Original article

Impact of rapid molecular screening for meticillin-resistant *Staphylococcus aureus* in surgical wards

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Background: This study aimed to establish the feasibility and cost-effectiveness of rapid molecular screening for hospital-acquired meticillin-resistant *Staphylococcus aureus* (MRSA) in surgical patients within a teaching hospital.

Methods: In 2006, nasal swabs were obtained before surgery from all patients undergoing elective and emergency procedures, and screened for MRSA using a rapid molecular technique. MRSA-positive patients were started on suppression therapy of mupirocin nasal ointment (2 per cent) and undiluted chlorhexidine gluconate bodywash.

Results: A total of 18 810 samples were processed, of which 850 (4·5 per cent) were MRSA positive. In comparison to the annual mean for the preceding 6 years, MRSA bacteraemia fell by 38·5 per cent ($P < 0·001$), and MRSA wound isolates fell by 12·7 per cent ($P = 0·031$). The reduction in MRSA bacteraemia and wound infection was equivalent to a saving of 3·78 beds per year (£276 220), compared with the annual mean for the preceding 6 years. The cost of screening was £302 500, making a net loss of £26 280. Compared with 2005, however, there was a net saving of £545 486.

Conclusion: Rapid MRSA screening of all surgical admissions resulted in a significant reduction in staphylococcal bacteraemia during the screening period, although a causal link cannot be established.

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Introduction

The incidence of hospital-acquired meticillin-resistant *Staphylococcus aureus* (MRSA) infection is rising worldwide, over and above the increase in meticillin-sensitive *S. aureus* (MSSA) infection. In the UK, the incidence of MRSA septicaemia increased by 5·5 per cent between 2001 and 2003–2004[1] with a corresponding rise in MRSA-related deaths[2]. Indeed, the UK is reported to have one of the highest rates of MRSA infection in Europe[3].

MRSA-colonized patients may have acquired the bacterium from previous hospital and nursing home admission, but others are truly community acquired[3–5]. The identification of MRSA carriers on admission and use of topical suppression may reduce the rates of MRSA infection[6]. Previously, routine MRSA screening relied on culture techniques with a turnaround time of up to 3 days. Polymerase chain reaction (PCR) technology now enables results to be reported within hours, so topical suppression protocols can start immediately.

The aim of the present study was to establish the feasibility and cost-effectiveness of rapid molecular screening for MRSA in surgical patients within a teaching hospital, and to monitor the effect of rapid screening and topical suppression therapy on the rate of MRSA wound infection and bacteraemia.

Methods

After obtaining ethics committee approval, all patients admitted in 2006 (January to December inclusive) to the University College London Hospitals (UCLH) Foundation Trust for critical care, routine or emergency

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surgery (i.e. incision) were targeted for rapid MRSA screening. In those scheduled for elective surgery, cotton swabs (in Amies transport medium) from both nostrils were taken in the preadmission clinic. In emergency patients, nasal swabs were obtained on admission to the ward. Swabs were analysed in batches of 30 to 46, two to three times daily during the working week. Positive and negative controls were included in each run for quality control.

PCR was performed using the GeneOhm® MRSA Test (Becton Dickinson, Franklin Lakes, New Jersey, USA), which achieves detection of MRSA in a nasal swab by target amplification with primers and probes designed to detect the right-hand region of the *mecA* cassette and neighbouring *orfX* gene. The amplified targets are detected by using fluorescent beacon technology[7]. Inhibited samples (those in which the internal control was not detected) were repeated after freezing the lysate at −20°C for approximately 2 h. If there was still inhibition on repeat, a further swab was requested and, if surgery was anticipated within 3 days, the suppression protocol was instigated.

When a patient was found to be MRSA positive, the appropriate doctor or preadmission clinic was informed by telephone and asked to contact the patient to prescribe the suppression protocol. Outpatients were asked to visit the hospital pharmacy to collect a prescription written by the microbiologist.

The suppression protocol was expected to start 5 days before surgery, or the operation might be delayed. In more urgent cases, the suppression protocol was commenced immediately. Mupirocin nasal ointment (2 per cent) was applied to the inside of the nostrils three times daily, and undiluted chlorhexidine gluconate 4 per cent (Hibiscrub®; Moinlycke Health Care, Dunstable, UK) was used as a bodywash. Patients were advised to use undiluted Hibiscrub® as a shampoo to wash hair on days 1, 3 and 5, and to change their clothing and bedlinen daily.

If antibiotic prophylaxis was required, existing practice was to use a combination of teicoplanin and gentamicin. Patients who required emergency surgery before the result of MRSA screening was available were given mupirocin nasal ointment and chlorhexidine wash. The suppressive measures were continued until the result of MRSA screening was known. Blood cultures were obtained when the temperature rose above 37·5°C (either peripherally or from a central or arterial catheter).

The hospital wound surveillance team has examined surgical wounds in all specialties for at least 6 months every year since 2000 by a combination of observation, questioning of staff, examination of case notes, and telephone or postal contact with patients[8]. After discharge, surveillance was performed at 1–2 months. Patients were excluded from wound surveillance if they stayed in hospital for fewer than two nights or if the procedure did not involve wounding (for example, endoscopy alone).

Cost–effectiveness analysis

The annual saving to the hospital attributable to the MRSA screening programme was assessed by comparing the numbers expected (E) in the absence of screening (using incidence rates for 2000–2005 and for 2005 alone) with the observed numbers (O) for 2006. The saving is given by the expression $(E - O) \times C$, where C is the cost per bacteraemia (or wound). C was calculated from the mean treatment costs for MRSA bacteraemia (£3500) and wound infection (£4018), primarily through prolonged hospital stay[8,9]. The estimated daily labour costs (all staff) of looking after an infected patient at UCLH was £314 in a general ward, £1002 in the high-dependency unit and £1390 in the intensive care unit (ICU)[8]. Other costs, such as dressings, drainage and antibiotics, accounted for only 2 per cent of costs. The saving was then translated into bed-years using the benchmark cost of an average medical/surgical bed (£200 above the estimated trimpoint – the point after which a length of stay is determined to be abnormally long).

The cost-effectiveness of the programme was calculated by comparing the saving with the annual cost of screening (including reagents, equipment and staffing).

Statistical analysis

Most statistical tests were performed using Stata™ version 9.0 (StatCorp, College Station, Texas, USA). Incidence rates were compared with Fisher's exact test. The χ^2 test for trends was used to assess monthly and quarterly changes in MRSA prevalence on admission screening. Time to event data were collected for inpatients with positive MRSA screening results and analysed by means of survivorships between January and September 2006. Median times to event and their 95 per cent confidence intervals (c.i.) were calculated from the time to 50 per cent survival in Kaplan–Meier survivorships. For estimates of screening compliance, each surgical operation was considered compliant with the screening protocol if the inpatient had been screened within 6 months before and 2 weeks after surgery.

Results

Between 16 January and 31 December 2006, 20 447 screening samples were received, of which 18 810 were

Table 1 Proportion of patients with meticillin-resistant *Staphylococcus aureus* colonization on admission

Surgical specialty	Elective surgery	Emergency surgery	Total
Anaesthetics	2 of 95 (2)	0 of 11 (0)	2 of 106 (1·9)
Cardiothoracic	25 of 1184 (2·1)	7 of 186 (3·8)	32 of 1370 (2·3)
General surgery	59 of 1459 (4·0)	21 of 279 (7·5)	80 of 1738 (4·5)
Maxillofacial	51 of 977 (5·2)	9 of 163 (5·5)	60 of 1140 (5·3)
Orthopaedics	40 of 1813 (2·2)	30 of 652 (4·6)	70 of 2465 (2·8)
Plastics	15 of 225 (6·7)	16 of 415 (3·9)	31 of 640 (4·8)
Urology	84 of 1929 (4·4)	9 of 81 (11)	93 of 2010 (4·7)
Vascular	13 of 254 (5·1)	2 of 38 (5)	15 of 292 (5·1)
Unknown	0 of 2 (0)	5 of 29 (17)	5 of 31 (16)
All specialties	289 of 7938 (3·6)	99 of 1854 (5·3)	388 of 9792 (4·0)
ICU	n.r.	n.r.	235 of 2736 (8·6)

Values in parentheses are percentages. ICU, intensive care unit; n.r., not recorded.

processed. The remaining samples were discarded as they were from inappropriate sites ($n = 627$), duplicate nares ($n = 423$) or patients found to be MRSA positive on a previous screen ($n = 587$).

There were 850 MRSA-positive samples (4·5 per cent of all samples processed). Patients admitted for emergency surgery were more likely to be colonized (99 of 1854 patients; 5·3 per cent) than those undergoing elective surgery (289 of 7938; 3·6 per cent; $\chi^2 = 10{\cdot}9$, $P = 0{\cdot}001$), resulting in an overall prevalence of 4·0 per cent for all surgical admissions. *Table 1* shows MRSA isolates stratified by surgical specialty and ICU admission. A continuous audit of surgical prophylaxis (as part of the wound surveillance programme) showed no policy changes in antibiotic prophylaxis effective against MRSA between 2000 and 2006[8]. Tests for trend failed to reveal statistically significant changes in the prevalence of MRSA positivity on admission during 2006.

Processing of specimens

A total of 215 positive admission episodes were audited. Median time lags for the processing of positive samples are shown in *Table 2*. The busiest days for laboratory processing were Monday and Tuesday, as a result of the backlog of unprocessed samples collected during the weekend.

MRSA bacteraemia

Fifty-three patients developed MRSA bacteraemia over the study interval, 41 in screened and 12 in non-surgical patients. The annual means and ranges for 2000–2005 were 67 (53–87) and 29 (17–45) respectively in the equivalent patient populations.

The overall rate of MRSA bacteraemia per 1000 patient-days fell by 38·6 per cent compared with 2005 ($P < 0{\cdot}001$; two-tailed Fisher's exact test) and by 38·5 per cent compared with the annual mean for 2000–2005 ($P < 0{\cdot}001$) (*Table 3*). In addition, there was a 32·1 per cent reduction in MSSA bacteraemia compared with 2005 ($P < 0{\cdot}001$) and a 30·4 per cent reduction compared with the annual mean for 2000–2005 ($P < 0{\cdot}001$) (*Table 3*).

Table 2 Median time lag for events in the processing of positive samples

	Time lag
From sample collection to receipt in laboratory ($n = 135$)*	13·7 (9·78, 15·1) h
From receipt of sample in laboratory to obtaining result ($n = 212$)*	21·8 (21·0, 22·5) h
From obtaining result to telephone call ($n = 215$)*	1·03 (0·83, 1·41) h
From receipt of sample in laboratory to start of surgery ($n = 217$)†	0·96 (−0·08 to 5·75) days‡
From start of suppression to surgery ($n = 200$)†§	−0·42 (−1·90 to 2·85) days‡

Values are *median (95 per cent confidence intervals) and †median (interquartile range). ‡A negative value indicates that surgery took place before the sample had been processed. §If less than 5 days to surgery, then suppression continued into the postoperative period.

MRSA wound infection

The rate of isolation of MRSA from wounds fell by 27·9 per cent compared with 2005 ($P < 0{\cdot}001$) but by only 12·7 per cent compared with the annual mean between 2000 and 2005 ($P = 0{\cdot}021$) (*Table 3*). The 2006 MSSA isolation rates did not change significantly compared with those for 2005 (4·4 per cent reduction; $P = 0{\cdot}430$), but increased by 12·7 per cent compared with 2000–2005

Table 3 Incidence rates for meticillin-resistant and meticillin-sensitive *Staphylococcus aureus* bacteraemia and wound infection

		MRSA (per 1000 patient-days)		MSSA (per 1000 patient-days)	
Year	No. of patient-days	Bacteraemia	Wound	Bacteraemia	Wound
2000–2005	1 469 399	0·39 (573)	1·44 (2110)	0·59 (860)	2·58 (3788)
2005	186 867	0·39 (73)	1·74 (325)	0·60 (112)	3·04 (568)
2006	221 027	0·24 (53)	1·25 (277)	0·41 (90)	2·90 (642)

Values in parentheses are numbers of patients. MRSA, meticillin-resistant *Staphylococcus aureus*; MSSA, meticillin-sensitive *S. aureus*.

Table 4 Cost-effectiveness of the rapid meticillin-resistant *Staphylococcus aureus* test screening programme

	MRSA		MSSA		
	Blood	Wound	Blood	Wound	Total
Expected numbers					
Based on 2005 figures	86	384	132	672	
Based on 2000–2005 figures	86	317	129	570	
Observed numbers					
2006	53	277	90	642	
Cost savings (£)					
Versus 2005 figures	£115 500	£429 926	£147 000	£120 540	£812 966
Bed-year equivalents	1·58	5·89	2·01	1·65	11·1
Versus 2000–2005 figures	£115 500	£160 720	£136 500	−£289 296	£123 424
Bed-year equivalents	1·58	2·20	1·87	−3·96	1·69

MRSA, meticillin-resistant *Staphylococcus aureus*; MSSA, meticillin-sensitive *S. aureus*.

($P = 0·006$) (*Table 3*). Although there was a reduction in wound infection in seven of 11 specialties covered by wound surveillance, the overall prevalence was unchanged because of a rise in wound infection in general surgery (surveillance data available only for January to July 2006).

MRSA isolates

There were no significant differences in the proportion of mupirocin resistance (predominantly low levels) in wound and blood isolates between 2005 and 2006: 93 (13·9 per cent) of 671 *versus* 74 (15·7 per cent) of 472 isolates ($P = 0·396$). In surgical and critical care patients in 2000–2006, 11 (6·7 per cent) of 163 isolates tested (281 not tested) were sensitive to ciprofloxacin and 54 (12·3 per cent) of 438 (six not tested) were sensitive to erythromycin.

Compliance with screening and treatment

Compliance with screening in different surgical specialties improved during 2006 (*Fig. 1*). Of 218 audited patients found to have MRSA at or before surgery, 92 either received no topical suppression or it was started only after the procedure. In 30 (33 per cent) of these patients MRSA was later isolated from the surgical wound. The other 126 patients received suppression (at least one dose) before the procedure; in 26 (20·6 per cent) of these patients MRSA was later isolated from the wound ($P < 0·05$, χ^2 test).

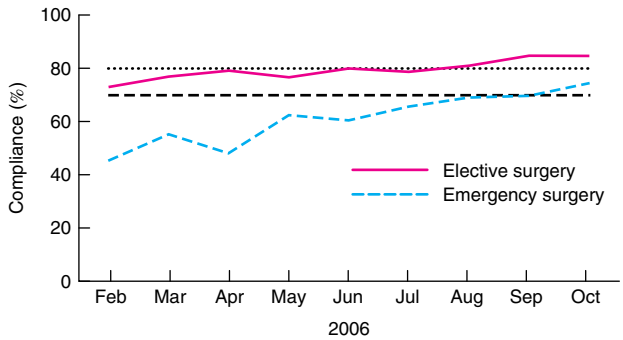

Fig. 1 Screening compliance stratified by elective and emergency surgery. Compliance was measured as the percentage of surgical episodes classified as screened. Dotted and dashed horizontal lines indicate 80 and 70 per cent compliance respectively

Costings

Table 4 shows that the observed reduction in MRSA bacteraemia and wound infection rates was equivalent to a

saving of 3·78 beds per year (£276 220) compared to the annual mean for the preceeding 5 years. The reduction in infection rates was observed both in patients who were screened and in those who were not; in many wards these patients were mixed, so separate costings have not been attempted.

The annual cost of screening was estimated at £302 500 (cost per test: kit £11·59 including value added tax and cost of repeats, £1 for disposable tips, £1 for telephoning results and £3·01 per test for labour; less previous annual spending of £9900), which is equivalent to 4·1 beds for the year. The programme is therefore cost-effective and demonstrates large cost savings when compared to costs incurred during years of peak incidence (for example, 2005).

Discussion

In 2004, the UK Department of Health set a target of a 60 per cent reduction in MRSA bacteraemia by 2008. In January 2006, UCLH became the first National Health Service Trust (public sector corporation) nationally to introduce a rapid molecular MRSA detection technique for routine screening of most surgical patients. Before the start of this project, validation of the technique against culture showed a sensitivity of 95·0 per cent and a specificity of 98·8 per cent, with a positive predictive value of 84·4 per cent and a negative predictive value of 99·6 per cent[7].

Although more than 40 different decolonization regimens have been tested during the past 60 years, topical intranasal application of mupirocin ointment and bodywash with 4 per cent chlorhexidine has proven to be the most effective measure[10]. However, showering of all patients with chlorhexidine before surgery is not effective in reducing surgical infection rates[11].

This study demonstrated a significant reduction in the MRSA bacteraemia rate of 38·5 per cent compared with 2000–2005 figures and 38·6 per cent compared with 2005. A possible explanation is the reduction in the turnaround time for reporting of the MRSA screening swab, such that the suppression protocol and appropriate surgical prophylaxis can be started quickly. There was no other change in the authors' practice, as careful attention to hand hygiene and specific surgical prophylaxis for MRSA carriers had been in place well before the start of this study. These results need to be interpreted with caution, however, as in 2005, 4 months before the commencement of screening, most inpatients had been moved to a new building – this coincided with an increased incidence of MRSA infection. Hence, comparison was made not only with 2005 but also with the preceding 6 years.

The effect on wound infection was modest in comparison with that on blood isolates. There is an appreciable recurrence of superficial MRSA colonization following topical suppression. Unlike bacteraemia, wound infection can be prolonged.

MRSA infection has a cost for the patient and healthcare providers that includes prolonged hospital stay and treatment of complications associated with the infection. Variations in MRSA infection rate, such as the peak reported in 2005, can make it difficult to assess the effect of a screening programme. Although the screening programme is costly, the reduction in MRSA surgical wound infection and bacteraemia produces nearly equivalent savings and the improvements in quality of life for patients are considerable.

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