Abstract: The aim of this study was to determine how often methicillin-resistant Staphylococcus aureus (MRSA) is found in aerosols while health care workers were undertaking routine care of patients (e.g. taking blood pressures, making beds). Air sampling was conducted using an air sampler and environmental settle samples in single rooms of patients who were either colonised or infected with MRSA, using a Merck MAS -100 air sampler and MRSA chromogenic agar. The air samples and environmental settle samples were collected between the 0700 and 1530 hrs over a ten day period. A total of 99 air samples and 26 environmental settle samples were collected: 29/99 (29%) of the air samples and 5/26 (19%) of the environmental settle samples were positive for MRSA. Of the ten rooms sampled, eight (80%) had MRSA present in air samples. Concentrations ranged from 1 to 128 colony-forming units per cubic metre. Thus MRSA can frequently be aerosolised. Although the overall contribution of aerosolisation in the transmission of MRSA is unclear, these findings add further evidence to justify the use of gloves and gowns for staff having contact with MRSA-positive patients or going into the rooms, as environmental contamination is likely to be frequent. Masks should be used more often, especially whenever activities likely to generate aerosols occur, such as bed-making, sputum suction or chest physiotherapy.

Author Address: gemckenzie@csu.edu.au

URL: http://dx.doi.org/10.1071/HI08025
http://researchoutput.csu.edu.au/R/-?func=dbin-jump-full&amp;object_id=9634&amp;local_base=GEN01-CSU01

CRO Number: 9634
TITLE: Is methicillin-resistant *Staphylococcus aureus* aerosolized when health care workers carry out activities for patients?

**RUNNING TITLE: Is MRSA aerosolized in the health care setting?**

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**Word counts**
Abstract: 239
Paper: 2829
OBJECTIVE: To determine how often methicillin-resistant *Staphylococcus aureus* (MRSA) is found in aerosols while health care workers (HCWs) were undertaking routine care of patients (e.g. taking blood pressures, making beds).

METHOD: Air sampling using an air sampler and environmental settle samples in single rooms of patients who were either colonized or infected with MRSA, using a Merck MAS-100 air sampler and MRSA chromogenic agar. The air samples and environmental settle samples were collected between the 0700 and 1530 hrs over a ten day period.

RESULTS: 99 air samples and 26 environmental settle samples were collected. 29/99 (29%) of the air samples and 5/26 (19%) of the environmental settle samples were positive for MRSA. Of the ten rooms sampled, eight (80%) had MRSA present in air samples. Concentrations ranged from one colony forming unit per cubic metre (CFU/M³) to 128 CFU/M³.

CONCLUSION: MRSA can frequently be aerosolized. Although the overall contribution of aerosolization in the transmission of MRSA is unclear, these findings add further evidence to justify the use of gloves and gowns for staff having contact with MRSA-positive patients or going into the rooms, as environmental contamination is likely to be frequent. We believe masks should be used more often, especially whenever activities likely to generate aerosols occur, such as bed-making, sputum suction or chest physiotherapy.

**Keywords:** methicillin-resistant *Staphylococcus aureus*, MRSA, cMRSA, aerosolized, Merck MAS-100, health care worker (HCW), personal protective equipment (PPE), chromogenic agar, colony forming units
**Introduction**

Health care acquired infections (HCAI) contribute to the increasing economic burden of the health care system, and are an important preventable cause of morbidity and mortality. In the United States of America (USA) in 2000, HCAI relating to methicillin-resistant *Staphylococcus aureus* (MRSA) cost between $US1.5 billion and $US4.2 billion.¹ Noskin et al² reported that inpatients in the USA in 2000 and 2001, who were identified with an MRSA infection, increased their length of stay in hospital by as much as three times, their medical expenses by three times and their risk of death by five times. In Australia, MRSA causes 2,000 episodes of bacteremia per year, most of which are healthcare related.³

MRSA, first reported in 1961, has become the most prevalent and important antimicrobial-resistant pathogen causing HCAI and community-acquired infection.⁴ In the United Kingdom in 1999, MRSA accounted for 37% of all *Staphylococcus aureus* infections compared to only 3% in 1991.⁵ The proportion of *S. aureus* blood stream infection (BSI) caused by MRSA varied in different European countries in 2002. In Denmark it was 1%, the Netherlands 1%, Austria 11%, Germany 19%, Spain 23%, France 33%, Italy 38%, Greece 44% and the United Kingdom 44%.⁶ In comparison, in Australia (1999–2002), it was 26%.³

When MRSA was first identified, outbreaks were managed by a ‘seek and destroy’ approach. ‘Seek and destroy’ has been described as adherence to rigorous transmission-based control policies that include active screening surveillance cultures to identify colonized patients and applying strict barrier precautions for patients colonized or infected with MRSA.⁷ This type of approach has been successful in keeping MRSA at very low levels in hospitals in Denmark, The Netherlands and Western Australia.⁷ In most areas of Australia however, this approach is
not followed mainly because of a lack of single rooms and costs in implementing it. Also not all believe that such an approach is appropriate as they consider it may simply control the spread of MRSA rather than eradicate it.\textsuperscript{8}

MRSA has the ability to spread rapidly within health care facilities and cause serious infections.\textsuperscript{9} Many health care facilities have not been able to stop the spread of MRSA despite a combination of active screening surveillance and isolation of patients upon identification of MRSA.\textsuperscript{10} Unfortunately, MRSA is now endemic in many countries including the USA and most countries in southern Europe, with a recent escalation of MRSA in Germany and Great Britain.\textsuperscript{10} In Australia, MRSA is now entrenched in most of our hospitals and non-multi-methicillin-resistant \textit{Staphylococcus aureus} in the community (cMRSA) is also on the rise.\textsuperscript{11,12}

The main mode of transmission of MRSA appears to be from patient to patient, with the transient colonization of the hands of health care workers (HCWs) one of the most important vehicles of transmission. Airborne transmission is considered to also occur but only with a low frequency and thus is not usually taken into account for infection control precautions.\textsuperscript{5}

In most hospitals, HCWs are required to wear a gown, don gloves and perform hand hygiene with an antimicrobial hand wash or hand rub when dealing with patients with MRSA (although in some hospitals in Australia, patients colonised with MRSA are not isolated). Coia et al\textsuperscript{13} suggest that HCWs should consider masks when procedures may generate aerosols containing \textit{S. aureus} and that the door of the patient’s room should be closed to minimise spread. However, there is currently limited evidence to support the use of airborne
precautions to prevent the spread of MRSA. This study was undertaken to evaluate whether MRSA could potentially be transmitted by aerosols.

Methods
Air sampling using a Merck MAS-100 impactor was combined with a passive process (settle plates). This study was conducted in one medical and one surgical unit within our 500-bed tertiary referral hospital, over ten separate days in ten single patient rooms during November 2006.

Participants
The ten patients selected were known to be either colonized or infected with MRSA (Table I). The selection process of the patient was from an alerts list that is generated daily in infection control after notification from the microbiology laboratory. Patients were either colonized (a positive screening sample but negative clinical samples) or infected (a positive clinical specimen together with clinical evidence of infection) with either cMRSA or multi-resistant MRSA.10

To ensure that the air was not contaminated by a colonized HCW, MRSA isolates from positive air samples were compared to the clinical isolates from the same patient using the antibiograms to ensure they were the same. In addition control plates were used in nearby rooms to ensure they were not contaminated with MRSA.

An information sheet was given to each patient or their family and written consent was obtained. Demographic information of the patient was recorded including the patient’s MRSA
status (whether the patient was colonized or infected with MRSA). To ensure consistency with the sampling, two nursing staff were trained to collect the samples. Ethics approval was given from the ACT Health Human Research Ethics Committee of the researchers’ hospital (ETH.6/06.433). No funding was sought for this study.

Air sampling

The apparatus was placed approximately 1 metre from the head of the patient. Ten air samples from ten patient rooms (totalling 100 samples) were to be collected. The air was aspirated or suctioned at a nominal rate of 100 litres per minute for a period of 10 minutes (i.e. 1000 litres over a 10 minutes period), onto a selective chromogenic MRSA agar plate. The company’s conversion chart that was supplied with the air sampling machine was used to correct the CFU count. Impaction velocity of airborne micro-organisms on the agar surface was approximately 11m/second. This velocity collects particles >1μm. After 10 minutes of collection, the plate was removed and taken to the microbiology laboratory. Colony counts were expressed as CFU/M³.

Environmental settle samples

Petri dishes containing the chromogenic agar were used as settle plates and left open to the air for a given period of time. Microbes fall onto the surface of the nutrient, and after incubation colonies are determined to be proportional to the level of microbial contamination of the air.

Three environmental settle samples from each of the ten patient rooms were collected giving a total of 30 environmental samples. The method used for collection of 20 plates was the 1/1/1 method where the plates are left in position for one hour, one metre above the floor and one
metre from the wall with no obstruction. The additional ten plates were placed under the bed for one hour which was outlined in a study undertaken by Shimori et al.

**Selection of sampling time/period**

The sampling time/period was between 0700 and 1530 hours as this was considered the busiest time of day for direct patient care to take place. Sampling was to take place while HCWs assisted patients in and out of bed, making patients’ beds, patients undergoing physiotherapy, patients having wounds dressed and undergoing observations.

**Laboratory procedure**

On reaching the microbiology laboratory the plates were incubated in a dark room at 35°C. The plates were examined at 24 hours and 48 hrs for the presence of pink colonies (which represented MRSA). Tube coagulase, DNAase and sensitivity testing were undertaken on any suspicious colony.

**Statistical analysis**

Statistical analysis of this small sample was not undertaken due to the small numbers of CFU/M³ being identified. Samples collected were many and varied not allowing for comparison of any one activity.
Results

Participants

Of the ten patients’ rooms sampled, in eight rooms (80%) MRSA was found on air sampling (Table I). Of the eight rooms that were identified as positive, two patients carried cMRSA, seven patients multi-resistant MRSA and one patient had both types of MRSA. Patients’ time in hospital varied from two days to 12 months.

The ages of the patients ranged from 21 to 88 years (average age 56 years). Three patients were female and seven were male. Seven patients were colonized and three infected with MRSA. Of the ten patients, six had MRSA identified on a nasal screening surveillance but the other four were negative on nasal screening. Of the three patients with infection, none had a positive nasal swab. During the time of air sampling, four patients were on antibiotics to treat MRSA. Only one patient of the two patients, who were in single rooms where MRSA was not identified on air sampling, was on antibiotics. Many of the patients in this study had chronic wounds, which may possibly make them more likely to have heavy aerosolization after manipulation of bed linen.

Correlation of the clinical isolates and the air sample isolates showed that all isolates from air appeared to be the same as the patients’ clinical isolates.

Control plates were collected from four patients’ rooms that were known not to have MRSA during the sampling period. The plates from the controls were all negative for MRSA.
Air sampling

Of the proposed 100 air samples to be collected, 99 were completed over a ten day period. Of these 99 samples, 29 were found to be positive (29%). Air was collected whilst a variety of direct patient care activities were taking place (Table II). The lowest numbers cultured were 1 CFU/M³ recorded when a patient was undergoing the dressing of a wound and the highest count, 128 CFU/M³ when a patient’s bed was being made. The mean of the 29 positive samples was 19 CFU/M³.

Environmental settle sampling

Of the proposed 30 environmental settle samples only 26 were successfully collected. Of these five (19%) plates grew MRSA. The four samples that failed to be collected were accidentally contaminated or were swept away by the cleaner. The highest number were ten CFU/plate was recorded on the patient’s over-table and the lowest was two CFU/plate from under the patient’s bed on the floor.

Discussion

Our findings confirm that MRSA can be frequently airborne and contaminate the environment through aerosolization (as evidenced by positive settle plates). We were surprised that 80% of rooms were positive on air sampling for MRSA. This shows that MRSA has the ability to contaminate the environment by the airborne route as well as by direct contact from hands. MRSA thus has the ability to transfer via the movement of dust in air currents to surfaces that might be touched by patients and healthcare workers or by air that might be inhaled.

Wilson et al5 considered airborne mode of transmission of MRSA being under-emphasized but there are only limited studies that have previously examined this issue. Our small study also
supports these conclusions. Shiomori et al\textsuperscript{16} showed that MRSA containing particles were carried on particles both $<4\ \mu m$ and $4-8\ \mu m$ in size, the former of which have the potential to colonize the nares or cause respiratory infection. Despite the ability of MRSA to be frequently aerosolized it remains unclear why all patients colonised or infected with MRSA aren’t therefore consistently colonized in their nose. Only seven of our ten patients who were colonised or infected had positive nasal screenings.

The highest numbers of colony counts of MRSA were detected while staff were making beds (five of the ten rooms). Sheets in our hospital are changed daily with freshly laundered linen. We do not know what techniques staff used for taking off the old linen or making the beds e.g. whether the linen is folded out gently prior to and during bed making, or shaken. If shaken then this might cause an increase in the circulation of air and disturbance of MRSA already in the environment. Shiomori et al\textsuperscript{16} believed that it is necessary to examine the techniques of bed making as well as the frequency of linen being changed and what type of material they were made from.

Our findings reinforce the importance of careful disinfection of inanimate environments and support those of Sexton et al in their study on the cleaning of the environment.\textsuperscript{17} Sexton et al\textsuperscript{17} argued that the public is increasingly concerned about both the risks of HCAI and the state of cleanliness in many hospitals. Therefore, environmental decontamination is an increasingly important priority. MRSA isolates are likely to settle on innate surfaces that staff and patient will then contact with their hands.
Dancer\textsuperscript{18} looked at the environment and cleaning and found that items such as bed linen, patients’ gowns and over bed tables provide the highest degree of MRSA contamination. About one third of surfaces on average harboured MRSA. Hardy et al\textsuperscript{19} looked at the contamination of the environment by using environmental screening. Their study showed that MRSA was isolated in all screenings whether the patient was colonized or infected with MRSA. They concluded that the environment plays a large part in the transmission of MRSA and attention should be paid to cleaning the environment to lessen the bioburden of the organism.

Wilson et al\textsuperscript{5} identified MRSA in an ICU by using an air sampler. Our study supports their findings and shows that MRSA can be aerosolized in varying numbers. It gives support to the theory that airborne transmission is both possible, plausible and under appreciated.\textsuperscript{5}

Currently the accepted practice for patients with MRSA is to use additional (contact) precautions - namely gown, gloves, hand hygiene with an alcohol/anti-microbial solutions and placing patients in single rooms. It is worth reassessing however, whether there is also a role for masks for HCWs in reducing patient-to-patient transmission of MRSA by preventing nasal colonisation of HCWs.\textsuperscript{8} Masks would also have the added advantage of likely decreasing the number of times that a HCW touched their nose and thus reducing the chance of contaminate hands from the nose or their noses from contaminated environmental surfaces via the HCW’s hands. We believe our data suggests that wearing of masks should be used more often in the control of MRSA, especially whenever activities likely to generate aerosols occur, such as bed-making, sputum suction or chest physiotherapy.\textsuperscript{13}
Further consideration should be given to the doors of the patients’ room remaining closed during activities such as bed-making and chest physiotherapy. Visitors and allied HCWs should be restricted and patient’s movements around the health care facility should be minimised. Emphasis should also be given to reducing the bioburden of organisms by ensuring that cleaning standards are maintained, waste management is controlled and linen is handled correctly. In addition, because of likely frequent contamination, all areas of the health care facility should undergo periodic and thorough cleaning, including bedside tables, bedding and curtains.\textsuperscript{13}

**CONCLUSION**

This study showed that aerosolization of MRSA occurs frequently within rooms of patients colonised or infected with MRSA. This increased the risk that HCWs and/or patients of becoming colonised with MRSA in their noses or hands by either direct inhalation of MRSA or by acquiring it on their hands after the organisms settles on innate surfaces.

This in turn has the potential to facilitate transmission of MRSA to other patients. Gould\textsuperscript{1} believes that the cost of NOT controlling MRSA is much greater than the cost of control. We support the continued multifaceted approach by health care facilities if MRSA is to be controlled. Patients must continue to be cared for in single rooms with additional (contact) precautions including the use of a mask when there is any activity being undertaken that might create aerosols or air currents such as bed making and physiotherapy. The appropriate and frequent cleaning of all surfaces that may have MRSA settle on them is also very important.
Dancer\textsuperscript{18} states that lack of isolation facilities and the continued pressure on the availability of beds provide serious challenges to standard infection control principles. Therefore, it is imperative that consideration be given when health care facilities are built or undergoing renovations that there are also enough single rooms set aside to care for patients identified to have MRSA.

We need active screening surveillance of high-risk patients to allow early identification of patients colonized with MRSA. These patients need to be placed in single rooms to help minimise the spread of MRSA to other patients. HCW’s must continue to perform good hand hygiene to reduce the burden of pathogens. A high level of cleaning must be carried out to ensure that the bioburden of pathogens is reduced within the health care environment including patient equipment such as tourniquets, pens and bedside tables and any other areas on which MRSA might settle.

By ensuring all these measures and infection control polices are in place we should see a reduction in the number of cases of preventable illness and death from HCAI as well as in patient length of stay and economic burden to the community.
Acknowledgments

I wish to thank my supervisors, who are my co-authors, for their encouragement and support during this study. I would like to thank Leon Tetlow and Helena Beltrami and the staff of the Canberra Hospital Microbiology Department for their patience and help in reading and processing of the microbiology plates and the HCWs who helped collect the samples for the study. Finally, thank you to my friends and colleagues in the Infection Prevention and Control Unit of the Canberra Hospital for their ongoing support.
References


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Table I: Characteristics of patients with MRSA infection or colonization with number of air sampling and environmental settle plates collected.

<table>
<thead>
<tr>
<th>Patient number</th>
<th>Sex/age</th>
<th>Underlying disease</th>
<th>Infection/colonization</th>
<th>Nasal carriage</th>
<th>Positive Air sample/No. Air samples collected</th>
<th>Positive settle plates/No: Settle plates collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F/54</td>
<td>Chronic ulcers</td>
<td>Colonized (UK16**)</td>
<td>Yes</td>
<td>3/10</td>
<td>0/2</td>
</tr>
<tr>
<td>2</td>
<td>M/30</td>
<td>Pressure ulcers</td>
<td>Infection (MRSA*)</td>
<td>No</td>
<td>0/9</td>
<td>0/3</td>
</tr>
<tr>
<td>3</td>
<td>M/35</td>
<td>Pressure ulcers</td>
<td>Colonized (MRSA)</td>
<td>Yes</td>
<td>0/10</td>
<td>0/3</td>
</tr>
<tr>
<td>4</td>
<td>M/21</td>
<td>Sputum (tracheotomy)</td>
<td>Infection (MRSA/cMRSA***)</td>
<td>No</td>
<td>7/10</td>
<td>0/3</td>
</tr>
<tr>
<td>5</td>
<td>M/60</td>
<td>Pressure ulcer</td>
<td>Colonized (UK 16)</td>
<td>No</td>
<td>8/10</td>
<td>3/3</td>
</tr>
<tr>
<td>6</td>
<td>M/84</td>
<td>Stroke</td>
<td>Colonized (MRSA)</td>
<td>Yes</td>
<td>3/10</td>
<td>1/2</td>
</tr>
<tr>
<td>7</td>
<td>F/80</td>
<td>Bowel obstruction</td>
<td>Colonized (MRSA)</td>
<td>Yes</td>
<td>5/10</td>
<td>1/2</td>
</tr>
<tr>
<td>8</td>
<td>M/60</td>
<td>Ulcer of foot</td>
<td>Colonized (cMRSA)</td>
<td>Yes</td>
<td>1/10</td>
<td>0/2</td>
</tr>
<tr>
<td>9</td>
<td>M/52</td>
<td>Abscess on back</td>
<td>Infection (cMRSA)</td>
<td>No</td>
<td>1/10</td>
<td>0/3</td>
</tr>
<tr>
<td>10</td>
<td>F/88</td>
<td>Bilateral amputee</td>
<td>Colonized (UK15**)</td>
<td>Yes</td>
<td>1/10</td>
<td>0/3</td>
</tr>
</tbody>
</table>

MRSA* methicillin resistant *Staphylococcus aureus* that are all multi resistant and hospital acquired
UK 15 and 16** are health care acquired methicillin resistant *Staphylococcus aureus* that are not multi resistant
cMRSA*** community MRSA that are not health care acquired and not multi resistant
Table II: B Colony counts and distribution of positive air sampling plates

<table>
<thead>
<tr>
<th>Patient sex and age</th>
<th>Patient in and out of bed (Pr*)</th>
<th>Repositioning patient or observations (Pr)</th>
<th>Making bed (Pr)</th>
<th>Physio (Pr)</th>
<th>Physio (Pr)</th>
<th>Patient resting (Pr)</th>
<th>Wound dressing (Pr)</th>
<th>Staff tidying room (Pr)</th>
<th>Patient talking with visitors (Pr)</th>
</tr>
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<tbody>
<tr>
<td>1 F/54</td>
<td>29</td>
<td>1</td>
<td>8</td>
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<td>0</td>
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<td>0</td>
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<tr>
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<td>0</td>
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<td>0</td>
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</tr>
<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>4 M/21</td>
<td>37</td>
<td>27</td>
<td>128</td>
<td>42</td>
<td>24</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>5 M/60</td>
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<td>12</td>
<td>115</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>25</td>
<td>34</td>
<td>4</td>
</tr>
<tr>
<td>6 M/84</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
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<tr>
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<td>0</td>
<td>3</td>
<td>0</td>
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<td>2</td>
<td>0</td>
<td>0</td>
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</table>

*Pr is the probable statistical total (conversion chart supplied with Merck Mas-100 Air Sampler). Figures are given as calculated number of bacteria per 1,000 litres of air sampled.