Ghasson Shabha – Birmingham City University, UK

Aiming to further reduce MRSA spread

The effectiveness of current design and management intervention systems in combating hospital-acquired Methicillin Resistant *Staphyloccus aureus* (MRSA) infections in British hospitals is examined in this article. MRSA is a prevalent bacterium in UK hospitals which, together with other organisms, remains a cause for concern amid increasing incidences of healthcare-associated infection (HCAI). It has penetrated virtually every hospital, and a chronic endemic state remains in most, with episodes of cross-infection and outbreaks.

Plans for more robust deep cleaning systems to combat superbugs including MRSA might be advantageous. These are part of other measures which have been introduced to control the spread of infection to some extent, but how robust and effective are they in controlling the spread of the infection? What technological improvements and interventions can be made to maximise MRSA control in hospitals, and what role can facilities managers (FMs) play in addressing the problem of such far-reaching complexity in the light of the wealth of MRSA knowledge-base generated over the past few years?

This article assesses the effectiveness of the current design and management systems in controlling the spread of MRSA in secondary care Trusts in England. Current technological developments in hospital design and environmental systems will also be reviewed and analysed. Effective day-to-day management systems will be explored, and the roles and responsibilities of facilities managers as knowledge integrators in tackling MRSA addressed.

What makes hospitals difficult to manage?

Hospitals are very complex, highly serviced organisations, which makes them very difficult to manage. They can perhaps best be described as an array of many interdependent, interwoven technologically complex services, human and environmental control systems, and their many processes, interactions, influences and interfaces. Hospitals are invariably in a state of change encompassing, as they do, a complex matrix of activities and diverse range of users, including visitors, patients and staff. Additionally they require robust, round-the-clock management input to ensure effective functionality, which is often costly. Equally, of course, a hospital environment can be a reservoir for potentially infectious agents, which must be controlled and managed effectively (NHS, 2001).

MRSA can easily circulate through the air supply and return via ventilation systems.

MRSA has increasingly become one of the major sources of HCAI in hospitals in Britain, and the main contributory factor to 100,000[A] cases per annum, leading to approximately 5,000 deaths in the UK every year, according to a National Audit Office (NAO) report (July 2006). MRSA is a Gram-positive bacterium which can be transmitted through cross-contamination and direct contact. Additionally it thrives in relatively non-humid environments, when compared to *Listeria* and *Salmonella*, and feeds on flakes of dead, dry human skin (Dancer, 1999). It can withstand desiccation at a higher temperature of 18-37°C, and is thus a frequent component of hospital dust, making it more likely to spread via ventilation and air-conditioning systems.

The spread of infection in a hospital is a complex process and difficult to manage. As shown in Figure 2, it relies mainly on a trio of factors: i) source, ii) mode of transmission and iii) susceptible recipient(s). The source can be a person who could be a patient and/or staff in an outbreak scenario, object, environment or substance from which the infectious agent is transmitted to the host (NHS 2001).

The relationship between host and the internal environment is quite critical, as this might contribute to, and accentuate, HCAI. However, when hosts, the primary source of cross-infection, are factored into any equation, the laws of logic are constantly being moved and become more difficult to predict and manage. Mode of transmission can be via direct contact, cross-contamination, airborne, or a combination of both, as shown in Table 1.

Many contributory design and environmental factors to outbreaks of MRSA infection have been identified in literature, including ward design, bed occupancy,[C] and intensity of use of particular hospital areas. In the past, hospital design focused on low cost per square metre. This was based on models of nursing care derived from industrial settings, where the transmission of infection was not the primary consideration (Butcher, 2006). New design models have been developed subsequently to address these deficiencies that incorporate the latest evidence-based research on infection control to ensure patient safety and minimise cross-infection due to sharing of facilities and medical equipment. It can be argued that design factors can indirectly affect modes of transmission during day-to-day patient and staff activities, with the pattern of use of hospital space, medical equipment, devices and furniture all potentially leading to cross-contamination. By the same token, bed occupancy and intensity and frequency of use

Ghasson Shabha

Ghasson Shabha is Facilities Management MSc course leader at the School of Property, Construction and Planning at Birmingham City University.

> 'Hospitals are becoming more airtight and warmer to comply with Building Regulations, compromising indoor air quality significantly.'

of particular hospital areas impacts on the proximity of users to each other, with closeness more likely to increase cross-contamination. Daily staff procedures and practices may be another trigger.

Lessons from the US have shown that incorporating into healthcare facilities new private rooms, installing more sinks to encourage frequent handwashing, and new ventilation system design, were all key factors in incidences where the impact of HCAIs has been reduced.[D] In one particular case study an 11% fall in infection rates since a building's opening was attributed to the use of private rooms (Van Enk, 2006).

Other wide-ranging design measures to reduce HCAIs have been proposed by the American Institute of Architects (AIA) in the Institute's new guidelines including, *inter alia*, separation of patients with communicable diseases in damp-dusted, separately ventilated areas, securing a safe clinical environment, and appropriate provision of isolation rooms and facilities. Hospital speciality[E] and ward speciality[F] are also relevant, while intensive care and endoscopy units, and internal wards, are more susceptible to MRSA infection than others.

Several preventative methods have been developed to inhibit the growth of bacteria by providing long-term, hard-wearing surfaces

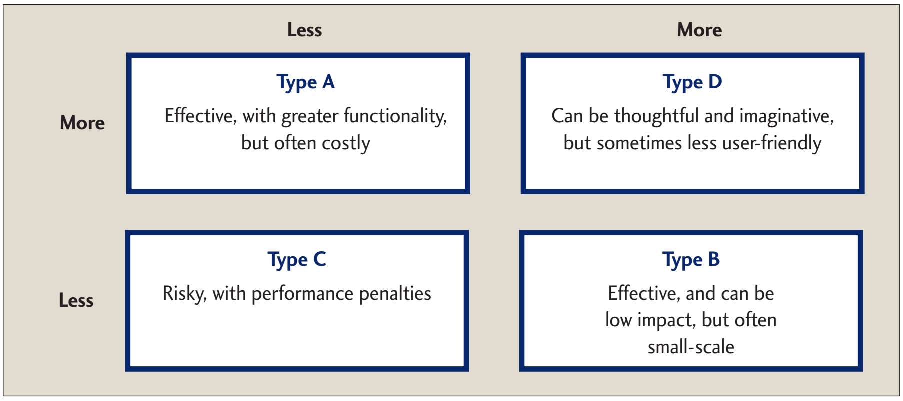

Figure 1: Technological complexity of buildings (Bordas & Leman 2001).

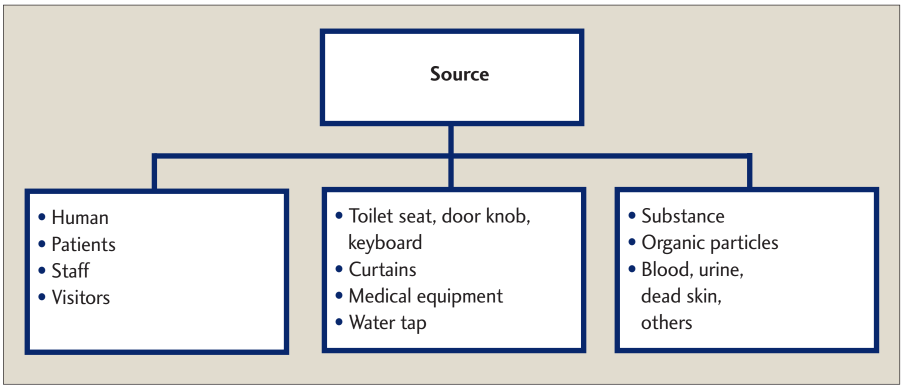

Figure 2: Source of infection.

which contain anti-bacterial properties. Currently several products have been introduced into the UK market. These include BioCote, Addmaster and Dulux antibacterial paint among many others. (www.biocote.com, www.AddMaster.co.uk, www.icipaints.com)

The efficacy of such products is determined by accessibility of the antibacterial agent/additives at the coating/bacteria interface. This is mainly based on slow release of the agent to maintain an effective concentration at, and near, the material's surface. MRSA spread via medical equipment and appliances has also been highlighted in existing literature; the demands for emerging medical technology conflict with the need to control and contain microorganisms that lead to cross-contamination. Improving procedural/ managerial measures to ensure that safety and wellbeing of patients is followed through,

Table 1: Modes of transmission.

Modes of transmission	Possible culprits	Current technological intervention	Managerial implications
Direct contact	• Carrier (patient, staff, visitors), furniture, room equipment, curtains. • Infectious agent (organic substance). • Objects.	• Clinical screening. • Anti-bacterial coatings (silver and copper).	• Deep cleaning. • Hygiene protocols. • Uniform management. • Isolation of immuno-suppressed.
Cross-contamination	• Equipment/devices (ventilator, peripheral catheter, urinary catheter, mechanical, ventilator, parenteral nutrition, blood pressure cuffs, stethoscope). • Sanitary appliances, floors, walls and other hard surfaces.	• Silicon membrane. • Silver coating technologies. • Copper coating technologies.	• Disinfecting techniques. • Decontamination. • Rigorous cleaning.
Airborne	• Hospital dust circulated through mechanical ventilation AC systems (filters, internal wall of ducting, diffusers). • Air pressure differentials in areas where infected patients are cared for.[B] • Both humidity level and air temperature are pertinent media for the growth and spread of MRSA.	• Design of isolation rooms held at negative pressure to reduce aerosol escape to those outside the room, and a higher air-change rate to allow rapid removal of aerosols. • Fumigation. • U/V techniques. • Filtration techniques.	• Duct cleaning. • Disinfecting protocols.

and the implementation of new surveillance, screening and detection systems, may prevent further spread of MRSA infection (HSC 2000/002, 032).

There is a need for an in-depth understanding of the mechanism of how MRSA colonies spread in existing hospitals. Humidity level and air temperature are pertinent media for the growth and spread of airborne and surface cross-infection of MRSA.

Improving ventilation systems

Most patients spend up to 90% of their time indoors. Several claims have been made regarding the link between the cleanliness of the air, its level of ionisation, and the performance of people working in the conditioned space (MacRae, 2007). MRSA has been considered to be a frequent component of hospital dust. It can easily circulate through the air supply and return via ventilation systems, posing a major risk of cross-infection. The situation has been exacerbated due to the need to conserve and optimise energy efficiency, leading to significant reduction in natural ventilation from fresh air. This is currently below the latest requirement of Part F of the Building Regulations, which stipulates a minimum circulation rate of 12 litres/person/sec.

Hospitals are becoming more airtight and warmer to comply with Building Regulations, compromising indoor air quality significantly. This might prove to be detrimental to patient wellbeing, due to higher risk of airborne cross-infection in sensitive hospital areas such as those for bone marrow treatment, intensive care and A&E care.

The changes in energy efficiency regulations require buildings to be "better sealed" and "more airtight". The new Part F Document provisions have been designed to ventilate buildings having air permeability down to $3m^3/h/m^2$ at 50 Pa, allowing designers to plan to "worst case", as Buildings Regulations document Part L allows air permeability up to $10m^3/h/m^2$. As hospitals are becoming more airtight and warmer, they are more likely to require air-conditioning systems.

Role of filtration processes

Several methods of filtration have been developed over the past few years. Multi-stage filtration has been introduced by Toshiba (www.toshiba-aircon.co.uk). In wall-mounted air-conditioning applications it has been claimed that the newly introduced low-resistance filters can capture organic particles as small as viruses. The "7 stages" filtration process begins with pre-filtering to trap large particles and dust. Further trapping takes place at the next stage to ensure that airborne viruses and bacteria are held for elimination.

The selection and maintenance of filters is paramount. Many particulates could easily bypass ordinary filters; thus careful consideration should be given to fitting high-efficiency filters where possible. A good portion of particulates will then be prevented from entering the building at the intake ducts.

www.defenselink.mil

Bed occupancy and intensity, and frequency of use of particular hospital areas, impact on the proximity of hospital users to each other.

Tri-Air Development offers an air purifier which simulates the production of fresh air to destroy airborne viruses and bacteria in minutes in any building (www.tri-airdevelopments.com). The system combines three decontamination technologies, including non-thermal plasma, ultraviolet catalysis, and Open Air Factor (OAP), to create a fresh environment that is lethal to viruses and bacteria.

Maintaining internal relative humidity below 60% significantly reduces the potential for microbial growth in buildings (Kilcoyne, 2006), but will this be applicable to MRSA? Environmental conditions can affect the survival and persistence of microorganisms on indoor surfaces. For instance humidity levels are known to influence microbial survival and growth, such as that of mould, mildew and bacteria, inside ductwork and ventilation diffusers, leading to a high concentration of allergen, odour and toxin production in the ambient environment. Non-humid environments appear to be optimal for MRSA to thrive in given that the "comfort zone" of 21˚C to 24˚C is well within the MRSA survival temperature range of 18˚C to 37˚C.

So, what measures can be undertaken to reduce the impact of indoor temperature and relative humidity (RH) on MRSA survival?

To minimise the risk of infections, ductwork's internal surfaces must be cleaned. Otherwise there will be a gradual accumulation of dust incorporating a higher proportion of organic compounds (OC), primarily including hair and skin flakes – the main nutrients for microorganisms such as MRSA, and *C. difficile*. The obvious question here is what can be done to minimise the risk of cross-infection to patients from such sources?

> 'Hospitals are very complex, highly serviced organisations, which makes them very difficult to manage.'

Internal surfaces

The choice of materials for internal surfaces is pivotal; avoiding surfaces which might become reservoirs for pathogens, i.e. porous furnishings, might be crucial in minimising the likelihood of contamination, according to Makison and Swan.

NHS guidance on the selection of hard surfaces and finishing focuses on the need for smooth, easily cleaned, and adequately wear-resistant, materials. Further emphasis is given to the use of coving between floors and walls, in order to prevent the accumulation of dust and dirt in corners and crevices, and avoiding unsealed joints and tiles, as they may produce a reservoir for infectious agents. MRSA appears to be most sensitive to relative humidity of 52% for most of the hard surfaces, as compared to 42% for painted wood (Makison, 2006). This is based on the assumption that the surfaces surrounding the occupants are at a similar ambient temperature of 21˚C to 24˚C; this falls well within the MRSA survival temperature range of 18˚C to 37˚C (McCulloch, 2000, Dancer, 1999).

Other factors which impede such process include surface material and availability of food particles and presences of nutrients (Boulange-Petermann, *et al*, 2004). Porosity of surface and type of coatings, whether varnished, painted, or enamelled, have also been identified as culprits, as they affect surface permeability, (www.healthcare.altro.co.uk/en-GB/product/; Makison, 2006)

'Strategically managing' MRSA

There seems to be a multiplicity of interrelated factors involved in the spread of MRSA. Any attempt to disentangle these

Table 2: Ventilation changes rate – air changes per hour.

Assembly halls	4-8
Bakeries	20-30
Banks	4-8
Bathrooms	6-10
Battery charging rooms	6-8
Bedrooms	2-4
Billiard rooms*	6-8
Boiler rooms	15-30
Cafes and coffee bars	10-12
Canteens	8-12
Cellars	3-10
Churches	1-3
Cinemas and theatres	10-15
Club rooms*	10-12
Compressor rooms	10-20
Dairies	8-10
Dance halls*	8-12
Dye works	20-30
Electroplating shops	10-12
Engine rooms	15-30
Entrance halls, corridors	3-5
Factories and workshops	8-10
Foundries	15-30
Garages	6-8
Glasshouses	25-60
Hairdressing salons	10-15
Hospitals – sterilising	15-25
– wards	6-8
Kitchens – domestic	15-20
– commercial	20-30 min
Laboratories	6-15
Launderettes	10-15
Laundries	10-30
Lavatories	6-15
Lecture theatres	5-8
Libraries	3-5
Living rooms	3-6
Mushroom houses	6-10
Offices	6-10
Paintshops (not cellulose)	10-20
Photo and X-ray darkrooms	10-15
Public house bars	10-15
Recording studios	10-12
Recording control rooms	12-25
Restaurants	8-12
Schoolrooms	5-7
Shops and showrooms	8-12
Shower baths	15-20
Stores and warehouses	3-6
Swimming baths	10-15
Toilets	6-10
Welding shops	15-30

** Increase by 50% where heavy smoking occurs, or if the room is underground.*

> 'There is a need for an in-depth understanding of the mechanism of how MRSA colonies spread in existing hospitals.'

independently to measure their impact on patient wellbeing will be onerous, and almost impossible to achieve in practice. Given the complexity of the problem, this study argues that a more holistic strategic approach for tackling the spread of MRSA is needed. This can be achieved via judicious hospital design and infection control management systems and robust risk control assessment. MRSA outbreaks are directly related to internal finishing and air-conditioning systems. In any strategic formulation two key areas need to be addressed – a more strategic analysis of how we identify MRSA and its carriers, including detection of patient and staff carriers, and minimising MRSA through judicious use of internal finishing of walls and floors to reduce cross-contamination. Building professionals must be fully appraised of the risks associated with specifying finishing materials, as inappropriate selection can potentially lead to spread and colonisation of microorganisms. Areas of major concern might include the cleanliness of the internal surfaces of ducting systems, diffusers and grilles,[1] the robustness of filtration systems against infections and microorganisms, air handling system functions, incorrect and malfunctioning air exchangers, and blocked air vents and air diffusers.

Both hard surfaces and ventilation/air-conditioning systems may be influential and, to a large extent, pivotal to MRSA transmission. A robust risk management strategy over the lifespan of NHS premises and facilities is needed. This requires an in-depth understanding of the mechanism of how infection is spreading, including proactive involvement of the infection control team and facilities managers at the early design stage.

An intelligent "safety by design" management system needs to be developed as a novel approach for tackling the spread of MRSA in British hospitals. A real-time predicative system for managing the spread of MRSA on hard surfaces (in particular ventilation and air-conditioning systems) needs to be perfected, together with an interchangeable knowledge database relating to effective control measures in hospitals which could be incorporated into the NHS Expansive-Data-Network for fighting MRSA.

Footnotes

A Data from the Government and Health Protection Agency shows that, between April 2003 and March 2004, MRSA infections in England alone have increased by 3.6% from 7,384 to 7,647. This has been estimated to cost the NHS £1 billion a year (BBC, 16:8, 2005). There is also higher operational cost associated with higher infection rate, including healthcare costs, disability, and loss of income due to infection, which can be added to the equation.

B Techniques such as aerosol particle tracer sampling and computational fluid dynamics can be applied to study the performance of negative pressure rooms, and to assess how design variables can affect their performance.

C A Government target has led to higher bed occupancy, while staff shortages and increased use of unqualified staff have compounded strict hygiene protocols (www.bbc.co.uk 2006).

D This is referring to Bronson Methodist Hospital, Michigan, which is part of the Pebble Project.

E 'Single speciality' Trusts (lowest on MRSA), (Trusts undertaking orthopaedics, or cancer or child health services). 'Specialist' Trusts (Trusts with specialist services which receive patients referred from other Trusts for these services). 'General acute' Trusts (Trusts providing general acute healthcare services). The highest in the MRSA ratings.

F Ward speciality can be categorised into medical, surgical, obstetrics and gynaecology, and critical care medicine among many other specialties (Hospital Infection Society and Infection Control Nurses Association, 2007).

References

1 Approved Code of Practice, (2001). The Control of Legionellosis in Hot and Cold Water Systems. (MISC 150). Document HS (G) 70, Operational Circular (OC 255/11) Health and Safety Executive.

2 Blum A. (2006), How Hospital Design Saves Lives, in *Business Week*, August 15, 2006.

3 Boulange-Petermann *et al.* (2004) Hygienic Assessment of Polymeric Coatings by Physico-Chemical and Microbiological Approaches, *Journal of Adhesion Science and Technology*, 18, 2: 213-225.

4 Butcher D. (2006), Hospital Composition Saves Life, 26 October in www.news.thomasnet.com (cited 18 Nov 2007).

Table 3: Recommended minimum fresh air supply (www.vent-axia.co.uk).

Air space per person	Air supply per person	Air changes per hour (ACH)
$3m^3$	17 litres/s	20.0
6	11	6.5
9	8	32.0
12	6	1.8

www.saifeehospital.com

5 Cornet M., Levy V., Fleury L. *et al* (1999). Efficacy of Prevention by High-efficiency Particulate Air Filtration or Laminar Airflow. *Journal of Hospital Infection*, 66, 1; SAGE Publications.
6 Dancer S. (1999). Mopping up Hospital Infection. *Journal of Hospital Infection*, 43, 85-100.
7 Fleischer M. *et al* (2006). Microbiological Control of Airborne Contamination in Hospitals, in *Indoor and Built Environment*, 15; 1:53-56. SAGE Publications.
8 Kunori T. *et al* (2002). Cost-effectiveness of Different MRSA Screening Methods. *Journal of Hospital Infection*, 51:189-200.
9 McCulloch, J. (2000). Infection Control: Science, Management and Practice, Whurr, London.
10 Makison C. & Swan J. (2006), The Effect of Humidity on the Survival of MRSA on Hard Surfaces, in *Indoor and Built Environment*, 15; 1:85-91, SAGE Publications.
11 NHS Estate (2001), Infection Control in the Built Environment: Design and Planning, HMSO, London.
12 NHS Estate (1993). Control of *Legionellae* in Healthcare Premises. Health Technical Memorandum (HTM), 2040. Health Building Notes (HBN 4 – Supplement 1).
13 Health Protection Agency (2006). Mandatory Surveillance of Healthcare Associated Infection Report 2006. Department of Health, England.
14 Hospital Infection Society and Infection Control Nurses Association (2007). The Third Prevalence Survey of Healthcare Associated Infections in Acute Hospitals in England 2006 – Report for the Department of Health, England.
15 NHS Estate (1994). Ventilation in Healthcare Premises. Health Technical Memorandum (HTM) 2025, Vols 1-4, Department of Health, HMSO, London.
16 National Audit Office (2000). Report by the Comptroller and Auditor General: The management and Control of Hospital-acquired Infection in Acute NHS Trusts in England. The Stationery Office, London.
17 McCulloch, J. (2000). *Infection Control: Science, Management and Practice*. Whurr, London.
18 Skoog J. (2006). Relative Air Humidity in Hospital Wards – User Perception and Technical Consequences, in *Indoor and Built Environment*, 1:93-97. SAGE Publications.
19 Van Enk R. (2006). Modern Hospital Design for Infection Control, in *Healthcare Design*, September 2006. published in (www.businessweek.com/innovate/content/aug2006/id20060815_289604.htm).
20 Wagenvoort, J. *et al* (2000). Better Environmental Survival of Outbreak versus Sporadic MRSA Isolate.
21 Walkers J, *et al* (2007). Hospital and Community Infection and the Built Environment –design and testing of infection control rooms. *Journal of Hospital Infection*. June 2007 pp 43-49.