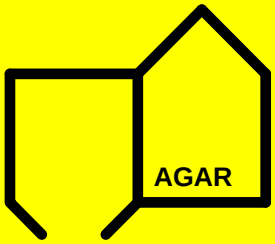

The Australian Group on Antimicrobial Resistance
http://antimicrobial-resistance.com

Staphylococcus aureus Survey
2009 Antimicrobial Susceptibility Report

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Antimicrobial Susceptibility Report of *Staphylococcus aureus* Isolates from the Australian Group on Antimicrobial Resistance (AGAR)

2009 Surveillance Report

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Executive Summary

The Australian Group on Antimicrobial Resistance (AGAR) performs regular multicentre period-prevalence studies to monitor changes in antimicrobial resistance. In 2009, 30 laboratories from each state and mainland territory of Australia participated in national surveillance of *Staphylococcus aureus* resistance. The survey included only unique isolates from clinical specimens collected 48 hours or more after hospital admission. This is the third hospital-acquired infections AGAR survey.

Regional prevalence of MRSA varied from 27.3% in South Australia to 41.4% in New South Wales/Australian Capital Territory. The overall prevalence of MRSA in inpatients was 33.6%. Resistance to erythromycin (70.9%), clindamycin (constitutive resistance) (35.0%), tetracycline (45.1%), cotrimoxazole (41.6%), ciprofloxacin (71.2%) and gentamicin (43.7%) was common in MRSA and varied considerably between regions. Resistance levels were below 4% for fusidic acid, rifampicin, high-level mupirocin and daptomycin. Resistance was not detected for vancomycin, teicoplanin, quinupristin-dalfopristin or linezolid. Regional variation in resistance is due to the differential distribution of MRSA clones between regions and particularly of the major health-care associated MRSA (HA-MRSA) clone, ST239-III (Aus 2/3 EMRSA) which is predominant in the eastern states and is resistant to multiple non-β-lactam antimicrobials. Resistance to non-β-lactam antimicrobials with the exception of erythromycin (12.0%) was uncommon in MSSA and no resistance was detected for vancomycin, teicoplanin, quinupristin-dalfopristin, daptomycin or linezolid.

The national proportion of *S. aureus* that are MRSA was similar in this survey to the two previous inpatients hospital surveys conducted by AGAR in 2005 and 2007. Yet, during the time frame, resistance to many antimicrobials, in particular tetracycline, co-trimoxazole and gentamicin, has significantly decreased. This suggests that non-multiresistant community-associated MRSA (CA-MRSA) clones are becoming more common in the hospital setting and may be replacing the long-established multiresistant clones such as ST239-III. Given hospital outbreaks of CA-MRSA in Australia are thought to be extremely rare it is most likely that patients colonised at admission with CA-MRSA have become infected with the colonising strain during their hospital stay.

There is ample and consistent evidence that infection control strategies based on screening, isolation and decolonisation are successful and highly cost effective. These strategies offer the best defence in preventing healthcare-acquired infections of colonising CA-MRSA in Australian hospitals.

1 Introduction

Staphylococcus aureus is a major pathogen both in the hospital environment and the wider community. It causes a wide variety of infections in man that are associated with considerable morbidity and significant mortality. Manifestations of *S. aureus* infection range from skin and soft tissue infections such as impetigo and furunculosis to invasive infections such as osteomyelitis, necrotising pneumonia and infective endocarditis. Invasive infections are frequently associated with life threatening bacteraemia infections. A study of 1,865 cases of *S. aureus* bacteraemia by the Australia New Zealand Cooperative on Staphylococcal Sepsis (ANZCOSS) has shown that all-cause 30-day mortality for *S. aureus* bacteraemia was 20.6%[1]. In Australia, as in most of the world, antimicrobial resistance in *S. aureus* is a major impediment to effective treatment. A subsequent ANZCOSS study of 3,430 bacteraemia cases showed that 30-day mortality varied significantly for isolates with different susceptibility patterns with mortality increasing as resistance to the number of antimicrobials increased: mortality for methicillin susceptible *S. aureus* (MSSA) was 16.5%, for non-multiresistant methicillin resistant *S. aureus* (MRSA) 19.4%, for ST22-IV-like MRSA (typically resistant to one or two non-β-lactam antimicrobials) 24.4% and for multiresistant ST239-III-like MRSA 31.7%[2]. Hospital strains are frequently resistant to methicillin and multiple other antimicrobials[3].

Strategies exist to combat MRSA causing healthcare associated (HA) infections such as staff and patient screening, contact precautions, patient isolation and decolonisation of positive patients[4]. Although infection control strategies are expensive, the cost per MRSA infection is often more expensive: estimated to be €2, 730 in one Spanish hospital[5] and US$9,275 in a French intensive care unit (ICU)[6]. Another effective option available to hospitals is to restrict the use of antimicrobials. A 70% reduction in cephalosporin usage resulted in a 30% reduction in MRSA cases in an Italian ICU despite being offset by increased fluoroquinolone use[7]. The United States of America successfully reduced the HA-MRSA infection rate from 1.4 to 0.6 episodes per 1,000 patient days after fluoroquinolone use was reduced by 34%[8]. An Australian cardiac surgical unit reported no cases of HA-MRSA surgical site infection (SSI) after changing antibiotic prophylaxis protocols from cefazolin to vancomycin and rifampicin. Prior to the intervention more than 50% of the SSIs in the unit were MRSA. The estimated cost saving was AUD$576,655 over the following 12 months based on the reduction of all SSIs[9]. Limited success in reducing MRSA transmission has been achieved through enhanced hand hygiene[10,11]. The Australian Group for Antimicrobial resistance (AGAR) has performed antimicrobial resistance period-prevalence surveys in Australia since 1986[12]. Presently, 30 laboratories from all states and mainland territories of Australia contribute to AGAR surveys. Hospital inpatient surveys have been conducted biennially since 2005, alternating with biennial community surveys[13]. The findings of the 2009 AGAR hospital inpatients survey are presented here and results compared to the two previous hospital inpatients surveys.

2 Methods

From the 1st July to the 30th November 2009, each laboratory collected up to 100 consecutive *S. aureus* isolates from hospital inpatients (hospital stay >48 hours at the time of specimen collection). Only one isolate per patient was tested. Each *S. aureus* isolate was judged to come from a potentially infected site. Specimens received for the purpose of gathering surveillance data were excluded. Hospital laboratories collected only from one institution. The four private laboratories collected from institutions they serviced.

2.1 Species Identification

S. aureus was identified by morphology and positive results of at least two of the following tests: slide coagulase test, tube coagulase test, appropriate growth on chromogenic agar and demonstration of deoxyribonuclease production. Additional tests such as fermentation of

mannitol, growth on mannitol-salt agar or polymerase chain reaction for the presence of the *nuc* gene may have been performed for confirmation.

2.2 Susceptibility Testing Methodology

Participating laboratories performed antimicrobial susceptibility tests using the Vitek2® AST-P579 card. Penicillin susceptible strains were tested for β-lactamase production using nitrocefin. CLSI breakpoints[14] were utilised for all antimicrobials excluding mupirocin and fusidic acid[15].

2.3 Quality Control

As all participating laboratories are NATA accredited, routine quality control testing of antimicrobial susceptibility test methods is an integral part of routine procedures. Quality control strains for this survey were ATCC strains 29212, 29213 and BAA-1026.

2.4 Statistical Analysis

The difference between proportions were tested using Chi-square test with alpha set at the 5% level and Fisher's exact test for 95% confidence limits (GraphPad® Prism Software). Relative risk and 95% confidence intervals (CI) were calculated using VassarStats (http://faculty.vassar.edu).

3 Demographics

Both public (26) and private laboratories (4) participated in the study. Participants included New South Wales (7), ACT (1), Queensland (6), Victoria (6), Tasmania (2), Northern Territory (1), South Australia (3) and Western Australia (4). There were 2,728 isolates from 30 institutions (Table 1). To ensure institutional anonymity data from NSW and ACT, from Tasmania and Victoria and from Queensland and Northern Territory have been combined.

3.1 Regional Source of Isolates

The number of participating institutions and the number of isolates collected from each region is shown in Table 1.

Table 1. Isolates by region

Region	Number of Institutions	Total	%
New South Wales (NSW) Australian Capital Territory (ACT)	8	655	24.0
Queensland (Qld) Northern Territory (NT)	7	685	25.1
South Australia (SA)	3	282	10.3
Victoria (Vic) Tasmania (Tas)	8	723	26.5
Western Australia (WA)	4	383	14.0
Total	**30**	**2,728**	**100**

3.2 Age

Over half (53.8%) of all isolates were contributed by patients 62 years and older (Table 2).

Table 2. Age of patients

Age Range (years)	n	%
0-1	184	6.7%
2-16	95	3.5%
17-40	360	13.2%
41-61	621	22.8%
62-101	1468	53.8%
Total	**2,728**	**100**

4 Specimen Source

Skin and soft tissue infection specimens contributed the majority (71.2%) of isolates followed by respiratory specimens (17.3%). Blood culture isolates contributed 6.1% of the total with significantly (*P*<0.0001) more isolates causing non-invasive (91.9%) than invasive (8.1%) infections (Table 3).

Table 3. Source of isolates

Specimen Source	n	%
Skin and Soft Tissue	1942	71.2%
Respiratory	473	17.3%
Blood	167	6.1%
Urine	93	3.4%
Sterile Body Cavity	52	1.9%
CSF	1	0.04%
Total	**2,728**	**100**
Invasive	220	8.1%
Non-Invasive	2,508	91.9%

5 Susceptibility Testing Results

5.1 Methicillin-resistant *S. aureus*, 2009

Cefoxitin was used to test for methicillin-resistance. The proportion of MRSA was 33.6% (95%CI 31.8%–35.4%) nationally (Table 4) with significantly different (*P*<0.0001) proportions across Australia ranging from 27.3% (95%CI 22.2%–32.5%) in South Australia to 41.4% (95%CI 37.7%–45.2%) in NSW/ACT. The proportion of non-invasive *S. aureus* that were MRSA (33.9%) was not significantly higher than for invasive isolates (30.0%) (*P*=0.241).

Table 4: Proportion of MRSA by region and source

	All isolates			Invasive*			Non-invasive		
Region	**n/N**	**%**	**95%CI**	**n/N**	**%**	**95%CI**	**n/N**	**%**	**95%CI**
NSW/ACT	271/655	41.4	37.7-45.2	26/65	40.0	29.0-52.1	245/590	41.5	37.6-45.6
Qld/NT	210/685	30.7	27.3-34.2	14/49	28.6	17.9-42.4	196/636	30.8	27.4-34.5
SA	77/282	27.3	22.2-32.5	3/18	16.7	5.8-39.2	74/264	28.0	23.0-33.7
Vic/Tas	250/723	34.6	31.2-38.1	14/57	24.6	15.2-37.1	236/666	35.4	31.9-39.2
WA	108/383	28.2	23.9-32.9	9/31	29.0	16.1-46.6	99/352	28.1	23.7-33.0
Aus	916/2728	33.6	31.8-35.4	66/220	30.0	24.3-36.4	850/2508	33.9	32.1-35.87

* Blood, CSF and sterile body cavity

Within regions, the proportion of MRSA in the different institutions also varied (Table 5). The difference in MRSA proportions by institution varied by 10 percentage points (PP) in WA, 25 PP in Qld/NT, 30 PP in NSW/ACT, 32 PP in SA and 45 PP in Vic/Tas.

Table 5: Proportion of MRSA by institution

Region	Lab Code	% MRSA
NSW/ACT	1	25.0
	2	50.0
	3	37.9
	4	42.0
	5	39.0
	6	49.0
	7	20.0
	8	47.0
Qld/NT	10	39.0
	11	18.0
	12	37.0
	13	16.0
	28	41.0
	29	34.1
	30	30.0
SA	14	27.0
	15	42.0
	16	9.8
Vic/Tas	18	13.1
	19	42.0
	20	32.5
	21	7.3
	22	51.0
	23	52.3
	31	34.0
	32	35.5
WA	24	24.1
	25	32.0
	26	33.0
	27	23.0
Australia		33.6

There were significant differences in the proportion of MRSA isolated in the five sources of infection (*P*=0.0002) with MRSA isolated most commonly from urinary isolates (50.5% of the time) followed by respiratory specimens at 40.2% (Table 6).

Table 6: Proportion of *S. aureus* that are MRSA by specimen type

	All isolates		
Source of Infection	**n/N**	**%**	**95%CI**
Skin and soft tissue	613/1942	31.6	29.5-33.7
Respiratory	190/473	40.2	35.9-44.7
Blood/CSF	57/168	33.9	27.2-41.4
Urine	47/93	50.5	40.6-60.5
Sterile Body Cavity	9/52	17.3	9.4-29.7

In 2009, as in past AGAR hospital isolates surveys, increasing age was a risk factor for methicillin resistance (Table 7). Inpatients 41 years and older were 1.6 times more likely (RR 1.6, 95%CI 1.4-1.9) to have an MRSA not MSSA infection compared with younger patients.

Table 7: Age by methicillin susceptibility of *S. aureus*

	MRSA			MSSA		
Age (y)	**n**	**Row %**	**Column %**	**n**	**Row %**	**Column %**
0-1	18	9.8	2.0	166	90.2	9.2
2-16	20	21.1	2.2	75	78.9	4.1
17-40	108	30.0	11.8	252	70.0	13.9
41-61	214	34.5	23.4	407	65.5	22.5
62-101	556	37.9	60.7	912	62.1	50.3
Total	916	33.6	100	1,812	66.4	100

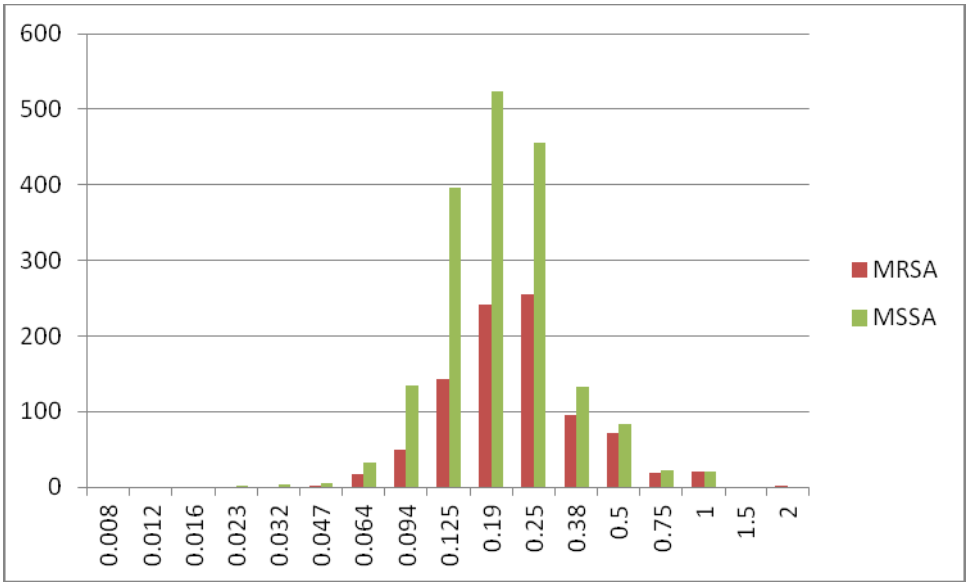
Resistance in MRSA to non-β-lactam antimicrobials varied significantly between states. Amongst the MRSA, resistance to the non-β-lactam antimicrobials was common except for fusidic acid, rifampicin, mupirocin and daptomycin where resistance was below 4% (Table 8 and Figure 1). Resistance was not detected for vancomycin, teicoplanin, quinupristin-dalfopristin or linezolid. Resistance levels varied between regions with NSW/ACT having the highest proportions for four of the top five antimicrobials for resistance. Compared with NSW/ACT, WA had lower levels of resistance by 28 to 53 PP for erythromycin (28 PP), tetracycline (52 PP), co-trimoxazole (52 PP), ciprofloxacin (53 PP) and gentamicin (52 PP). For constitutive clindamycin resistance both SA and WA had lower rates than the other states. Nearly half of MRSA (446/916, 48.7%) were multiresistant (resistant to 3 or more non-β-lactams). The proportion of MRSA that were multiresistant ranged from 11.1% in WA to 59.4% in NSW/ACT.

Table 8: MRSA: number and proportion non-susceptible

	NSW/ACT (n=271)		Qld/NT (n=210)		SA (n=77)		Vic/Tas (n=250)		WA (n=108)		Aus (n=916)		Difference across regions	
Drug	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**X^2**	**p**
Erythromycin	212	78.2	141	67.1	56	72.7	186	74.4	54	50.0	649	70.9	32.93	**<0.0001**
Clindamycin*	138	50.9	79	37.6	9	11.7	84	33.6	11	10.2	321	35.0	78.63	**<0.0001**
Tetracycline	150	55.4	105	50.0	36	46.8	119	47.6	3	2.8	413	45.1	92.39	**<0.0001**
Co-trimoxazole	147	54.2	90	42.9	28	36.4	114	45.6	2	1.9	381	41.6	90.72	**<0.0001**
Ciprofloxacin	225	83.0	127	60.5	53	68.8	215	86.0	32	29.6	652	71.2	148.1	**<0.0001**
Gentamicin	150	55.4	103	49.1	33	42.9	111	44.4	3	2.8	400	43.7	90.99	**<0.0001**
Fusidic Acid	4	1.5	11	5.2	3	3.9	7	2.8	3	2.8	28	3.1	5.924	0.2049
Rifampicin	2	0.7	16	7.6	0	0.0	10	4.0	2	1.9	30	3.3	19.21	**0.0007**
Mupirocin†	2	0.7	2	1.0	0	0.0	1	0.4	1	0.9	6	0.7	0.6890	0.9527

* Constitutive resistance
† High-level resistance

Figure 1: Daptomycin minimum inhibitory concentration (susceptible MIC ≤1mg/L)



5.2 Trend data: methicillin-resistant *S. aureus*, 2005 - 2009

The national proportion of MRSA in 2009 was 33.6% which was not significantly different from the proportions identified in 2005 or 2007 (31.9% and 32.9% respectively, *P*=0.1823) and the proportions were stable across all regions (Table 9).

Table 9: Proportion (%) of *S. aureus* that are MRSA, 2005 to 2009

	NSW/ACT	QLD/NT	SA	Vic/Tas	WA	Aus
2005	43.4	26.7	24.7	31.6	22.5	31.9
2007	41.3	31.0	27.2	33.3	19.0	32.9
2009	41.4	30.7	27.3	34.6	28.2	33.6
X^2 for trend	0.6683	2.565	0.5669	1.419	3.452	1.779
p	0.4136	0.1093	0.4515	0.2336	0.0632	0.1823

Some significant improvements in resistance to the non-β-lactams have occurred since the first AGAR hospital inpatients survey in 2005 (Table 10). Nationally, resistance has decreased for erythromycin (80.0% in 2005 to 70.9% in 2009, *P*<0.0001), clindamycin (44.2% to 35.0%, *P*<0.0001), tetracycline (59.4% to 45.1%, *P*<0.0001), co-trimoxazole (60.3% to 41.6%, *P*<0.0001), ciprofloxacin (76.8% to 71.2%, *P*=0.0052), gentamicin (60.6% to 43.7%, *P*<0.0001) and rifampicin (5.2% to 3.3%, *P*=0.048) while resistance has remained stable for fusidic acid (4.3% to 3.1%, *P*=0.1621) and high-level mupirocin (0.6% to 0.7%, *P*=0.979). The national decreases in resistance may primarily be the result of significant regional decreases in NSW/ACT and Vic/Tas particularly for erythromycin, tetracycline, co-trimoxazole and gentamicin. Significant falls in rifampicin resistance occurred in Qld/NT and SA.

Table 10: Proportion of MRSA resistant to the non-β-lactams, 2005 to 2009

	NSW/ACT	QLD/NT	SA	Vic/Tas	WA	Aus
Erythromycin						
2005	86.5%	72.9%	60.7%	90.4%	57.5%	80.0%
2007	80.5%	75.0%	70.4%	86.4%	41.7%	77.2%
2009	78.2%	67.1%	72.7%	74.4%	50.0%	70.9%
X^2 for trend	7.642	1.729	2.695	22.37	0.8087	21.33
p	**0.0057**	0.1886	0.1006	**<0.0001**	0.3685	**<0.0001**
Clindamycin						
2005	68.7%	41.8%	8.3%	41.2%	10.0%	44.2%
2007	49.5%	44.3%	11.3%	30.5%	8.3%	37.9%
2009	50.9%	37.6%	11.7%	33.6%	10.2%	35.0%
X^2 for trend	17.95	0.7983	0.4976	2.891	0.0052	15.52
p	**<0.0001**	0.3729	0.4805	0.0891	0.9424	**<0.0001**
Tetracycline						
2005	69.0%	44.6%	35.7%	83.0%	6.2%	59.4%
2007	62.8%	49.1%	42.3%	67.1%	3.3%	54.9%
2009	55.4%	50.0%	46.8%	47.6%	2.8%	45.1%
X^2 for trend	12.3	1.068	20.29	66.23	1.369	37.73
p	**0.0005**	0.3014	0.1543	**<0.0001**	0.242	**<0.0001**
Co-trimoxazole						
2005	70.1%	51.4%	32.1%	80.8%	7.5%	60.3%
2007	62.2%	56.6%	40.8%	65.3%	3.3%	55.9%
2009	54.2%	42.9%	36.4%	45.6%	1.9%	41.6%
X^2 for trend	16.76	3.211	0.3364	63.93	3.678	64.87
p	**<0.0001**	0.0732	0.5619	**<0.0001**	0.0551	**<0.0001**
Ciprofloxacin						
2005	89.4%	62.7%	54.8%	88.2%	42.5%	76.8%
2007	85.9%	67.0%	69.0%	88.7%	26.7%	76.7%
2009	83.0%	60.5%	68.8%	86.0%	29.6%	71.2%
X^2 for trend	5.391	0.2726	3.54	0.5581	3.098	7.804
p	**0.0202**	0.6016	0.0599	0.455	0.0784	**0.0052**
Gentamicin						
2005	69.8%	55.4%	33.3%	79.5%	5.0%	60.6%
2007	62.5%	57.1%	38.0%	64.8%	5.0%	55.5%
2009	55.4%	49.1%	42.9%	44.4%	2.8%	43.7%
X^2 for trend	14.03	1.695	1.548	62.91	0.6337	52.76
p	**0.0002**	0.1929	0.2134	**<0.0001**	0.426	**<0.0001**
Fusidic acid						
2005	3.6%	5.6%	11.9%	1.7%	3.7%	4.3%
2007	3.3%	6.6%	8.5%	1.4%	5.0%	4.2%
2009	1.5%	5.2%	3.9%	2.8%	2.8%	3.1%
X^2 for trend	2.383	0.0406	3.416	0.6994	0.1597	1.955
p	0.1226	0.8402	0.0646	0.403	0.6894	0.1621
Rifampicin						
2005	1.4%	17.5%	6.0%	2.6%	1.2%	5.2%
2007	0.9%	15.1%	4.2%	2.4%	0.0%	4.8%
2009	0.7%	7.6%	0.0%	4.0%	1.9%	3.3%
X^2 for trend	0.6873	8.492	4.23	0.8033	0.198	3.911
p	0.4071	**0.0036**	**0.0397**	0.3701	0.6564	**0.048**
High-level mupirocin						
2005	0.8%	0.0%	1.2%	0.4%	1.3%	0.6%
2007	0.3%	2.8%	0.0%	1.9%	1.7%	1.3%
2009	0.7%	1.0%	0.0%	0.4%	0.9%	0.7%
X^2 for trend	0.05434	0.479	1.363	0.008	0.0519	0.0007
p	0.8157	0.4889	0.243	0.9284	0.8197	0.979

5.3 Methicillin-susceptible *S. aureus*, 2009

The majority (66.4%) of *S. aureus* isolates were MSSA. Resistance to non-β-lactam antimicrobials with the exception of erythromycin (12.0%) was uncommon in MSSA (Table 11). No resistance was detected for vancomycin, teicoplanin, quinupristin-dalfopristin, daptomycin or linezolid.

Resistance levels between regions varied significantly for clindamycin, tetracycline, co-trimoxazole, gentamicin and high-level mupirocin. NSW/ACT had the highest rates of resistance for these antimicrobials with the exception of high-level mupirocin which was highest in Qld/NT.

Table 11: MSSA: number and proportion non-susceptible

	NSW/ACT (n=384)		Qld/NT (n=475)		SA (n=205)		Vic/Tas (n=473)		WA (n=275)		Aus (n=1812)		Difference across regions	
Drug	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	X^2	**p**
Penicillin	330	85.9	411	86.5	180	87.8	421	89.0	230	83.6	1572	86.8	4.856	0.3024
Erythromycin	50	13.0	68	14.3	18	8.8	52	11.0	30	10.9	218	12.0	5.553	0.2351
Clindamycin*	12	3.1	5	1.1	2	1.0	5	1.1	1	0.4	25	1.4	11.66	**0.0200**
Tetracycline	22	5.7	4	0.8	8	3.9	8	1.7	9	3.3	51	2.8	21.96	**0.0002**
Co-trimoxazole	14	3.6	5	1.1	5	2.4	11	2.3	0	0.0	35	1.9	13.98	**0.0074**
Ciprofloxacin	12	3.1	4	0.8	4	2.0	10	2.1	10	3.6	40	2.2	8.282	0.0818
Gentamicin	10	2.6	2	0.4	1	0.5	9	1.9	0	0.0	22	1.2	14.83	**0.0051**
Fusidic Acid	11	2.9	19	4.0	9	4.4	16	3.4	12	4.4	67	3.7	1.621	0.8050
Rifampicin	1	0.3	1	0.2	0	0.0	1	0.2	0	0.0	3	0.2	1.123	0.8906
Mupirocin†	0	0.0	7	1.5	0	0.0	3	0.6	1	0.4	11	0.6	9.763	**0.0446**

* Constitutive resistance
† High-level resistance

5.4 Trend data: methicillin-susceptible *S. aureus*, 2005 - 2009

Nationally, there were no significant changes in the trends for resistance for MSSA in any of the antimicrobials tested. In Vic/Tas, there was a significant increase in resistance in penicillin by 7 PP between 2005 and 2009 (82.0% and 89.0% respectively, *P*=0.0022). Changes occurred in resistance patterns for tetracycline with a 3 PP decrease in resistance from 2005 and 2009 in Vic/Tas (5.1% and 1.7% respectively, *P*=0.0051) and an increase by 3 PP for tetracycline resistance in WA (0.0% to 3.3% respectively, *P*=0.0045) (data not shown).

6 Discussion

This survey demonstrates that MRSA remains a significant burden in Australian hospitals. However, the trend data generated may have some limitations. The mix of laboratories has altered over time with one fewer New South Wales and one fewer South Australian laboratory participating in the 2009 survey compared with the 2005 survey. However, an analysis of results of the 28 laboratories that participated in all surveys gave similar results with no changes to the statistical significance of the antimicrobial resistance trends in MRSA or MSSA either regionally or nationally.

For 2009 the national proportion of *S. aureus* that were MRSA was 33.6% which was similar to the proportion in 2005 (31.9%, *P*=0.19) and 2007 (32.9%, *P*=0.18). Yet, differences between regions were significant with NSW/ACT having a higher proportion than other regions. Differences between

institutions within a region may be explained by the mean age of the different populations serviced by the institution (one institution in Victoria and one in South Australia are children's hospitals) and by differences in infection control protocols. Approximately a third of blood/CSF and skin and soft tissue *S. aureus* infections were methicillin resistant. The proportion for respiratory and urine specimens was higher with half of all *S. aureus* isolated from urines having methicillin resistance. The overall proportion of MRSA in invasive (mainly bacteraemia) isolates was similar to that of non-invasive isolates (30.0% and 33.9% respectively, *P*=0.2724). The high proportion of MRSA in invasive isolates is of concern as MRSA bacteraemia is associated with increased mortality compared with MSSA[16,17]. Direct comparison with prevalence in other countries is difficult due to methodological differences. For example, the European surveillance system reports the proportion of MRSA in bacteraemia isolates in both inpatients and outpatients. Amongst 198 continuous contributing laboratories in 22 European countries the proportion of MRSA compared with MSSA significantly decreased from 2002 to 2009. Targeted MRSA public health initiatives in several countries was cited as a possible cause of this decline. The overall proportion of MRSA in Europe in 2009 varied markedly from less than 1% in Iceland and Norway to 58% in Malta[18]. The Netherlands and the Scandinavian countries have consistently kept MRSA at very low levels in their hospitals over long periods.

Amongst the MRSA in this study, more that 70% were resistant to erythromycin and ciprofloxacin, and more than 40% were resistant to tetracycline, co-trimoxazole and gentamicin. Regional differences were again common due to different MRSA clones circulating in Australia. In the 1980s and 1990s multiresistant strains (later typed as ST239-III or Aus2/3 EMRSA) became epidemic in the eastern Australian states with some spread to hospitals in South Australia, the Northern Territory and Tasmania[19]. In 1982, a state-wide MRSA policy was introduced in Western Australia with the aim of preventing these strains from becoming established in WA hospitals. As a result, MRSA with tetracycline, co-trimoxazole and gentamicin resistance (characteristic of ST239-III) are rare in WA - less than 3% in this survey. Erythromycin and ciprofloxacin resistance was more widespread in this survey with at least 30% of MRSA with this profile in any region. Erythromycin and ciprofloxacin resistance is common in ST239-III strains but is also characteristic of ST22-IV (EMRSA-15). ST22-IV is a common healthcare-associated MRSA (HA-MRSA) in Australia and is found in all regions[20,21]. Resistance was not detected for vancomycin, teicoplanin, quinupristin-dalfopristin or linezolid. Compared with previous AGAR hospital inpatient surveys in 2005 and 2007, the proportion of MRSA resistant to erythromycin, clindamycin, tetracycline, co-trimoxazole, ciprofloxacin, gentamicin and rifampicin has decreased nationally lead by significant decreases in NSW/ACT and Vic/Tas whilst the proportion of *S. aureus* that are MRSA has remained stable in all regions and nationally. This finding suggests that non-multiresistant community strains of MRSA are increasing in Australian hospitals at the expense of the long-established multiresistant ST239-III. Given reports of outbreaks of CA-MRSA in Australian hospitals are rare,[22,23] it is likely that many infections in hospital inpatients are caused by the patients' own colonising strains acquired prior to admission. It appears that current infection control procedures are successful in preventing their spread. Although at present in Australia there is no evidence of increasing resistance in local CA-MRSA[24], data from the United States of America show that previously non-multiresistant CA-MRSA can acquire multiple resistances over time[25]. With community clones such as the Qld clone (ST93-IV), South Western Pacific (ST30-IV) and WA 1 (ST1-IV) well established in Australia[13,26], it is important to monitor susceptibility patterns to MRSA over time as this information will guide therapeutic practices. In addition to this threat, virulent multiresistant overseas CA-MRSA have recently been isolated in Australia[27] and only time will tell if these difficult to treat clones become established in the Australian community or healthcare institutions.

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