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Winning the battle but losing the war: methicillin-resistant *Staphylococcus aureus* (MRSA) infection at a teaching hospital

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Summary

A methicillin-resistant *Staphylococcus aureus* (MRSA) control policy, aimed at eradication, was established at a 1000-bed hospital in 1985, applied consistently for 10.5 years, and then relaxed. Its components included screening of high-risk patients, transfer of carriers to exhaust-ventilated isolation rooms, closure of wards to new admissions when local transmission was detected, MRSA screening during outbreaks, and prospective collection of clinical and epidemiological information. During the eradication policy period, every 6 months, a mean of 5.1 patients (range 1–12) already carrying MRSA were admitted, and a mean of 3.6 (range 0–16) acquired carriage in the hospital. The largest outbreak comprised 11 patients despite epidemic MRSA strain EMRSA-16 being introduced six times, and MRSA did not become endemic. MRSA-positive admissions increased progressively from 1993; nursing staff workload increased, areas available for alternative patient accomodation were reduced, the resulting ward closures interfered with clinical services, and hence the control policy was relaxed in mid-1995. Isolation facilities were overwhelmed with 622 new patient-isolates in the next 18 months, and there were 67 clinical infections in 1996. The proportion of blood cultures positive for MRSA rose nearly sevenfold by 1996 and 27-fold by 1997. Thus, repeated eradication of MRSA, even epidemic strains, by use of a stringent policy, is possible given sufficient resources, whereas flexible national guidelines designed to control, but not eradicate, epidemic staphylococci, are currently unlikely to be successful. The costs of eradication policies need to be weighed against those of endemicity.

Introduction

In the UK, 16 epidemic methicillin resistant *Staphylococcus aureus* strains have been described, and currently three of these (EMRSA-3, -15 and -16) are most commonly referred to the Staphylococcus Reference Unit, Central Public Health Laboratory, Colindale.[1] Referrals of EMRSA-15 and -16 are rising progressively, and informal discussions indicate that transmission of these strains has become endemic in many hospitals in England and Wales with numerous associated clinical infections. Surprisingly, only one detailed report of the establishment of EMRSA-16 endemicity at the local level has been published.[2] This involved a district general hospital where MRSA had apparently not been encountered before;

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infection control efforts were rapidly overwhelmed, and the strain become endemic at the hospital. Hence, the abilities of EMRSA-15 and -16 to compete with other strains, and their impact on tertiary referral hospitals with long-term experience of MRSA control and good isolation facilities, have not been documented.

A standardized MRSA control policy had been established at Addenbrooke's Hospital, Cambridge in 1985 which was similar to, but more detailed than the UK national guidelines introduced in 1990.[3] This policy was strictly enforced between 1985 and mid-1995, with minimal changes. This report describes 12 years of full surveillance (a 10.5-year period before the MRSA policy was relaxed in mid-1995, and the course of MRSA control over the next 1.5 years), plus 1 year of very limited surveillance. The hospital's first EMRSA-15 outbreak is summarized to illustrate the working of the original policy.

Methods

Hospital and patient details

Addenbrooke's NHS Trust is a 1000-bed district, tertiary referral and teaching hospital. There are currently 151 single-bedded rooms, 19 of which are exhaust-ventilated, including 12 on a specialist Infectious Diseases ward. About 1000 patients per annum are transferred directly from other hospitals, and many more are admitted after recent discharge from other hospitals.

Infection Control Nurses visited all in-patients usually on the day they were found to be MRSA-positive. From 1985, infections were defined according to Centres for Disease Control criteria,[4] and from mid-1993 the definitions of the UK Hospital Infection Society were used.[5] Written records of cases were kept, including standardized epidemiological and clinical information from 1989. All cases with apparently newly-introduced strains and their early positive contacts were investigated for recent hospital admissions. Whenever possible, Infection Control Teams in their hospitals of origin were also contacted to enquire about local MRSA problems. Apparently newly-introduced strains were recorded as having been introduced to Addenbrooke's NHS Trust if a plausible external source could be identified and if there was no plausible local source.

Numbers of blood cultures performed per annum, and numbers of *S. aureus* bacteraemias, were obtained from contemporary written and computer records. Numbers of Finished Consultant Episodes,[6] the standard measure of hospital in-patient workload in the UK, for the period 1992–6 were obtained from computer records of Addenbrooke's NHS Trust Finance Department. These included in-patient and day-case episodes (not extra-contractual referrals), and were available only by financial year. Reliable and consistent measurements of hospital inpatient workload are not available for earlier years, hence it has not been possible to calculate MRSA acquisition rates per in-patient day, admission or discharge. From 1993 the GRASP System[7] measure of nursing staff workload was used throughout Addenbrooke's NHS Trust.

Bacteriological methods

Screening swabs for MRSA carriage taken by staff on general wards were inoculated to ¼ of a Mannitol Salt Agar plate (5% sodium chloride, incubated at 37 °C overnight in air), then placed in Brain Heart Infusion Broth containing 5% sodium chloride and incubated for 24 h before subculture to ¼ of a Mannitol Salt Agar plate. All screening swabs from single patients taken by the Infection Control Nurses (and by some other wards) were placed in single broths. The first MRSA isolate of each sensitivity pattern from each patient was stored at –70 °C and referred to the Staphylococcus Reference Unit, Central Public Health Laboratory, Colindale, for confirmation and phage typing.

MRSA control policy 1985–94

From 1985, all clinical wound swabs from in-patients were inoculated to ¼ Mannitol Salt Agar plate and investigated for MRSA, but this was stopped in 1990 because of the low return. From 1985, MRSA screens were to be performed on all admissions to intensive care units, the Transplant Ward, and on previously MRSA-positive patients. In 1993, admission screening was introduced for all who had been in-patients outside the East Anglian Region during the previous 3 months, and for those who had been in-patients at hospitals outside the UK. Whenever possible, patients were isolated in single rooms until the results of screens were available. Audit in mid-1995 revealed that screening was done within 24 h of admission in about 75% cases, but that isolation was possible in only 25%, mainly because isolation facilities were full.

Newly recruited staff were screened by the Occupational Health Department (nose, broken skin) if they had worked on a ward in any hospital during an MRSA outbreak, or had worked in hospitals in London or outside the UK within the past 2 years.

Figure 1 summarizes the procedures when a new strain of MRSA was isolated from a patient. Immediate action was taken, including isolation and attempted clearance of the index case, standardized

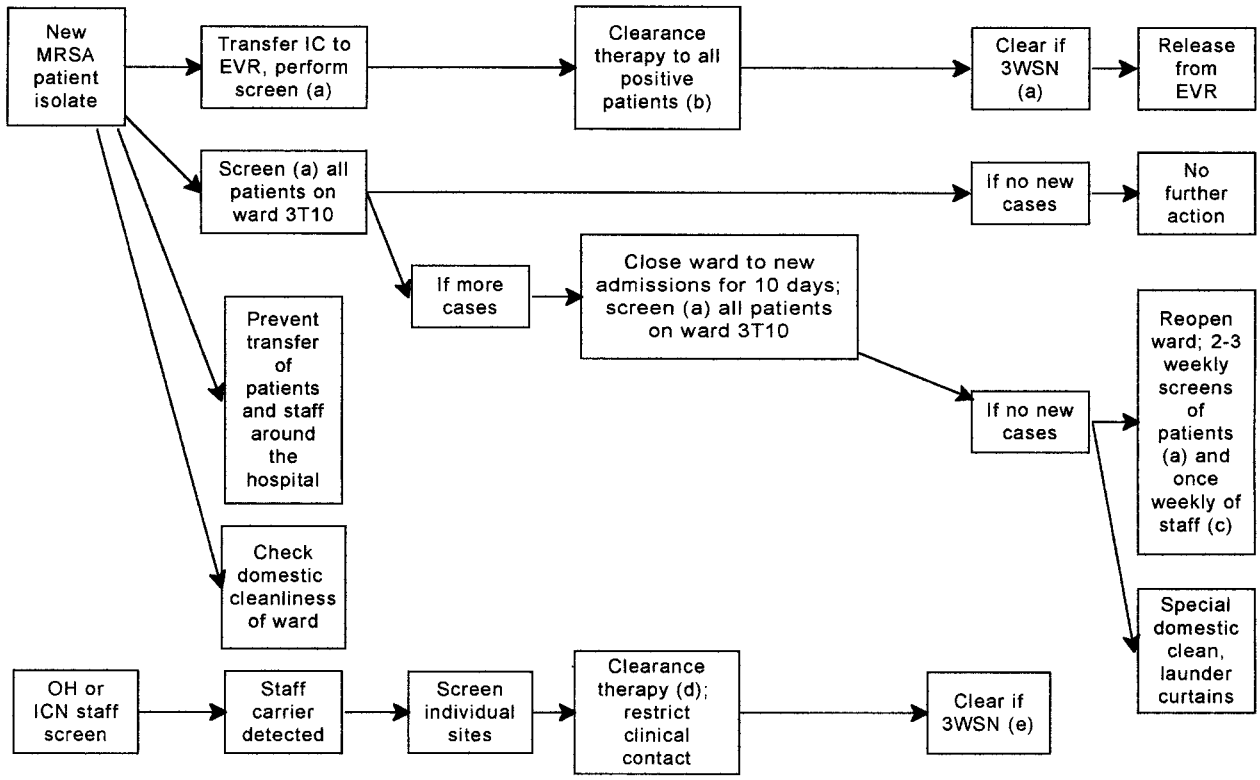

Figure 1. Summary of MRSA control policy employed from 1985 to July 1995. IC, index case; EVR, exhaust-ventilated isolation room on Infectious Diseases Ward, Intensive Care Unit or Transplant Ward; 3T10, screened three times over a 10 day period; 3WSN, screened weekly (screen a) for 3 consecutive weeks; OH, Occupational Health Department; ICN, Infection Control Nurse. Screens were: (a) nose, throat, skin breaks, catheter urine; (c) nose, broken skin; (e) nose, throat, broken skin. Clearance regimens were: (b) (patients) individual carriage sites screened, then given 5 days therapy with mupirocin to anterior nares and skin lesions, triclosan bath concentrate, chlorhexidine hairwash, hexachlorophane dusting powder to axillae and groins, chlorhexidine dental gel, and vancomycin gargles; (d) (staff) individual carriage sites screened, then given nasal mupirocin for 5 days. Carriage at other sites was treated as in (b), but vancomycin gargles were not used. Staff whenever possible remained off clinical duties for 24 h. In EVRs, staff wore gloves, surgical facemasks and gowns. All screening of patients was performed by Infection Control Nurses, and all screening of staff either by the Occupational Health Department or by Infection Control Nurses.

repeated screening of patients on the index ward, restriction of movement of exposed patients and staff, and cleaning of the ward environment. Wards were closed to new admissions if a second patient in contact with the index case was found to be positive with the same strain (usually defined at this stage by antibiotic sensitivity pattern), indicating that transmission had occurred on the ward. According to this policy, the end of an outbreak was defined as 5 or 6 negative screens over 3.5–4.5 weeks.

Results

Experience before autumn 1994

Before autumn 1994, a mean of 5.1 patients per 6 months (range 1–12) had been admitted to Addenbrooke's NHS Trust with MRSA (Figure 2), and a mean of 3.6 patients (range 0–16) had acquired MRSA carriage locally. The largest number of secondary cases following a single introduction was 10. Multiple different strains of MRSA had been involved, including admission of six patients with EMRSA-16 after January 1992 (spread from these occurred to only eight secondary cases). Endemicity had not been established, and clinical infections were uncommon (see Table 1).

Most MRSA introductions and outbreaks until 1991 were associated with the Transplant Ward, where bacteraemias and attributable mortality ensued among the ward's vulnerable in-patients. Thereafter the aim of the Infection Control Team at the time (Dr R.E. Warren and Mrs P. Whipp) was to maintain eradication of the organism. Although disruption of clinical services occurred during ward closures, it was often possible to find alternative patient accommodation. For example, newly-admitted, critically-ill patients were admitted to a spare recovery room adjacent to the main operating theatres when an MRSA outbreak occurred on the adult ICU, and they

Table 1 Clinical infections with MRSA, infection rates, number of staff positive and bacteraemia data 1989–97

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997
Blood*	1	0	0	1	2	1	12	18	74
Wound	1	1	1	4	3	3	14	37	–
IVI	0	1	0	0	1	0	4	5	–
Urine	0	0	0	0	0	0	2	2	–
Chest	0	0	0	0	0	1	7	5	–
Total no. infections	2	2	1	5	6	5	39	67	–
Infection rate** (%)	29	22	10	26	25	6	18	14	–
No. staff positive	0	0	2	4	8	40	14	19	42
Staff positivity rate† (%)	–	–	1	1	2	3	1	44	44
Total *S. aureus* bacteraemias (% MRSA)	–	–	–	–	83 (2.4)	88 (1.1)	100 (12.0)	121 (14.9)	182 (40.7)
B/c performed	–	–	–	–	9431	9895	10778	12028	13258
B/c positivity rate (%)††									
MRSA	–	–	–	–	0.021	0.010	0.11	0.15	0.56
MSSA	–	–	–	–	0.86	0.88	0.82	0.86	0.78
Nursing utilization[$] (%)	–	–	–	–	117.2	115.7	122.3	124.5	125.8
Daily census[$$]					20.4	20.0	21.3	21.5	21.8

IVI, significant numbers of MRSA colonies (>20) isolated from intravenous line tip. *Patients who had MRSA bacteraemia and infection of another site are listed only under 'Blood'. Patients with multiple positive blood cultures are counted only once if the cultures were less than 10 days apart. All other figures relate to patient not isolate numbers. **Number of MRSA clinical infections as a proportion of total MRSA patient isolates. †Number of staff positive for MRSA as a proportion of staff members screened at least once during the year. Multiple screens of the same individual taken during single outbreaks are only counted once. ††Percentage of total blood cultures performed from which MRSA or MSSA were isolated. B/c, blood culture. [$]Mean utilization percentage[7] of available nursing time for the 30 wards with complete data. A further 11 wards had incomplete data and were excluded. [$$]Mean number of patients per day on the 30 wards.

were nursed with staff who did not also work on the original ICU. Agency nursing staff were usually available to support cohorting of staff and patients. Hence, bed closure was minimized at the expense of increased staffing costs. Until 1991–2, once MRSA transmission on a closed ward had apparently ceased, any remaining exposed patients were usually transferred *en bloc* to the Infectious Diseases Ward until three screens over 10 days were negative. Latterly, other pressures on isolation beds made this impracticable, and such patients were usually cohorted with dedicated staff on their original ward.

EMRSA-15 outbreak in autumn 1994

EMRSA-15 was first isolated from an elderly patient in September 1994, and this was followed by a large outbreak lasting 13 weeks which involved 33 patients and 28 staff on four wards (two in the Department of Medicine for the Elderly, one surgical and one medical). Three wards were closed to new admissions for a total of 17 weeks. Figure 3 shows the composite outbreak curve.

Thirty-two patients received 34 courses of MRSA clearance therapy, each lasting 5 days. Sixteen of these (47%) were successful whereas seven courses failed (21%), but two of these responded to repeat therapy. All but two of the successful episodes were preceded by prolonged rather than transient colonization. Eleven courses were unassessable. Twenty-four staff were managed by the Occupational Health Department and were successfully cleared, but only four had persistent rather than transient carriage.

Only two clinical infections were seen (infection rate 6.1% of MRSA-positive patients), and both occurred in post-operative patients who had been transferred to the surgical ward. A total of 3354 separate samples were processed during the outbreak, and 57 (1.7% of screens performed) patient and staff carriers were detected by screening. A detailed description of the eradication of this outbreak will be published elsewhere.

Revised MRSA control policy

Because the rate of ward closure in the first 6 months of 1995 was compromising the clinical functions of the hospital, the MRSA control guidelines were relaxed in July 1995 after discussion among the Infection Control Team, Infectious Diseases Physicians, other clinicians and managers. More secondary cases (usually between 2 and 10) were allowed before wards were closed, and the variables considered are shown in Table 2. Wards were reopened after only two negative screens within a 7-day period. Staff screening was delayed usually until two or three secondary cases had been detected, although staff skin lesions were sought from the beginning. Patients with in-patient contact in any hospital within the past 3 months were screened, as were all admitted from nursing homes. Most patients received one course of MRSA clearance therapy, but this was often delayed until skin breaks had resolved and intravenous and urinary catheters had been removed. Oral vancomycin was not used, but some patients and staff received additional oral rifampicin plus fusidic acid.

The revised MRSA management guidelines reduced the rate of ward closure from one ward per 30 days for the first half of 1995, to one per 98 days for the second half and to one per 72 days throughout 1996.

Table 2 Factors considered by the Infection Control Team when deciding whether to close an affected ward to new admissions from July 1995

Factor group	Factor encouraging closure
Patient-related	High infection/colonization ratio among affected patients.
	Affected patients had not been isolated in single rooms.
	Intensive nursing care had been required.
	Affected patients had colonized sputum, exfoliative skin conditions or were nursed on therapeutic airbeds.
Ward-related	Ward affected was an Intensive Care Unit, acute surgical, orthopaedic or transplant ward where a high infection/colonization ratio might be expected.
	Ward affected was not regularly screened for MRSA.
	Ward affected had poor isolation facilities.
	Environmental contamination was detected.
Hospital-related	Hospital's EVRs were fully occupied.
Staff-related	Staff skin lesions were detected.
Organism-related	The strain of MRSA was suspected or known to be an EMRSA, or had already demonstrated an ability to spread rapidly.

EVR, exhaust-ventilated isolation room on Infectious Diseases Ward, Intensive Care Unit or Transplant Ward.

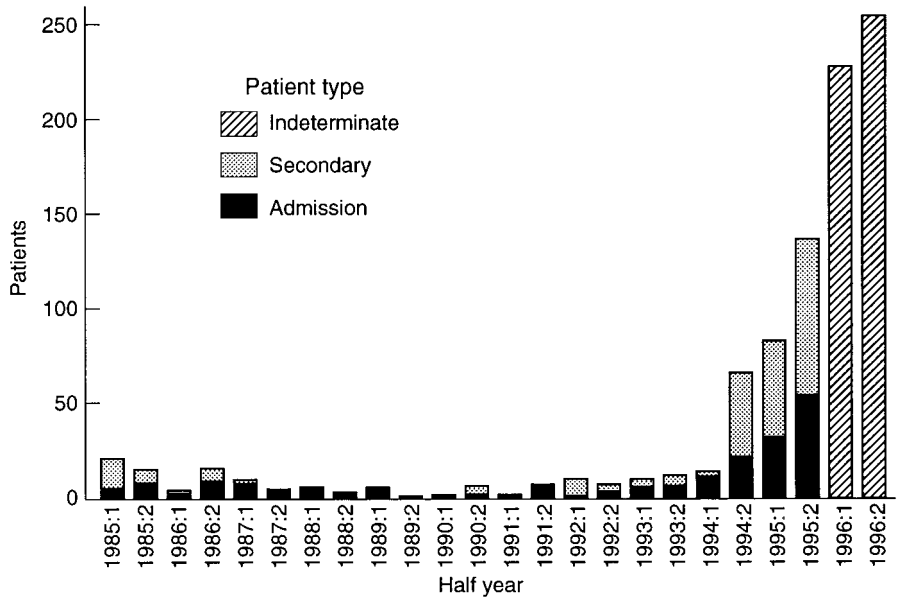

Figure 2. MRSA at Addenbrooke's NHS Trust 1985–96. Vertical bars indicate the numbers of new patients each 6 months who were admitted with pre-existing MRSA carriage (Admission), and numbers who were believed to have acquired MRSA carriage within Addenbrooke's NHS Trust (Secondary). Attribution to Admission or Secondary groups was not possible in 1996, hence patients in this period are classified as Indeterminate.

Subsequent MRSA experience

Rising numbers of introductions of EMRSA-15 and -16 were seen from autumn 1994. Table 1 shows the sites of clinical MRSA infections and the infection rate among patients, the numbers of staff positive per year from 1989, the numbers of blood cultures performed, and methicillin-sensitive *S. aureus* (MSSA) and MRSA bacteraemias recorded from 1993, and mean utilization percentage of available nursing staff for the 30 wards with complete data from 1993 to 1997. With the exception of 1994, utilization of available nursing staff rose progressively from 117.2% in 1993 to 125.8% in 1997. Utilizations between 90 and 100% create a quality climate, those between 111 and 130% indicate that staff are working to maximum capacity, and those above 130% imply that staff are having to prioritize even essential tasks.[7] In 1993, seven wards had average utilization percentages above 130 for the 12-month period, and this number had risen to 12 in 1997. Figure 4 shows blood culture data for 1993–7. Numbers of Finished Consultant Episodes at Addenbrooke's NHS Trust rose steadily from 51 016 in 1992–3, 68 191 in 1993–4, 74 670 in 1994–5, to 77 634 in 1995–6.

EMRSA-15 comprised about 60% of patient isolates during 1996, and EMRSA-16 about 30%. Because of workload pressures which reduced surveillance activities by the ICT, and because the majority of patients were affected with one or another of only two phage types, it was often impossible to determine the source of EMRSA-15 and -16 strains, hence place of acquisition of MRSA cannot be shown in Figure 2 for 1996. Transmission was especially common on DME wards, with 132 new cases detected in 1996 (33% of the hospital total for the year), and 402 in 1997 (34%). Outbreaks on acute wards sometimes followed transfer of patients from DME wards to acute wards after surgical operations, as was seen in the first EMRSA-15 outbreak (Figure 3). Increasing numbers of previously positive patients were readmitted from home and other community sources, especially elderly patients. These amounted to between 20 and 25 per month by mid-1996. Both strains have become endemic within Addenbrooke's NHS Trust. In 1996, the number of known MRSA carriers in the hospital varied between 30 and 50 (3–5% total beds), and at one time in Autumn 1997 the number exceeded 90 (9%). These numbers can

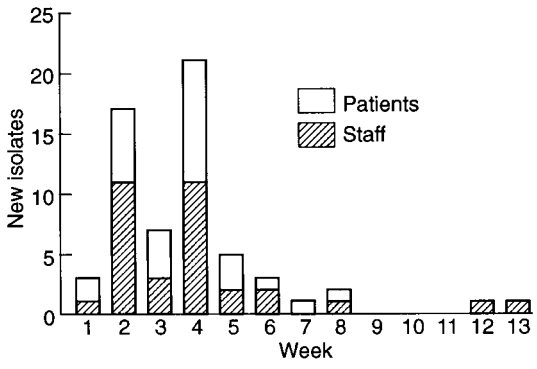

Figure 3. Outbreak curve of 33 patients and 28 staff following the first introduction of EMRSA-15 to Addenbrooke's NHS Trust in September 1994.

no longer all be isolated in single rooms on many units within the hospital, where cohorting in bays is now performed. Alternative patient accommodation became progressively less readily available from 1993–4. For example, in 1993 the spare theatre recovery room occasionally used previously as a 'clean' ICU area was converted to an extra operating theatre plus offices. Comprehensive epidemiological and clinical data collection became unsupportable in 1997, although bacteraemias were still monitored as before, hence only bacteraemic isolates are recorded in Table 1 for that year. We recorded 526 new MRSA-positive patients in the first half of 1997, and 646 in the second half. Thus, the total number of MRSA-positive patients for the 13-year period was 2109.

Discussion

Although the startling rise in the prevalence and clinical significance of MRSA described in this paper will be familiar to many UK Infection Control teams, the consequences of this change for individual hospitals have passed largely undocumented. Staphylococcal transmission is influenced by many factors, which makes it hazardous to draw firm conclusions about causation from observed changes in prevalence. Similarly, well-controlled trials of the numerous possible individual interventions are virtually impossible to perform. In Addenbrooke's NHS Trust, with an initially low prevalence of MRSA and relatively extensive isolation facilities, a policy that gave prompt attention to all the likely modes of transmission eradicated multiple introductions and small outbreaks throughout a 10-year period. Since 1993, a steady rise in the number of patients already carrying MRSA when admitted enforced a relaxation of the policy, and resulted in a marked increase in the rate of nosocomial transmission and the numbers of clinically significant MRSA infections (see Figure 2 and Table 1). Battles were still being won by eradication of individual outbreaks even in mid-1995, but the war had been lost by the relentlessly increasing pressure of opposing numbers.

Flexible control policies are superficially less disruptive and appear less demanding of resources than are those that aim at eradication. However, the average costs of nosocomial infections in UK hospitals are considerable[8] and use of the expensive glycopeptide antibiotics vancomycin and teicoplanin within Addenbrooke's NHS Trust for prophylaxis and therapy is rising annually, as are the associated numbers of drug monitoring assays (data not shown). This picture will be common to any hospital in which MRSA is prevalent. We do not have all the information necessary to calculate the cost of the establishment of MRSA endemicity at Addenbrooke's NHS Trust and our referring units, but it cannot simply be assumed to be less than that of the alternative strategy in which all local hospitals strive for eradication. We agree with Bowler[9] that studies on the relative costs to society of alternative staphylococcal control policies are urgently needed, because investment, for example, in improved isolation facilities may be rewarding when balanced against the costs of infection.

Very few studies of long-term MRSA surveillance at the hospital level have distinguished between locally-acquired cases and cases positive on admission, and those that did have usually classified all cases detected 48 h or more after admission as nosocomial.[10] In our experience, MRSA was first isolated from many index cases, who had undoubtedly been positive on admission, long after this time, and a number of patients were shown to have first acquired MRSA carriage or infection within a few hours of being admitted. Our allocation of patients to 'newly admitted' or 'locally acquired' groups is unlikely to have been fully accurate, but it was consistently applied and we believe it is the best that can be achieved in the context of a routine Infection Control service.

Different components of the original strict control policy were probably important in various outbreaks, but no delay ensued while the epidemiology of each was investigated and selective control procedures later applied. Others have reported successful eradication of MRSA with prompt implementation of comprehensive control measures that included isolation of carriers and ward closure.[11] In a study similar to our own, Linnemann *et al.*[12] demonstrated a prolonged reduction in MRSA cases hospital-wide while a stringent isolation policy was in force, and a rise in prevalence after its withdrawal. Perhaps in parallel with our experience of the DME acting as an MRSA reservoir, the outbreak described by Linnemann *et al.* was perpetuated by a poorly-designed burns unit, and the prevalence fell markedly when a modern unit with better patient segregation was opened.[12] In contrast, others have reported reduced MRSA prevalence with emphasis being placed only on routine barrier precautions.[13,14] The significance of these studies is weakened, however, because eradication from the hospitals was not achieved, much less detail is given about screening protocols, limited distinctions are made between newly-admitted and locally-acquired cases, and it is not possible to judge whether epidemic MRSA strains were involved.

Transmission of MRSA is now rising within many UK hospitals,[1] hence isolating high-risk admissions while screening results are obtained is increasingly demanding of Infection Control resources. Ward

closure and cohorting of staff and patients also cause considerable clinical disruption. As a result, some authors have called for all hospitals to be less 'aggressive' and adopt more 'reasonable' MRSA control measures.[15,16] However, these suggestions are not based on long-term, comprehensive surveillance data with comparative costings. Revised British guidelines for MRSA control are shortly to appear[17] and these will advocate a flexible response once initial efforts at eradication have failed.[18] If current trends continue, we predict that hospitals who initially aim for eradication will be forced by transfer of affected patients to follow the example of their more 'reasonable' neighbours.[10] We recommend, however, that eradication should be pursued for as long as is practicable, for we are not alone in documenting the rapid rise in MRSA acquisition after the capacity of a hospital's isolation facilities has been exceeded.[19] We have no evidence that the predominant route of transmission of MRSA under either policy was not, as usually reported, via the unwashed hands of staff.[10] It is possible that the major benefits of transferring all positive patients to exhaust-ventilated isolation rooms (EVRs) on the Infectious Diseases ward may have come predominantly from the skilled practices of the nursing staff rather than from reduced airborne transmission. It would be speculative to ascribe the recent rise in MRSA prevalence in Addenbrooke's Hospital to the relaxation of particular measures contained within the original policy: the increased admissions of already-positive patients (see Figure 2), rising nursing staff workload (see Table 1[7]), and possibly greater transmissibility of epidemic MRSA strains may also have been influential. Our choice of measures in the revised policy was aimed to reduce clinical disruption and ICT workload, while maintaining an overall level of control.

Active control measures have repeatedly been shown to reduce MRSA colonization and infection,[2,20] and Cookson[17] emphasized the cost-effectiveness of the relatively aggressive measures recommended by the BSAC Working Party in 1990.[3] Although the detection rate of new carriers with our policy was low (1.7%), others have demonstrated the epidemiological value and cost effectiveness of screening contacts and high-risk admissions.[17,21,22] Our original policy, in a hospital with 15% single rooms including a specialist isolation unit, could probably cope with about 30 MRSA admissions per year, plus associated re-admissions.

In Addenbrooke's NHS Trust, the total burden of serious staphylococcal clinical infection increased as MRSA became more prevalent. MRSA bacteraemia rose from 1–2 cases per year in 1994 and before (0–2.4% total *S. aureus* bacteraemias; see Table 1 and Figure 4), to 12 cases (12.0%) in 1995, 18 cases

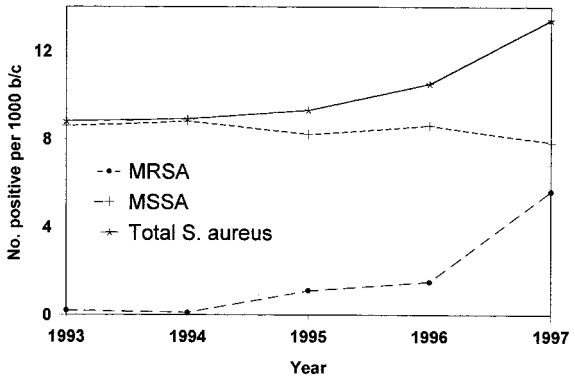

Figure 4. Changes in *Staphylococcus aureus* blood culture positivity rate at Addenbrooke's NHS Trust, 1993–7.

(14.9%) in 1996 and 74 cases (40.7%) in 1997. Numbers of blood cultures performed rose between 1993 and 1997, as did hospital workload, but the proportion positive for MSSA was unchanged (0.86%) in 1993 and 1996, and fell only a little in 1997 (0.78%). In contrast, the proportion of blood cultures from which MRSA was isolated rose sharply from 0.02% to 0.56%. Patients infected with MRSA tend to have been in hospital for longer, to have more severe underlying disease and to have received more antibiotic therapy than those with sensitive strains,[10,23,24] hence MRSA and MSSA tend to affect different populations. These factors may explain our observations and those of the majority[20,22,24–27] of others (but not all[12]) that numbers of clinical infections with MRSA rise and fall largely independently of those with MSSA.

Although the prevalence of MRSA bacteraemia rose steeply, the proportion of patients infected with MRSA compared with those only colonized has ranged between 6% and 29% without showing any marked trend (Table 1). This clinical infection rate is lower than has generally been reported for acute hospital units, and is more in line with that associated with long-term care facilities.[10] This may be a result of the comprehensive, repeated screening for asymptomatic carriers specified in our original policy, or to the involvement of many elderly patients at low risk of clinical infection. Because surveillance of infections other than bacteraemia has been discontinued, it has not been possible to gather comparable information after 1996 to investigate these hypotheses further.

'Epidemic' strains of MRSA presumably have special adaptations that fit them for dissemination within hospitals. Our original control measures had, however, coped with six introductions of EMRSA-16 before June 1994, and the first EMRSA-15 outbreak was also successfully controlled despite large numbers of patients and staff acquiring carriage in the early stages (Figure 3). MRSA became endemic at

Addenbrooke's NHS Trust first on the wards of the DME after numbers of interhospital transfers of positive patients rose, while nursing workload increased, and while flexibility in patient accomodation was reduced, hence bacterial properties may not be the only explanation for apparent 'epidemic' behaviour. More research is required to investigate the adaptations that enable EMRSA strains to be such successful nosocomial pathogens in the UK today.

Although controversial, attempts at clearing patients of MRSA carriage may be considered especially worthwhile in hospitals with a low prevalence.[10,28] For example, aggressive control measures that included clearance of carriers have been shown greatly to reduce both crude and attributable mortality rates,[21] and patients colonized with MRSA even on low-dependency units have four times the clinical infection rate of uncolonized patients.[29] Similarly, Pujol *et al.*[30] found that relative risks of staphylococcal bacteraemia in nasal carriers of MRSA in an ICU were nearly four times those of matched carriers of MSSA. Screening for and clearance of MRSA colonization from health-care workers are also contentious issues.[9,10,15,17,18] In 1996 and 1997, 44% of staff who were screened were positive, compared with 0–3% in previous years. This may indicate that the revised policy is genuinely more effective at identifying positive staff members. Alternatively, the background prevalence of MRSA carriage by staff may have increased, such that large numbers are now unknown carriers. Twenty-eight of the 40 staff positives in 1994 were detected in the early stages of the EMRSA-15 outbreak on the DME. The low sensitivity of staff screening in 1995, despite the new policy being in place from July, is due to large numbers of screens being performed at the end of the EMRSA-15 outbreak at the beginning of the year, most of which were negative.

Closure of wards to new admissions was a cornerstone of our original strict control measures. After introducing the new policy in mid-1995, we closed wards seven times in the next 18 months (normally when large numbers of clinical infections were seen), and MRSA transmission rapidly ceased in every case. We speculate that ward closure may be effective by reducing staff workload, leaving more time for Infection Control procedures. Several studies have associated outbreaks of cross-infection with periods of increased nursing staff workload.[31–33] Because of recruitment difficulties we have not tested the alternative strategy of increasing numbers of nursing staff while admissions continue. It is unfortunate that the GRASP System[7] was not in place before MRSA-positive admissions began to increase, but the system demonstrated that nursing workload rose after 1993 and 1994, with 12/30 (40%) assessed wards having to prioritize necessary care in 1997. The fall in nursing utilization percentage in 1994 may well be explained by the fall in mean daily patient census (see Table 1) which has in turn been attributed to bed closures that happened for contractual reasons. In addition, changes in skill mix were implemented in 1994 that increased the total numbers of staff on most wards while reducing the proportion of trained staff. By use of the GRASP system, we are currently analysing the effects of ward closure on nursing workload and MRSA transmission during individual outbreaks from 1994 to 1997, and this will be the subject of a future report.

Addenbrooke's NHS Trust's weak performance in the 1995 Hospital League Tables was attributed to the bed closures associated with MRSA outbreaks. Having uncommitted physical and staffing resources gives a hospital the flexibility to close wards to admissions and cohort staff and patients, while limiting the effects on other clinical services. Our experience may illustrate Casewell's assertion[34] that recent changes in UK health care, including reduced staffing levels and elimination of 'spare capacity', compromises the ability of hospitals to control the spread of MRSA. Prospects for control of the emerging vancomycin-resistant staphylococci[35] are also bleak if adequate staff numbers and isolation facilities are not available, and unless many hospitals agree that a sustained, active response is worthwhile.

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