-V [5C2]	1	Bengal Bay	3	1.1	3 (100%)
ST835-IV [2B]	5	WA-48	3	1.1	0
ST45-V [5C2]	45	WA-4	3	1.1	0
ST45-IV [2B]	45	WA-75	3	1.1	0
ST1-V [5C2]	1		2	0.7	0
ST5-V [5C2]	5	WA-90	2	0.7	0
ST59-IV [2B]	59	WA-15	2	0.7	0
ST72-IV [2B]	72	WA-44	2	0.7	0
ST75-IV [2B]	75	WA-8	2	0.7	0
ST45-V [5C2]	45		2	0.7	0
ST188-IV [2B]	1	WA-38	1	0.4	0
ST573-V [5C2]	1	WA-10	1	0.4	1 (100%)
ST5-V [5C2]	5	WA-14	1	0.4	0
ST575-IV [2B]	5	WA-25	1	0.4	0
ST5-V [5C2]	5	WA-35	1	0.4	0
ST5-V [5C2]	5	WA-108	1	0.4	0
ST5-V [5C2]	5	WA-109	1	0.4	0
ST1756-V [5C2]	5		1	0.4	0
ST7-V [5C2]	7		1	0.4	0
ST45-IV [2B]	45	WA-23	1	0.4	0
ST1970-V [5C2]	45	WA-106	1	0.4	0
ST59-IV [2B]	59	WA-55	1	0.4	1 (100%)
ST1304-IV [2B]	75	WA-72	1	0.4	0
ST953-IV [2B]	97	WA-54	1	0.4	0
Total			275		87 (31.6%)

Percentage figures in parenthesis relate to community-associated-methicillin-resistant *Staphylococcus aureus* isolates.
PVLPanton–Valentine leucocidin.

Table 9: Proportion of methicillin-resistant *Staphylococcus aureus* characterised as ST1-IV [2B] (WA1) and ST93-IV [2B], Australia, 2011, by region

	NSW/ACT	Qld/NT	SA	Vic/Tas	WA	Aus
ST1-IV [2B]	4.8%	11.2%	9.1%	3.5%	31.8%	9.0%
ST93-IV [2B]	5.7%	14.5%	9.1%	1.7%	6.1%	7.3%

this survey with at least 30% of MRSA with this profile in any region. Erythromycin and ciprofloxacin resistance is common in ST239-III [3A] (Aus 2/3 EMRSA) isolates but is also characteristic of ST22-IV [2B] (EMRSA-15). ST22-IV [2B] (EMRSA-15) is a frequently isolated HA-MRSA in Australia and was found in all regions. Resistance was not detected for vancomycin, teicoplanin or linezolid. Compared with previous AGAR hospital inpatient surveys, the proportion of MRSA resistant to erythromycin, clindamycin, tetracycline, co-trimoxazole, ciprofloxacin, gentamicin and rifampicin has decreased nationally with significant decreases in New South Wales/Australian Capital Territory and Victoria/Tasmania. The proportion of *S. aureus* that are MRSA has remained stable in all regions and nationally. This finding is due to non-multi-resistant CA-MRSA increasing in Australian hospitals at the expense of the long-established multi-resistant ST239-III [3A].

Given that reports of outbreaks of CA-MRSA in Australian hospitals are thought to be rare[17,18] it is likely that many infections in hospital inpatients are caused by the patients' own colonising strains acquired prior to admission. Community clones such as PVL negative ST1-IV [2B] (WA1) and PVL positive ST93-IV [2B] (Qld CA-MRSA) are well established in Australia,[19,20] and therefore it is important to monitor antimicrobial resistance patterns to MRSA over time as this information will guide therapeutic practices.

Acknowledgements

This study was primarily funded by a grant from the Australian Government Department of Health.

We gratefully acknowledge Hui-leen Tan, Lynne Wilson, Yung Lee, Denise Daley, Tam Le and Ka Yan Wong from the Australian Collaborating Centre for Enterococcus and Staphylococcus Species (ACCESS) Typing and Research; Frances O'Brien from the School of Biomedical Sciences, Curtin University; and the Western Australia Genome Resource Centre, Department of Clinical Immunology and Biochemical Genetics, Royal Perth Hospital for the molecular typing of MRSA.

Members of the AGAR in 2011 were:

Australian Capital Territory

Peter Collignon and Susan Bradbury, The Canberra Hospital

New South Wales

Tom Gottlieb and Graham Robertson, Concord Hospital

Miriam Paul and Richard Jones, Douglass Hanly Moir Pathology

James Branley and Donna Barbaro, Nepean Hospital

George Kotsiou and Peter Huntington, Royal North Shore Hospital

Colin MacLeod and Bradley Watson, Royal Prince Alfred Hospital

Iain Gosbell and Annabelle LeCordier, South West Area Pathology Service

David Mitchell and Lee Thomas, Westmead Hospital

Northern Territory

Jann Hennessy and Rob Baird, Royal Darwin Hospital

Queensland

Enzo Binotto and Bronwyn Thomsett, Pathology Queensland Cairns Base Hospital

Graeme Nimmo and Narelle George, Pathology Queensland Central Laboratory

Petra Derrington and Sharon Dal-Cin, Pathology Queensland Gold Coast Hospital

Chris Coulter and Sonali Coulter, Pathology Queensland Prince Charles Hospital

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Jenny Robson and Georgia Peachey, Sullivan Nicolaides Pathology

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Morgyn Warner and Fleur Manno, SA Pathology, Royal Adelaide Hospital

John Turnidge and Jan Bell, SA Pathology, Women's and Children's Hospital

Tasmania

Mhisti Rele and Kathy Wilcox, Launceston General Hospital

Louise Cooley and Rob Peterson, Royal Hobart Hospital

Victoria

Denis Spelman and Michael Huysmans, Alfred Hospital

Benjamin Howden and Peter Ward, Austin Hospital

Tony Korman and Despina Kotsanas, Monash Hospital Medical Centre

Sue Garland and Gena Gonis, Royal Women's Hospital

Mary Jo Waters and Linda Joyce, St Vincent's Hospital

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