

Surveillance and epidemiology of MRSA bacteraemia in the UK

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Surveillance of bacteraemia caused by methicillin-resistant *Staphylococcus aureus* (MRSA) in the UK has involved collection of data from hospital microbiology laboratories via several mechanisms, including a voluntary reporting scheme that has been operational in England and Wales since 1989 and mandatory reporting schemes that have been running independently in England, Wales, Scotland and Northern Ireland since 2001. In addition, surveillance schemes involving panels of participating sentinel laboratories that submit isolates for centralized susceptibility testing, such as the Bacteraemia Resistance Surveillance Programme run by the BSAC, have also been established. Each of these data sources have particular advantages, but they also have their individual limitations, with the result that they each give an incomplete picture if considered in isolation. However, by pooling the findings from these different but complementary surveillance programmes, a much more comprehensive and credible picture of the problem posed by MRSA is produced. These schemes have shown both a dramatic rise in the total numbers of cases of *S. aureus* bacteraemia reported annually and an increase in the proportion of such cases that involve MRSA (from 2% in 1990 to >40% in the early 2000s), although the most recent data indicate a slight reversal of these trends. Characterization of isolates of MRSA shows a marked temporal relationship between the rise in MRSA bacteraemias and the emergence and spread of two strains of epidemic MRSA, EMRSA-15 and EMRSA-16. Surveillance and control of MRSA infection continue to be high profile and further developments to the mandatory surveillance system in England are likely in the near future.

Keywords: nosocomial infections, *Staphylococcus aureus*, antibiotic resistance

Introduction

Shortly after the introduction of benzylpenicillin into clinical use in the early 1940s, isolates of *Staphylococcus aureus* were found that were resistant to penicillin, owing to production of β -lactamase. Under the selective pressure of increasing penicillin usage, the proportion of *S. aureus* that were penicillin-resistant increased, such that by 1948, over 50% of isolates in many hospitals were resistant.¹ The trend of increasing penicillin resistance both continued and persisted, as evidenced by the fact that 80–90% of *S. aureus* noted in recent surveys were resistant.^{2,3}

As part of the strategy for combating penicillin-resistant *S. aureus*, a series of semi-synthetic penicillin derivatives that were stable to staphylococcal β -lactamase were developed and introduced into clinical use during the 1960s.⁴ The first of these was methicillin, followed by the isoxazolyl penicillins oxacillin, cloxacillin, dicloxacillin and flucloxacillin. The latter agents were not only more active against penicillin-resistant staphylococci than methicillin, but had the advantage of being suitable for oral administration. Although studies conducted around the time that methicillin was introduced into use indicated that clinical isolates of *S. aureus* were uniformly susceptible to this agent, the first

isolate of methicillin-resistant *S. aureus* (MRSA) was reported from the UK in 1961, the year after the drug was introduced.⁵ Subsequent work showed that the resistance to methicillin was mediated by expression of a novel penicillin-binding protein with low binding affinity not only for methicillin, but for all licensed β -lactams.⁶ Although methicillin is no longer used in clinical practice, having been superseded by the isoxazolyl penicillins, particularly flucloxacillin in the UK, the acronym MRSA has continued to be used when referring to *S. aureus* resistant to these agents.

The isolate of MRSA reported in 1961 was the only one found among about 5000 isolates examined, and MRSA remained uncommon in the UK for several years thereafter. However, their prevalence gradually increased in the late 1960s, and by 1971 they comprised 5% of *S. aureus* isolates referred to the Staphylococcus Reference Laboratory.⁷ There was a subsequent decline in their prevalence in the mid-1970s, possibly owing to increased prescribing of aminoglycosides, to which many MRSA were susceptible at that time. However, by the late 1970s outbreaks owing to gentamicin-resistant MRSA were seen in a number of hospitals.⁸ During the 1980s, there was a resurgence in the prevalence of MRSA, possibly reflecting the emergence of strains with epidemic potential (discussed below). The remainder of this review will focus

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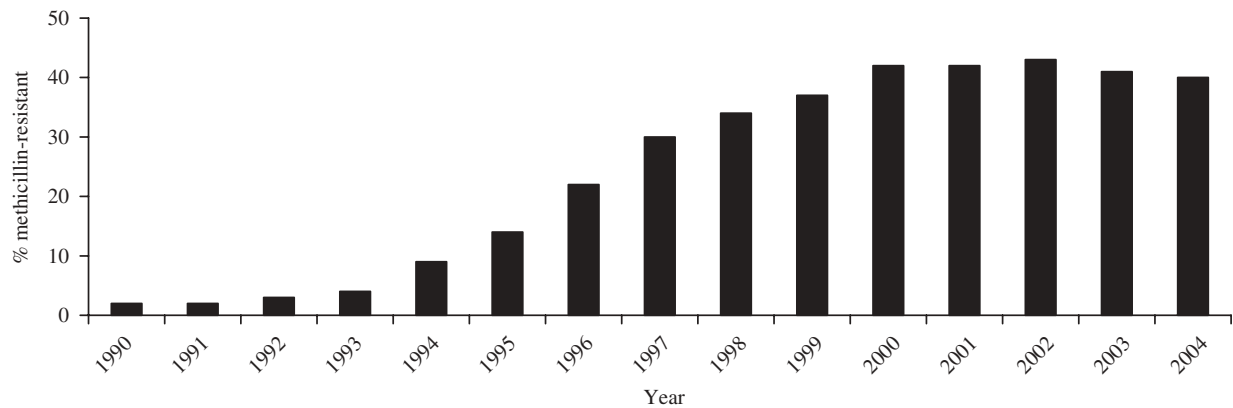


Figure 1. Data from voluntary reporting of the proportion of isolates of *Staphylococcus aureus* from blood culture that are methicillin resistant, England and Wales.

particularly on data accumulated throughout the 1990s and the present decade, during which time there was a dramatic rise in the occurrence of invasive MRSA infections in the UK.

Surveillance programmes for monitoring MRSA bacteraemia

Voluntary reporting of routinely generated susceptibility test results

The voluntary reporting of microbiological diagnoses by hospital laboratories to the Health Protection Agency (HPA), and its predecessor the Public Health Laboratory Service (PHLS), has been a mainstay of the surveillance of infectious disease in England and Wales for many decades. In particular, the agency's Communicable Disease Surveillance Centre (CDSC), which is now part of the HPA Centre for Infections, has played a central role in the collection and analysis of such data. For the past 30 years, laboratory reports sent to the PHLS/HPA have been stored in a computer database known as LabBase. Originally, laboratory reports were received by post as hand-written or typed forms, but since 1991, data have increasingly tended to be submitted electronically, initially through EpiBase, then via CoSurv.^{9,10}

Historically, microbiological reports submitted to the PHLS, did not include the results of antimicrobial susceptibility tests. However, following the increasing recognition of the problem posed by antimicrobial resistance and the establishment of a national Reference Laboratory for antimicrobial-resistant bacteria in the late 1980s, it was decided that data on the antimicrobial susceptibility or resistance of bacteria should also be collected. Thus, from 1989 onwards, hospitals have been requested to supplement laboratory reports of bacteraemia and meningitis by inclusion of the results of their routine susceptibility testing. This voluntary surveillance system provides antimicrobial susceptibility data not only for *S. aureus*, but also for a wide range of bacterial genera and species isolated from blood or CSF, with trends in resistance for the most commonly occurring organisms being reported regularly in the Communicable Disease Report Weekly (CDR Weekly), available on the HPA website (<http://www.hpa.org.uk/cdr/index.html>).

Analysis of voluntary reports of *S. aureus* bacteraemia in England and Wales showed a dramatic year on year increase in the proportion of isolates that were resistant to methicillin during

the 1990s, rising from 2% in 1990 and 1991 to a peak of 43% in 2002, with a slight decline thereafter (Figure 1).^{11–17} Moreover, analysis of the data by region showed that invasive MRSA infections are clearly a widespread problem, as increases in the proportion of *S. aureus* isolates that are methicillin resistant were noted in all health regions in England, as well as in Wales and Northern Ireland.^{15,16,18} In addition, data from the Scottish Centre for Infection and Environmental Health, which is now part of Health Protection Scotland, indicate that essentially the same situation exists in Scotland, with ~41% of *S. aureus* isolates from blood being methicillin-resistant in 2000–2001.¹⁹

Analysis of rates of MRSA bacteraemia using data stratified by patient age showed that the main burden of MRSA bacteraemia is in adults, particularly the elderly. Nonetheless, the rate of methicillin resistance among blood culture isolates of *S. aureus* from children aged <15 years increased from 0.9% in 1990 to 13% in 2000. The trend was most notable in infants, where the rate increased from 1% in 1990 to 15% in 2000, and the authors speculated that this may reflect an increase in MRSA from premature infants in neonatal units over that time period.²⁰ To investigate this further, in June 2005, HPA researchers, in collaboration with others including the British Paediatric Surveillance Unit of the Royal College of Paediatrics and Child Health, commenced a year-long programme of enhanced surveillance of MRSA bacteraemia in children.

Mandatory reporting of MRSA bacteraemia

A drawback of surveillance programmes based on voluntary reporting is under-ascertainment of cases. In the case of MRSA bacteraemia, this may take two forms, namely failure of a laboratory to report cases of *S. aureus* bacteraemia *per se*, or the situation in which the laboratory reports a case of *S. aureus* bacteraemia but fails to provide the results of susceptibility testing that indicate whether the isolate is methicillin resistant or susceptible.

In an attempt to provide consistency of reporting, the Department of Health has made it mandatory for acute NHS hospital Trusts in England to report all cases of *S. aureus* bacteraemia, and to report the number that are due to MRSA.²¹ This surveillance programme commenced in April 2001, with the resulting data for 6 or 12 month periods being published in the CDR Weekly or on the HPA website.^{22–26} In addition, results for individual Trusts are published on the Department of Health website (<http://www.dh.gov.uk/assetRoot/04/10/55/18/04105518.pdf>). With regard to the

surveillance methodology, data are reported by acute NHS Trusts in each health region in England to the relevant Local and Regional Services Division of the HPA and transferred to the CDSC at Colindale for national analysis. In this scheme, rather than simply reporting the proportion of *S. aureus* isolates that are methicillin resistant, the results are additionally presented as the rate of MRSA bacteraemia in each Trust per 1000 occupied bed days, the latest overnight bed occupancy data for each trust being derived from the KH03 dataset available from the Department of Health (<http://www.performance.doh.gov.uk/hospitalactivity/>).

At the time of writing, data for the 4 year period spanning April 2001 to March 2005 are available for England.²⁶ The proportions of blood culture isolates of *S. aureus* that were methicillin resistant in each of these four 12 month (April–March) periods were 40.4%, 38.9%, 39.7% and 38.9%, respectively, which are broadly consistent with the corresponding MRSA rates seen with the voluntary reporting scheme (Figure 1). During this time, the total numbers of MRSA reported in the mandatory surveillance scheme increased from 7249 in year 1 (2001–2002) to 7684 in year 3, with a decrease to 7212 in the fourth year.²⁶ The seemingly conflicting finding of a lower rate of methicillin resistance after the first year coupled with two successive yearly rises in the total number of MRSA isolates from blood, is explained by the concomitant increase in the numbers of methicillin-susceptible *S. aureus* isolated from blood, which rose from 10 684 in 2001–2002 to 11 692 in 2003–2004.²⁶

The other main finding from the mandatory reporting scheme was that the overall rate of MRSA per 1000 bed days in England varied within the range from 0.17 to 0.19 over the 4 year period, with the overall rate in the fourth year (0.17 per 1000 bed days) being the same as that reported in the first year of the scheme. The rates varied between different types of Trust, tending to be lowest in single speciality Trusts, and highest in specialist Trusts, with the rates in general acute Trusts falling between them.²⁵

Mandatory surveillance of MRSA bacteraemia was also established independently in Wales and Scotland in April 2001 and in Northern Ireland from April 2002 (although data from a pilot scheme undertaken in Northern Ireland from April 2001 to March 2002 are also available).^{27–29} Initially, all three surveillance programmes collected and analysed data reported directly by Trusts, using occupied bed days in each Trust as the denominator. However, the scheme was subsequently modified in Scotland, in that from January 2003, data from an additional source, namely blood culture isolates of MRSA referred to the Scottish MRSA Reference Laboratory, were also collected, the two datasets being combined and reconciled.³⁰ This enhancement resulted in an approximately 15% increase in the rate of MRSA bacteraemia ascertained. Although the mandatory reporting scheme should have included all cases of MRSA bacteraemia, the increased ascertainment noted in the combined surveillance programme indicates that this was not the case.

The mean overall rates of MRSA bacteraemia per 1000 occupied bed days in England, Wales, Scotland and Northern Ireland from 2001 to 2004 were in the ranges 0.17–0.19, 0.10–0.13, 0.14–0.18 and 0.12–0.17, respectively.^{25–29,31–35} Although the overall rates for the different geographical regions appeared to show some variation, it should be stressed that there was often marked intra-regional variation between the rates seen in different Trusts. For example, while the overall rate of MRSA bacteraemia in Wales between October 2003 and September 2004 was 0.11, the rates reported by the 13 Welsh Trusts during that time period ranged from 0.04 to 0.17.²⁷

Surveillance systems using sentinel laboratories

A number of surveillance studies using networks of sentinel laboratories have also investigated the prevalence of antimicrobial resistance among pathogens including *S. aureus* isolated from patients with bacteraemia in the UK. The SENTRY surveillance programme, which has been running since 1997, is international in scope, and allows comparison of data from different countries. However, a drawback of this project is that the number of participating laboratories in individual countries is often low, raising the issue as to whether the data presented for these particular countries are representative of each country as a whole. This problem was particularly marked for the UK during the first few years that the programme was running, as only one hospital laboratory contributed data from 1997 to 1999,^{36,37} although the number of participating laboratories increased to four by 2002.³⁸ The European Antimicrobial Resistance Surveillance System (EARSS) is another international surveillance programme in which some UK hospital laboratories participate. This scheme, which collects data on MRSA rates in *S. aureus* bacteraemia across Europe,³⁹ commenced in 1999, since when the number of UK laboratories participating has increased from 26 to 56. The increase in participating laboratories in large part reflects the fact that initially only hospitals in England, Wales and Northern Ireland participated, but since 2003, laboratories in Scotland have also joined the surveillance programme. The findings from the UK arm of EARSS are slightly higher, although broadly consistent with those from the voluntary reporting scheme described above, with the rates of methicillin resistance among blood cultures isolates of *S. aureus* increasing from 33% in 1999 to 43.6% in 2004.³⁹

The high proportion of MRSA among blood culture isolates of *S. aureus* in recent years was confirmed in the bacteraemia surveillance study carried out by the HPA Antibiotic Resistance Monitoring and Reference Laboratory under the auspices of the BSAC. In this study, which commenced in 2001 and involves 25 sentinel laboratories geographically dispersed throughout the UK and Ireland, the rates of MRSA among cases of *S. aureus* bacteraemia in 2001, 2002 and 2003 were 43%, 41% and 40%, respectively.^{40–42} Another surveillance scheme looking at rates of antimicrobial resistance among isolates from blood culture was that undertaken by the Nosocomial Infection National Surveillance Service.⁴³ In this surveillance study, which ran from May 1997 to March 2002, information was collected on 10 871 episodes of hospital-acquired bacteraemia in 10 300 patients from 96 English hospitals. Overall, 26% of the isolates were *S. aureus*, of which 54% were methicillin resistant. The higher proportion of MRSA seen in this study compared with the others described above probably reflects the fact that only hospital-acquired bacteraemias were included in the analysis. This meant that, in contrast to the other studies, cases of bacteraemia owing to methicillin-susceptible *S. aureus* that originated in the community were not included in the denominator when the proportion of isolates that were methicillin resistant was calculated.

The emergence and spread of epidemic strains of MRSA (EMRSA) in the UK

A questionnaire-based survey involving hospital microbiologists undertaken in the UK in early 1984 indicated that while MRSA were present in every health region, certain areas, notably London

and Merseyside, were particularly heavily affected.⁴⁴ Later that same year, phenotypic characterization of MRSA referred to the PHLS Staphylococcus Reference Laboratory by phage typing, biochemical tests and determination of antibiotic susceptibility patterns showed that the problem experienced in London largely reflected the spread of a single strain of MRSA.⁴⁵ This strain, which was clearly adept at spreading both within and between hospitals, was subsequently designated an epidemic MRSA strain and assigned the epithet EMRSA-1. In a subsequent survey over a 6 month period in 1987–1988, in which 660 isolates of MRSA from 570 patients were characterized, 14 strains of MRSA (including EMRSA-1) that affected more than one hospital were identified. These strains were all regarded as having epidemic potential and were designated EMRSA-1 to EMRSA-14.⁴⁶

In retrospect, the 14 strains of EMRSA varied markedly in their epidemicity. In the 1987–1988 survey, EMRSA-1, which was the strain originally identified as highly prevalent in London in 1984, occurred in 50 hospitals and was obtained from more than 40% of the patients included in the survey. In contrast, with the exception of EMRSA-3 and EMRSA-12, the other EMRSA strains identified each affected fewer than 10 hospitals. Further surveillance in the late 1980s and early 1990s showed a decline in the prevalence of EMRSA-1 and an increase in EMRSA-3.⁷ However, a major change in the epidemiology of MRSA infections in the UK was associated with the emergence in the early 1990s of two new EMRSA strains (designated EMRSA-15 and EMRSA-16), which were remarkably successful at spreading between hospitals.^{47,48} EMRSA-15 was initially identified in southeast England and the Midlands in 1991, subsequently spreading to hospitals in the north of England, while EMRSA-16 emerged at about the same time in Northamptonshire. Both strains have spread widely to affect a large number of hospitals across the UK and they remain the dominant strains of MRSA, accounting for 93–95% of MRSA isolates seen in recent years.^{49,50} More recently, another new epidemic strain (EMRSA-17), characterized by a high degree of multidrug resistance, was identified in southern England.⁵¹

Genetic characterization of MRSA and EMRSA strains by multi-locus sequence typing (MLST) has shed light on their evolution and population structure. The application of this technique, which involves comparison of the partial nucleotide sequences of so-called housekeeping genes, has shown that different lineages of MRSA have arisen from methicillin-susceptible strains of *S. aureus* on multiple occasions, by the acquisition of the *mec* gene complex, which encodes the genes required for methicillin resistance.^{52–54} Interestingly, while MLST confirmed that EMRSA-15 and MRSA-16 are not closely related in evolutionary terms, it revealed that some EMRSA strains (e.g. EMRSA-1, -4 and -11) that appeared distinct on the basis of phenotypic tests or PFGE belonged to the same genetic lineages.⁵³

The factors accounting for the epidemicity of EMRSA strains in general, and EMRSA-15 and -16 in particular, are not fully understood at present, although some risk factors for colonization or infection have been identified. Isolates of EMRSA-15 and -16 are commonly resistant not only to β -lactams but to erythromycin and ciprofloxacin,⁵⁵ and a study in Aberdeen Royal Infirmary, which had been affected by these strains, showed that there was a dynamic temporal relationship between the monthly rates of MRSA infection and previous use of macrolides, third-generation cephalosporins and fluoroquinolones.⁵⁶ This suggests that the use of antimicrobials to which an outbreak strain is resistant may be an important contributory factor for persistence of that strain. By the

same token, it might be that the introduction of ciprofloxacin into clinical use in the late 1980s contributed, at least in part, to the decline in the prevalence of EMRSA-1, as this epidemic strain was susceptible to ciprofloxacin.⁵⁵ Work undertaken in the USA has also shown that quinolone use is a risk factor for MRSA infection, as after adjustment for multiple variables, exposure to either ciprofloxacin or levofloxacin was significantly associated with isolation of MRSA but not methicillin-susceptible *S. aureus*.⁵⁷ Use of ciprofloxacin as a risk factor for colonization or infection with MRSA clearly merits further investigation, particularly as two possible mechanisms for promoting MRSA infection have been described. First, this agent has been shown to be secreted in sweat onto the skin,⁵⁸ where presumably it may act on quinolone-susceptible bacteria that comprise part of the normal skin microflora. The resulting reduction in the skin flora may facilitate the colonization of skin by quinolone-resistant MRSA, owing to the reduced number of bacteria competing to establish or maintain themselves in this ecological niche. Secondly, laboratory studies have shown that exposure of quinolone-resistant isolates of MRSA to subinhibitory levels of ciprofloxacin results in the induction of fibronectin-binding proteins and an associated increase in adhesion to fibronectin-coated surfaces.⁵⁹ This suggests that exposure of MRSA to ciprofloxacin *in vivo* may result in increased binding to fibronectin, either in host tissues or on the surface of coated indwelling prostheses.

The epidemiology of MRSA bacteraemia

As surveillance of MRSA infections in the UK has primarily involved ascertainment of cases of bacteraemia, the majority of the data available relate to infections in hospitalized patients. It is clear from these data, however, that hospitalized patients vary in terms of their risk of developing MRSA bacteraemia. As discussed above, analysis of data from the voluntary reporting scheme stratified by patient age showed that MRSA bacteraemia is more common in adults, particularly the elderly, although the rates in children have increased in recent years.²⁰ Similarly, data from the mandatory surveillance programmes indicate that the rates of MRSA bacteraemia vary between different types of Trust, suggesting that, in broad terms, patients in hospitals with different case mixes or patients in different specialties may have different levels of risk. Further support for this idea came in particular from the mandatory surveillance undertaken in Wales, which from October 2001 also collected data on the medical specialty where patients were being treated when blood cultures were taken. Analysis of these data showed that while the overall proportion of *S. aureus* bacteraemias owing to MRSA was 43%, the proportions varied markedly between specialties, ranging from 58–60% in general surgery and ICUs to 9.5% in paediatrics and 6.3% in special care baby units.⁶⁰

Although invasive MRSA infections have been seen primarily in the hospital setting, there has long been anxiety about their emergence in the community. It was widely assumed that if MRSA became a problem in the community it would reflect the 'escape' of MRSA from the hospital environment, probably initially to nursing and residential homes, and possibly thereafter into the general community. Indeed, at the time of the emergence of EMRSA-16 in Northamptonshire in the early 1990s, it was noted that the outbreak strain affected not only patients in three hospitals in that area, but also residents in six nursing or residential homes and three patients living at home.⁶¹ Of the three patients living at home, one, who had not been in hospital for 40 years, had a son who

had recently been an in-patient in a surgical ward, while the second attended a day hospital and the third was cared for by a relative who worked as a nurse in a long-stay ward in a local hospital. In a subsequent prevalence survey carried out between November 1996 and July 1998, 13 (4.7%) of 275 residents in 17 nursing homes in Northamptonshire were found to be colonized with MRSA.⁶² Although in these surveys patients in the community were colonized rather than infected with MRSA, there have been a number of other reports of serious and sometimes fatal infections in the community, often involving children. Such reports have emanated from diverse regions of the world including various European countries, the USA, Australia and New Zealand.^{63–66} Investigations revealed, however, that many of the patients affected had no demonstrable epidemiological links to a hospital or nursing home setting. Moreover, characterization of the isolates showed that they differed from typical nosocomial isolates in being susceptible to all classes of antimicrobials except β -lactams. More strikingly, molecular analysis showed them to be genotypically distinct from MRSA strains found in local hospitals. Analysis of community-acquired MRSA (CA-MRSA) from a number of different regions showed that in addition to the above phenotypic and genotypic traits, isolates appeared to characteristically contain a gene encoding a putative virulence determinant, the Pantone–Valentine leucocidin (PVL).⁶⁶

At the time of writing the HPA Staphylococcus Reference Laboratory had confirmed 100 isolates of CA-MRSA in England and Wales during the previous 3 years, and had further isolates of suspected CA-MRSA that were undergoing characterization.⁶⁷ This represented <0.005% of the MRSA isolates received by the Reference Laboratory each year. In contrast to previous reports, some of the isolates of CA-MRSA received by the Reference Laboratory have lacked the gene encoding PVL. This was seen particularly in a series of clonally related isolates that caused injection-site abscesses and bacteraemia in injecting drug users throughout in England and Wales.⁶⁸ Clearly, further surveillance and research is required if we are to define the extent of the problem posed by the occurrence of CA-MRSA in the UK.

Discussion

The combination of voluntary reporting of routinely generated susceptibility test results for blood culture isolates of *S. aureus* over the past 15 years, the introduction of mandatory reporting of bacteraemia owing to methicillin-susceptible and -resistant *S. aureus* in 2001 and the collection of data from sentinel laboratories in other surveillance studies, coupled with phenotypic and molecular characterization of isolates has yielded considerable insight into the occurrence and epidemiology of MRSA bloodstream infections in the UK. Although each of the data sources described have particular advantages, they also all have their individual limitations, with the result that they each give an incomplete picture if considered in isolation. For example, voluntary reporting has provided valuable demographic and clinical information but suffers from under-ascertainment of cases. In contrast, the mandatory reporting scheme has yielded data on total numbers and rates of MRSA bacteraemia that are more robust, but did not collect demographic or clinical data. Similarly, while susceptibility data collected from Trusts via either the voluntary or mandatory schemes will have been produced using a variety of laboratory testing methods, the data produced in studies such as the BSAC bacteraemia surveillance programme will have been produced by the centralized testing of isolates using standardized validated

methods. As there is no in-built quality assurance system in the voluntary or mandatory reporting schemes, it is reassuring that the data are highly comparable to those produced in the BSAC bacteraemia surveillance programme. Thus, by pooling the findings from the different surveillance programmes, a much more comprehensive and credible picture of the problem posed by MRSA is produced. This highlights the importance of bringing together information from complementary systems.

The most striking finding from surveillance is the dramatic increase in the proportion of *S. aureus* isolates from blood culture that are methicillin resistant that has occurred during the last 12 years (Figure 1). Analysis of the data has clearly indicated that the problem is one of UK-wide proportions, in that all health regions in England, as well as Wales, Scotland and Northern Ireland, have been affected. As a general principle, rates of antibiotic resistance can increase by the regular emergence of resistance in previously susceptible organisms under the selective pressure of relevant antibiotic usage, by the spread of already resistant pathogens from person to person, or by a combination of the two. With regard to the increase in MRSA that has been seen in the UK, the finding that the overwhelming majority of isolates tested belong to one or other of two epidemic clones clearly suggests that person-to-person spread is the main factor responsible. This is an important concept in terms of developing intervention strategies for controlling MRSA infections and has led some to highlight the critical importance of hand hygiene among hospital staff.⁶⁹

The surveillance strategies described above have enhanced our understanding of the epidemiology of MRSA bacteraemia in terms of the national and regional picture, and as such, provide a valuable framework for resource planning both on the part of government and private sector, including pharmaceutical companies engaged in research on anti-infectives. However, it should be stressed that optimization of patient care requires effective local surveillance of antimicrobial resistance at individual hospital and speciality/unit level. Although the data from the mandatory surveillance programme are fed back to Trusts, the objective was specifically to provide sufficient data to assess the extent to which rates of MRSA infection vary between similar types of hospital, and not to provide a substitute for local surveillance. Responsibility for monitoring local rates of MRSA infection (and infections due to other resistant pathogens) and acting on the findings continues to rest with individual Trusts. However, the data fed back to individual Trusts from the mandatory surveillance schemes provide a valuable adjunct to their local surveillance activities, and should be further enhanced by developments such as the inclusion of statistical process control charts, which provide individual Trusts with a means of distinguishing between natural variation in rates of MRSA bacteraemia and 'special cause' variation, which requires specific investigation.^{27,28,60}

With regard to future mandatory surveillance of MRSA bacteraemia, two particular issues have been identified that should impact on the quality and interpretation of the data collected. The first of these involves the collection of specialty-based data. As mentioned above, the mandatory surveillance scheme operating in Wales already collects such data and analysis has shown that there is marked variation in MRSA rates in different hospital specialties.⁶⁰ In a communication issued in June 2005, the Department of Health, under the auspices of the Chief Medical Officer and the Chief Nursing Officer, notified Trusts in England of their intention to collect information on the department or speciality where patients

were being treated at the time of infection.⁷⁰ The rationale for collecting this additional information is that it will give greater insight into risk factors for MRSA bacteraemia, which in turn will both provide a better evidence base for the formulation of national policy and help Trusts better understand their local situation, thus enabling them to take appropriate targeted action with regard to infection control.

A second issue to be addressed is the use of denominator data that can be applied in settings where patients do not stay in hospital overnight. The denominator used to date (i.e. occupied bed days) is commonly based on the number of occupied beds in a Trust counted overnight. While this is a useful denominator for undertaking broad comparisons of the MRSA rates in different Trusts, there is increasing awareness that for some particular specialties, this may generate misleading information. For example, renal patients are prone to develop bacteraemia, but many do not remain in hospital overnight. Should a renal patient develop MRSA bacteraemia, they would be included in the numerator data collected as part of the mandatory surveillance scheme, but they may not be included in the denominator (which is based on overnight bed occupancy) used for calculating the rate of MRSA bacteraemia. Thus, further work is required to generate a fuller understanding of the relative risk of developing MRSA bacteraemia in this particular hospital setting.

Given the clinical and financial impact of MRSA infection on the NHS, it is crucial that surveillance should continue in the UK for the foreseeable future. The surveillance undertaken to date has provided significant insight into the prevalence and epidemiology of MRSA infections, and continuation of these efforts, combined with improvements in the quality and quantity of the data collected, will both further our understanding and provide a mechanism for monitoring the effectiveness of intervention strategies.

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