Staphylococcus aureus bacteraemia as a quality indicator for hospital infection control

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ABSTRACT

Objective: To evaluate the practicality and effectiveness of a new program that made health care-associated *Staphylococcus aureus* bacteraemia (SAB) a quality indicator at Austin Health.

Design and setting: Roll-out of the program over 9 months and review over 27 months from January 2006. Every episode of SAB at Austin Health was promptly reviewed, and classified as community- or health care-associated and as inpatient- or non-inpatient-related. Feedback was provided to treating clinicians for every SAB episode considered potentially preventable, and education-based interventions were introduced where appropriate.

Main outcome measure: Episodes of SAB associated with health care at Austin Health per 1000 separations (hospital discharges) per month.

Results: We identified 131 episodes of health care-associated SAB, of which 90 (68.7%) were caused by methicillin-susceptible *S. aureus*, 96 (73.3%) occurred in inpatients, and 65 (49.6%) were associated with a vascular access device. The health care-associated SAB rate was 1.1 per 1000 separations in the first 9 months, and fell by 55% to 0.51 per 1000 separations in the subsequent 18 months. We estimated that there were 80 fewer SAB episodes (95% CI, 20–140) than expected had the initial rate remained unchanged, a notional saving of $1.75 million to Austin Health over 27 months. About 16 hours per month of clinical nurse consultant time was required to maintain the program, representing a 0.1 equivalent full-time position, or a cost of $7000–$9000 per year.

Conclusion: Introducing a structured program to investigate all health care-associated SABs, rather than only infections with methicillin-resistant *S. aureus*, revealed a large under-recognised burden of potentially preventable infections. The program was simple and low-cost, and the rate of health care-associated SAB has fallen significantly since its introduction.

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Methicillin-resistant *Staphylococcus aureus* (MRSA) bacteraemia is a frequent and dangerous complication of modern health care. At the very minimum, an episode of MRSA bacteraemia increases length of stay in hospital and has substantial financial costs, but some series have suggested that MRSA bacteraemia is associated with a mortality rate of 20%–25%.[1] In Western Australia, all MRSA infections have been notifiable since 1985.[2] In the United Kingdom, mandatory reporting of MRSA bacteraemia by National Health Service Trust hospitals commenced in May 2001.[3]

What is not always appreciated is that methicillin-susceptible *S. aureus* (MSSA) bacteraemia is also a serious health care-associated infection. In 2005, a report estimated a median rate of hospital-onset *S. aureus* bacteraemia (SAB) across 17 Australian hospitals of 0.7 cases per 1000 admissions.[4] In 2006, there was a call for SAB, whether due to methicillin-resistant or methicillin-susceptible strains, to be used as a quality indicator for hospital infection control programs.[5] Accordingly, a report from the Australian Commission on Safety and Quality in Health Care in 2008 identified health care-associated SAB as a key outcome measure for the National Hand Hygiene Initiative.[6] While WA has been the leader with respect to MRSA notification, Tasmania recently went further and has made all cases of SAB notifiable, regardless of whether they are health care-related.[7]

Since 2001, Austin Health has had a strong focus on control of MRSA through the introduction of an institution-wide program to provide and promote alcohol-chlorhexidine hand hygiene for all health care workers, and alcohol wipes for all shared equipment.[8] The rate of MRSA infections has fallen progressively over 7 years at Austin Health, and episodes of MRSA bacteraemia have become statistically less useful as a performance indicator. However, we, like others, observed patients with MSSA bacteraemia that was likely to be hospital-acquired.[4,5] To address this problem, we introduced the "AuSABs" (Austin-associated *S. aureus* bacteraemias) program, whereby all episodes of SAB, not just those caused by MRSA, were made quality indicators. In this report, we evaluate the effectiveness and practicality of our AuSABs program.

METHODS

The AuSABs program was designed and introduced at Austin Health, a large University of Melbourne teaching health service with three separate hospital campuses, but a single, central microbiology laboratory service. The program was progressively developed and rolled out over 9 months from January 2006, and we continued to review the impact over the subsequent 18 months.

Every SAB detected in our microbiology laboratory that was linked to an Austin Health patient triggered a review of the case (when possible, on the same day or next normal working day) by an infection control clinical nurse consultant and/or infectious diseases registrar. This review was separate from the immediate clinical management of the patient, which remained the responsibility of the unit under which the patient was admitted. We recorded the likely place of acquisition (community or hospital), admitting unit, likely source, presence of any vascular access device and, if applicable, details of device insertion and management. Any potential system errors that may have contributed to the episode were noted.

An episode of SAB, including its association with a vascular device, was defined according to published criteria (Box 1).[9,10] As part of our program, we introduced the term "AuSAB" (meaning SAB associated with health care at Austin Health), instead of "health care-associated SAB", to encourage a sense of ownership and responsibility for these adverse events at Austin Health. Where possible, the source of bacteraemia was determined by identification of a primary focus, which was confirmed where possible by isolating *S. aureus* with the same antibiogram from that site.

1 Definitions of *Staphylococcus aureus* bacteraemia (SAB) used in this study, derived from published criteria[9,10]

SAB	Isolation of *S. aureus* from one or more blood culture bottles. When patients had more than one blood culture positive for the same organism within a 14-day period, this was considered a single episode of bacteraemia.
Inpatient AuSAB	SAB acquired during hospitalisation at Austin Health, which was not present or incubating on admission, and was identified 48 hours or more after admission.
Non-inpatient AuSAB	SAB occurring in a known hospital outpatient within 48 hours of admission, who had one of: • an indwelling medical device (intravenous catheter, urinary catheter); • neutropenia ($< 1 \times 10^9$/L) contributed to by cytotoxic chemotherapy; • SAB within 30 days of a surgical procedure, and related to the procedure; or • SAB within 48 hours of invasive instrumentation or incision before onset of infection, and related to the procedure.
Community-associated SAB	SAB diagnosed within 48 hours of admission and not meeting the criteria for definition as an inpatient or non-inpatient AuSAB. ◆

Patients were followed until hospital discharge or 30 days after the episode of SAB. In the event of a patient's death, the AuSAB was retrospectively categorised as "contributory" or "non-contributory" to the death by consensus among a panel of infectious diseases physicians and registrars who were presented with de-identified patient information that included the admission diagnosis, underlying comorbidities, clinical history, and timing of the AuSAB episode in relation to the time of death.

Blood cultures were ordered as clinically indicated, and MRSA and MSSA isolates were identified by standard techniques.[11] Isolates from episodes of AuSAB were examined for clonality by means of pulsed-field gel electrophoresis (PFGE) of *Sma*I digests of chromosomal DNA. The resulting PFGE pattern was analysed using GelCompar II, version 3.5 (Applied Maths NV, Sint-Martens-Latem, Belgium), as described previously.[12] PFGE digestion patterns were considered clonal if GelCompar estimated a similarity of $\geq 80\%$.[12]

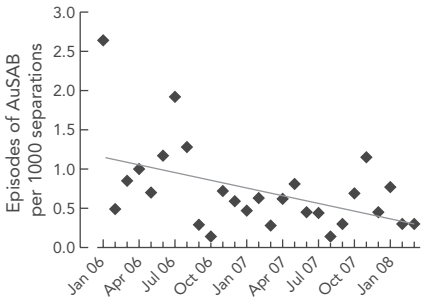
During the initial 9 months of the program, infection control staff publicised and explained the new program to hospital staff in the clinical areas in which AuSABs were being identified. The program included prompt investigation of every AuSAB by infection control staff, followed by "real time" feedback to relevant wards and departments. The feedback included the patient's name, the original reason for admission, and ways in which this episode could have been prevented, as we believed that linking an adverse event to an individual patient was likely to motivate change more strongly than just providing statistical rates. Based on investigation and discussion with relevant clinicians, infection control staff recommended changes in practice and education sessions in these high-risk clinical areas. Reassessments were performed to monitor adherence to recommended interventions, and to provide further assistance as required.

Statistical analysis

The main outcome measure was the rate of SAB associated with health care at Austin Health (AuSAB), expressed as the number of patient-episodes of *S. aureus* bacteraemia per 1000 total separations per month. Separations were obtained from "total separations" for Austin Health, an accounting statistic that measures all completed episodes of care, including day cases, and is equivalent to the number of discharges of all day-patients and overnight-patients of Austin Health.

Rates of AuSABs per 1000 separations in the initial 9 months and subsequent 18 months were compared by two-tailed χ^2 tests (Stata statistical software, release 5.0; StataCorp, College Station, Tex, USA). To calculate "cases prevented", a linear regression line was fitted to the entire 27-month dataset using GraphPad Prism 4 software (GraphPad Software, San Diego, Calif, USA), which also calculated the slope of the regression line (Box 2) and upper and lower 95% confidence limits of the slope. Using Excel (Microsoft, Redmond, Wash, USA), the area under the observed regression curve (AUC) was compared with the AUC obtained assuming the initial rate of 1.1 per 1000 separations had remained unchanged.

2 Rates of *Staphylococcus aureus* bacteraemia associated with health care at Austin Health (AuSAB), with fitted computer-generated linear regression curve



RESULTS

SAB rates

Over the 27 months of the program from 1 January 2006 to 31 March 2008, there were 182 486 separations (67% same-day patients or "non-inpatients"), accounting for an equivalent of 673 626 total occupied bed-days. During the same period, we investigated 247 episodes of SAB, of which 131 (53.0%) were classified as AuSABs (Box 3) by the definition in Box 1. Sixteen of the 131 patients with an AuSAB (12.2%) died, and it was considered that the AuSAB contributed to death in nine of the 131 cases (6.9%).

The overall AuSAB rate was 0.7 per 1000 separations (1.94 per 10 000 occupied bed-days) over 27 months. However, the rate was 1.1 per 1000 separations in the first 9 months, during which the program was being developed and implemented, and fell to 0.51 per 1000 separations for the subsequent 18 months ($P < 0.001$; Box 2). If the rate of 1.1 per 1000 separations had continued for the entire 27-month period, we estimate that there would have been 80 more patients with SAB (95% CI, 20–140) than we actually observed (an additional three cases per month, on average)

Laboratory and clonality findings

As shown in Box 3, MSSA was isolated in 90 (68.7%) and MRSA was isolated in 41 (31.3%) of the 131 AuSABs. All but one of the AuSAB isolates were typed by PFGE. The 41 MRSA isolates could be clustered by PFGE into eight groups, with one main group comprising 27 isolates and seven smaller groups with four or fewer isolates. In contrast, the 90 AuSAB MSSA isolates clustered into 33 different groups, 25 of which were comprised of only one or two isolates. Of the other eight MSSA PFGE groups, the

3 All investigated episodes of *Staphylococcus aureus* bacteraemia, 1 January 2006 to 31 March 2008*

Type of *S. aureus* bacteraemia	Causative organism			Total
	MSSA	Non-multiresistant MRSA	Multiresistant MRSA	
Total	180	7	53	240
Community-associated	90	4	15	109
Associated with health care at Austin Health (AuSAB)	90	3	38	131
Inpatient	63	2	31	96
Non-inpatient	27	1	7	35

MSSA = methicillin-susceptible *S. aureus*. MRSA = methicillin-resistant *S. aureus*.
* Seven patients were excluded from this table as their episodes of *S. aureus* bacteraemia were acquired at another hospital, although they were diagnosed and managed at Austin Health. ◆

two largest had 18 and 11 isolates, respectively, which were identified from AuSAB episodes throughout the 27-month period, and did not seem to predominate in any particular month or location.

Source of AuSABs

A proven or suspected source was identified in 116 (88.5%) of the 131 AuSABs, and 65 (49.6%) were associated with a vascular access device. Sources of infection for the other 51 AuSABs were surgical site (19; 14.5%), endocarditis (6; 4.6%), bone and joint (5; 3.8%), skin and soft tissue (5; 3.8%), urosepsis (6; 4.6%), pneumonia (2; 1.5%), intra-abdominal (2; 1.5%), and other sources (6; 4.6%). Of the 65 vascular access device infections, 45 (69%) were in inpatients and 20 (31%) in non-inpatients. Twelve (9.2%) of the 131 AuSABs occurred in patients in the intensive care unit and, of these, three were associated with a vascular access device. Devices involved in the 65 line-associated AuSABs included 18 central access devices (central venous catheters, Hickman catheters, Infus-A-Ports [AngioDynamics, Vilvoorde, Belgium]; 28%), 28 peripherally inserted devices (peripherally inserted central catheters, intravenous cannulas; 43%), 18 renal access devices (vascath and permcath catheters; 28%) and one case in which the identity of the device was unclear (1%).

During the 27-month program, there were six occasions when the monthly AuSAB rate exceeded 1.0 per 1000 separations (Box 2). On one occasion (November 2007), the cases could not be linked to a particular area, and were a mixture of line-associated and non-line-associated infections. The other five occasions when the monthly rate was high were within the 9-month roll-out period and, of the 68 AuSABs that occurred, 33 (49%) were line-associated. Of these 33, 17 were associated with "clinical area A" and nine with "clinical area B". Although it is difficult to establish with certainty, the infections seemed to be linked to issues with line insertion in clinical area A and accessing lines in clinical area B.

In clinical area A, we observed inadequate insertion techniques for percutaneous intravenous central catheter insertion, including a modified rather than full surgical scrub, poor patient skin preparation, inadequate training of new staff and poor environmental conditions. Staff from infection control and clinical area A responded as soon as they became aware of AuSABs in that clinical area by organising staff education, improving techniques, introducing checklists and holding progress and review sessions with infection control staff. Similar AuSAB auditing in clinical area B conducted with active support from clinical area B nurses suggested poor technique in accessing lines, including staff not disinfecting ports before administering intravenous therapy, lines being left unconnected, and use of inappropriate dressings. In collaboration with the staff of clinical area B, education forums were conducted, and improved line-accessing practices were instituted. During the subsequent 18 months of the program, there were 63 AuSABs; 32 (51%) of these were line-associated, of which 14 (44%) were associated with clinical area A and seven (22%) with clinical area B.

Program resources

The staff time necessary for data collection, investigation, interventions and feedback varied according to the number of SABs and AuSABS per month. However, assuming that there were up to 1.5 SABs per 1000 separations (< 10 cases per month) and up to 0.7 AuSABs per 1000 separations (< 5 AuSABS per month), we calculated that about 16 hours per month of infection control clinical nurse consultant time (representing a 0.1 equivalent full-time [EFT] position) was required to maintain the program. This labour cost would be about $7000–$9000 annually.

DISCUSSION

The AuSABs quality improvement program was associated with a 55% reduction in hospital-acquired SABs, probably preventing 80 costly and potentially fatal infections. From the outset, we deliberately named the program "AuSABs" for Austin-associated *S. aureus* bacteraemias to remind us and other Austin Health departments that these adverse events occur on our watch, are frequently preventable and are our responsibility. By refocusing our existing MRSA bacteraemia surveillance system to include all SABs, we uncovered a large, under-recognised burden of health care-associated bloodstream infection at our institution. A caveat to our report on this program is that it is a quality improvement project, and not research. The interventions were introduced progressively, and there was no application of randomised controlled methods. Therefore, we cannot assess the relative effectiveness of any one intervention, nor be certain that the improvement we observed was causally linked to our interventions. However, the program has several merits.

Episodes of SAB are an unambiguous marker of invasive infection, and more than half of the episodes we observed were health care-related. By monitoring all health care-associated SABs and not just MRSA, as with our previous strategy,[8] we detected 90 additional health care-associated SABs (of a total 131 [68.7%]) that were caused by MSSA. We also detected 35 health care-associated SABs in non-inpatients (26.7%), which may have been missed by a ward-based surveillance program, and even more may have been missed if we had aimed the surveillance program at high-risk wards, such as the intensive care unit, only. Our program showed that vascular access device-related bacteraemias accounted for 49.6% of AuSABs, and many of these were associated with system errors that were previously undetected, and were potentially preventable. Others have also suggested there is great potential within hospitals to reduce or nearly eliminate nosocomial infections, in particular catheter-related bacteraemias.[13-23]

Furthermore, the multifaceted interventions used in our program, including staff education, nurse empowerment, intervention bundles and checklists, are relatively simple to implement in busy hospitals, and have proved to be sustainable.[23]

The PFGE typing of our AuSAB isolates showed an expected pattern for MRSA, with a restricted number of previously recognised hospital-endemic clones. However, for the MSSA isolates, the PFGE showed a much greater diversity of clones, implicating varied sources and modes of transmission. These data suggest that many of these infections arise from strains already colonising patients at the time of admission, and are not the result of cross-transmission. However, we cannot exclude some degree of cross-transmission of MSSA. Hence, to prevent MSSA AuSAB infections, we needed to not only focus on staff hand hygiene, as we had for controlling endemic MRSA, but to review protocols and practices for inserting devices that breach skin, or accessing existing lines.

This quality improvement program was simple to perform and required relatively little time to maintain, at an estimated annual cost of $7000–$9000 (a proportion of 0.1 of an infection control clinical nurse consultant salary). Our findings mirror results obtained with a similar program at Canberra Hospital.[14] Compared with the small cost of establishing the program, the economic costs of health care-associated SABs are huge. Estimates vary, but in the United States, the cost of an episode of SAB ranges from US$20 000 to US$50 000.[1,15,16] Financial data for Australia are scarce, but assuming a cost of A$22 000 per episode,[5] the total AuSAB cost at our institution for 27 months was almost $3 million. So, the annual cost of running the program ($7000–$9000) was less than half the cost of one episode of SAB. By preventing an estimated 80 AuSAB infections, the program may have saved our institution $1.75 million, and prevented 5–6 deaths over 27 months.

The AuSAB program is now core business for our infection control team, with investigation and feedback integrated into the team's daily activities. Results are reported to the hospital executive, and are used as a performance indicator by the Infection Control Committee. The data generated from our program are also useful for comparison with other Australian hospitals, and the AuSAB rate has fallen below the previously published national median of 0.7 per 1000 admissions.[4] At Austin Health, our overall performance target is now less than 0.5 AuSABs per 1000 separations, but our target for those that are line-related should be close to zero.[23] The introduction of institution-wide SAB surveillance and feedback is a first step towards this goal.

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COMPETING INTERESTS

None identified.

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