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What can we learn from each other in infection control? Experience in Europe compared with the USA

S. Harbarth*

Infection Control Programme, University of Geneva Hospitals and Faculty of Medicine, Geneva, Switzerland

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SUMMARY

Infection control practices in Europe and the USA have been influenced and shaped over the last 50 years by various technological developments, historical experiences and research schools that have led to different approaches to the control and prevention of healthcare-associated infections. This narrative review attempts to answer the question: Which are the most useful lessons to be learned from this historical experience, as well as methods and measures advocated on both sides of the Atlantic, in order to determine best practices to control and prevent healthcare-associated infections and antimicrobial resistance? The review is intended neither as an expansion of ongoing debates on controversial scientific issues, nor as a complete historical review of modern hospital epidemiology, but should be considered rather a personal viewpoint that tries to bridge the gap between US-influenced hospital epidemiology and traditional microbiology-based hygiene in Europe.

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Introduction

Healthcare-associated infections (HCAIs) have become a worldwide problem.[1,2] Yet the reasons for the uneven geographic distribution of HCAI rates are not fully understood. For instance, there are important differences in the epidemiology of HCAIs and multidrug-resistant organisms (MDROs) between the USA and Europe.[3,4] Disparities may be explained by several determinants: (i) surveillance methods, including diagnostic practices and laboratory recognition; (ii) infection control knowledge and practices; (iii) antibiotic prescribing practices; (iv) hospital characteristics and patient case-mix; (v) cultural factors (e.g. hygiene behaviour); (vi) factors related to healthcare systems and associated quality standards; (vii) available resources dedicated to hospital hygiene; (viii) legal constraints; (ix) political commitment.[4–6]

Certainly, effects exerted at the macro level by the healthcare system and political environment contribute substantially to the observed differences in HCAI rates.[7,8] But even more importantly, HCAI control practices in Europe and the USA have been influenced and shaped over the last 50 years by various technological developments, historical experiences and research schools that lead to different approaches to the control and prevention of HCAI.[9] In particular, there is still ongoing controversy among European hospital hygienists (especially in Germany and Eastern Europe) about the benefits and limitations of epidemiological and patient outcome-centred methods for the prevention and control of HCAIs, since traditional microbiology-based approaches and 'holistic' strategies to hospital hygiene have until the 1990s dominated the field in Europe.[10,11] Therefore, the question arises: Which are the most useful lessons to be learned from this historical experience, as well as methods and measures advocated on

* Address: Infection Control Programme, Department of Internal Medicine, University of Geneva Hospitals, 1211 Geneva 14, Switzerland. Tel.: +41 22 372 98 28; fax: +41 22 372 39 87.
E-mail address: stephan.harbarth@hcuge.ch.

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both sides of the Atlantic, in order to determine best practices to control and prevent HCAIs and MDROs? The overview presented here is intended neither as an expansion of ongoing debates on controversial scientific issues such as MDRO screening and isolation practices, nor as a complete historical review of modern hospital epidemiology, but should be considered rather a personal viewpoint that tries to bridge the gap between US-influenced hospital epidemiology and microbiology-based hygiene in Europe.[12,13]

Useful lessons from the USA

Role of epidemiological methods and surveillance

Although many of the basic ideas of healthcare epidemiology can be traced back to Semmelweis, the formal application of epidemiological methods in infection control received a substantial boost only 100 years later during the 1970s and 1980s, with the publication of a number of methodologically oriented articles from US colleagues that brought innovation to the field.[14–17] Based on the assumption that HCAIs have causal and preventive factors that can be identified through systematic investigation, these studies demonstrated convincingly that epidemiological methods add important knowledge to reduce the risk and rates of HCAIs.[10] Thus, the conceptual framework was laid for many interventional and observational studies in the field. Since these early pioneering times of modern hospital epidemiology, many investigators and studies have demonstrated the explanatory power of descriptive, analytical and experimental epidemiology in our field.[18–22] Furthermore, advanced biostatistical tools such as process control charts have been introduced to better detect clusters of infections or other unusual in-hospital adverse events, and to evaluate the impact of interventions to prevent HCAIs (Figure 1).[23,24]

Several landmark studies from the USA have shown that accurate diagnostic and surveillance methods are essential for designing and organizing interventions to prevent HCAIs.[25,26] In response to questions raised about the efficacy of the methods adopted in hospital epidemiological practice, several studies attributed a decrease in nosocomial infections to effective HCAI control programmes.[27,28] These were followed by the Centers for Disease Control and Prevention (CDC) Study on the Efficacy of Nosocomial Infection Control (SENIC) in the late 1970s, which affirmed this association in a controlled, nationwide study.[29,30] SENIC demonstrated an overall 32% reduction in HCAI rates associated with specific surveillance and infection control components; the reduction effect varied, however, for the different HCAI subtypes (Figure 2). Financial incentives for hospital administrators to adopt effective and patient-centred HCAI control programmes became apparent.[31]

Evidence-based infection control and practice guidelines

In the early 1970s, the focus of hospital hygiene in the USA shifted from environmental control (e.g. waste management) to more evidence-based, patient-centred approaches. Routine environmental sampling was discarded as a wasteful and unproductive practice.[32] During the following decades, US HCAI surveillance and control programmes focused primarily on infection in patients and, in a more limited manner, healthcare workers. Investigations in the field of HCAI control have expanded to include the prevention of device-associated infections, recognition of new opportunistic infections in immunocompromised patients and control of antimicrobial

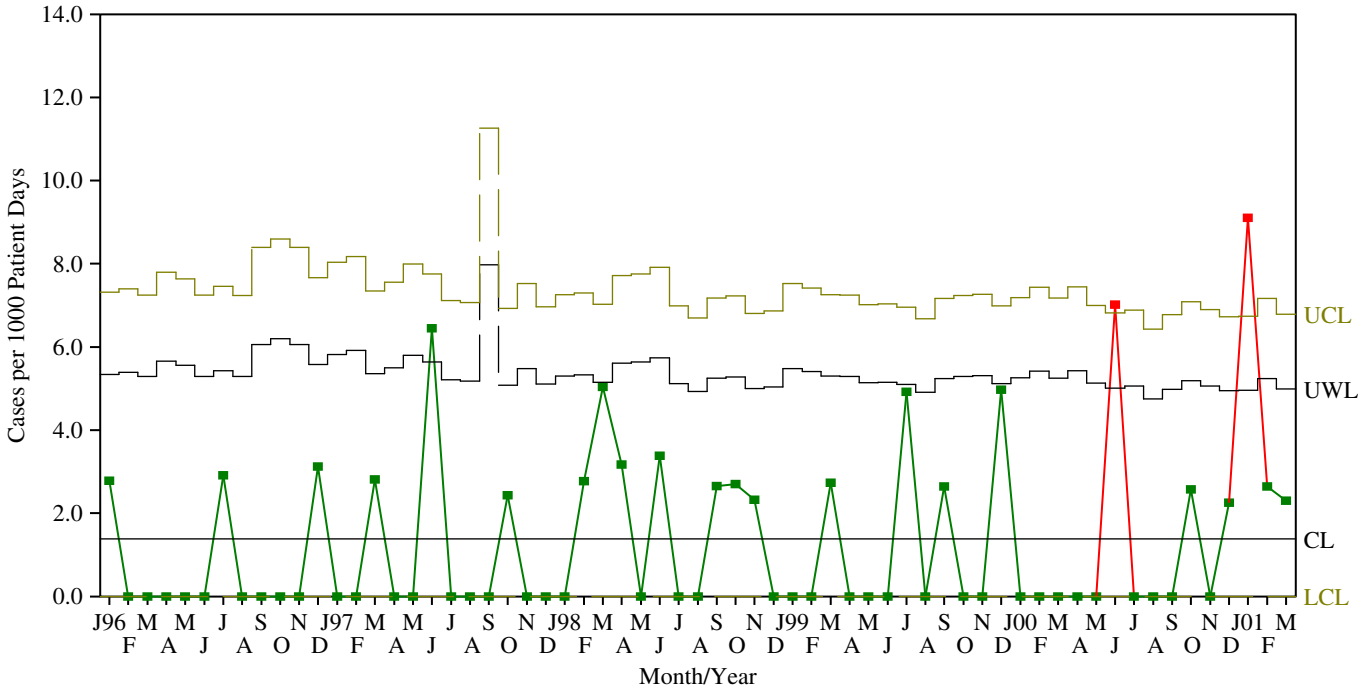

Figure 1. Neonatal nursery and intensive care unit, Children's Hospital Boston (MA, USA). Incidence density of patients with nosocomial enteric Gram-negative rods resistant to third-generation cephalosporins; January 1996 to March 2001. LCL, lower control limit; CL, control limit; UWL, upper warning limit; UCL, upper control limit.

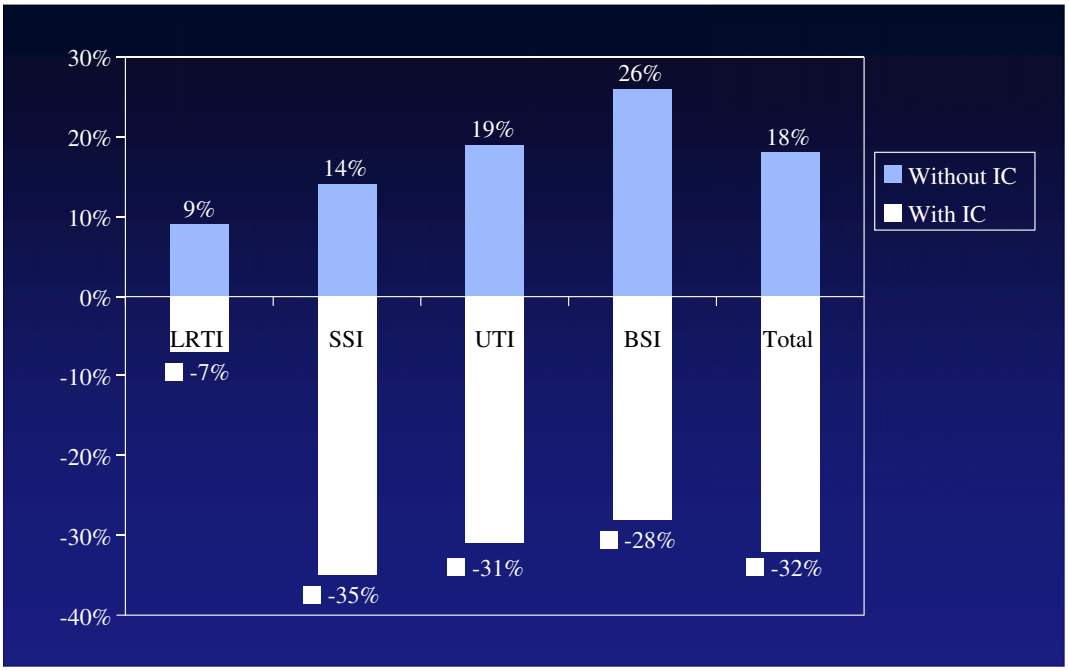

Figure 2. Impact of the Centers for Disease Control and Prevention (CDC) Study on the Efficacy of Nosocomial Infection Control (SENIC) that demonstrated an overall 32% reduction in HCAI rates associated with specific surveillance and infection control components (white bars), compared with control hospitals (grey bars).[29,30] LRTI, lower respiratory tract infection; SSI, surgical site infection; UTI, urinary tract infection; BSI, bloodstream infection. Reproduced from Haley *et al.*[30]

resistance through antibiotic stewardship.[33–35] Substantial research efforts have accompanied these developments and changes in HCAI control strategies.[36] Based on robust study design and large sample size, high-quality clinical studies conducted in the US have refuted the claims in favour of the routine application of preventive measures that had already been implemented and marketed in Europe, without solid proof of their efficacy, as shown recently with gentamicin–collagen sponges for infection prevention in cardiac and colorectal surgery.[37,38]

Infection control in the USA has one of the longest, best documented and probably most successful histories in the preparation, dissemination and acceptance of guidelines for preventive practices under routine clinical conditions.[39] Beginning in the late 1960s, many guidelines for infection control in various healthcare settings were released by the American Hospital Association's Advisory Committee on Infections in Hospitals, the CDC and professional societies, such as the Infectious Diseases Society of America (IDSA) and the Society for Healthcare Epidemiology of America (SHEA). Other organizations and medical societies with significant activity in areas relevant to infection control guidelines also contributed and helped to develop and disseminate specific HCAI control recommendations.

Limitations to evidence-based infection control

It must be highlighted that many practices in infection prevention and control of MDROs have not been validated by controlled clinical trials. Unfortunately, there are many important questions in infection control for which we may never obtain data from randomized trials because of limitations in funding, lack of feasibility, and ethical dilemmas.[40] Much of what has been recommended for infection control interventions over the past two decades is still based on experience, empiricism, and common sense.[36]

Clearly, there are limitations to evidence-based infection control. If important preventive measures and clinical decisions could be made only on the basis of high-quality level 1 evidence, infection control nurses and hospital hygienists would be paralysed and not all patients could be adequately protected throughout their hospital stay.[41] As an illustrative example from the USA one could cite the 'artificial fingernail story'. In the late 1990s, it required several outbreaks in different US hospitals that linked artificial fingernails of nurses to transmission of nosocomial pathogens to patients in order to issue a recommendation by the CDC that artificial nails, tips and wraps should not be worn by staff members providing direct patient care.[42–44] Not surprisingly, 'requiring short natural fingernails is a reasonable policy' even without clinical studies, a message reminding us of the famous article in the *British Medical Journal*'s Christmas edition of 2003 stating that 'parachutes reduce the risk of injury after gravitational challenge, but their effectiveness has not been proved with randomized controlled trials'.[43,45] One may argue that common sense applied together with knowledge of basic hand hygiene rules and relevant contextual information could have prevented those outbreaks by simply forbidding artificial fingernails among nurses in vulnerable patient care areas. Interestingly, in an editorial in the *New England Journal of Medicine*, the need for more personal accountability in hand hygiene behaviour was highlighted by well-known opinion leaders, in contrast to the long-prevailing 'no blame' attitude to excuse hand hygiene failures of personnel by 'system

problems'.[46] These authors even suggest that chronic failure to clean hands should result in a one-week suspension from clinical practice.[46]

Furthermore, many existing US guidelines in the infection control and clinical infectious disease literature do not follow the highest possible methodological standards for development of guidelines, as suggested by the Cochrane review group.[47] For instance, the first CDC hand hygiene guideline published in 2002, an otherwise exemplary appraisal of the evidence, did not include a detailed description of the systematic review process.[48] Two recent systematic reviews revealed that most of IDSA's prevention and treatment guidelines are based on expert opinion, non-randomized trials, and case studies.[49,50] Only about 15% of the guidelines were supported by randomized controlled trials. Nonetheless, more than 40% of the guidelines' recommendations were classified as class A, the strongest level of treatment recommendation. Overall, many US guidelines for infectious diseases and MDRO control leave uncertain the study selection criteria, data extraction process, and quality of the included studies.[40]

Interdisciplinary collaboration, quality improvement and innovation

Infection control in the USA can look back at a long-lasting history of multidisciplinary team work and interdisciplinary research.[51] By contrast with Semmelweis, who was more crusader than diplomat in his attempts to convince colleagues of the clinical effectiveness of hand hygiene, the US school of hospital epidemiology traditionally emphasized the importance of leadership and interpersonal skills in order to better advocate the sound principles guiding infection control practice.[52] Based on partnership with clinicians and administrators from various backgrounds, the modern US-trained hospital epidemiologist is able to develop intra-hospital ties, inter-hospital networks and collaborations that are crucial for interaction and discussion of sensitive issues related to suboptimal outcomes, harmful in-hospital events and costly interventions.[53,54] This team approach facilitates not only communication and collaboration in daily life but also interdisciplinary research projects that require expertise from various topic areas, a situation frequently encountered in healthcare epidemiological research.[36] Table I highlights a few examples of successful interdisciplinary research areas that link innovative ideas with expertise from areas outside traditional hospital hygiene.

Traditionally, US-based healthcare epidemiology and infection control have focused more on surveillance and less on intervention and implementation. A strong movement started in 2001 to 'close the quality gap' in US hospitals, with the aims of offering performance expectations, aligning payment/accountability with quality improvement, and promoting evidence-based practice.[8] Due to public pressure by consumer and patient groups (Figure 3), mandatory public reporting has been set up by law in 26 states of the USA, with variable success and impact.[55] Therefore, SHEA has developed guidelines requiring the participation of experts and the use of standard definitions and performance indicators.[56] Many different bodies (e.g. Agency for Healthcare Research and Quality; Institute for Healthcare Improvement) now act in synergy and contribute to a culture of safety in the USA, relying on executive leaders, professional teams and clinical staff to: (i) engage (make the problem real, admit that harm is untenable); (ii) educate (present the evidence, identify changes needed); (iii) execute (reduce complexity, hold efficient team meetings); and (iv) evaluate (based on measurement, feedback and visibility).[8] Nevertheless, public health and quality improvement initiatives in the USA remain decentralized and underfunded; hospitals are mainly private, except for a few public institutions and the Veterans Affairs hospitals, which have been able to conduct large-scale quality improvement initiatives to reduce meticillin-resistant *Staphylococcus aureus* (MRSA) rates.[57]

Infection control in the USA has been more technology-driven and prone to innovation compared with many European countries. For example, electronic medical records, electronic data collection and data mining systems now provide innovative and sophisticated data sources in many US hospitals.[36] These technological advances facilitate adherence to isolation protocols, increase efficiency of surveillance of HCAI and antimicrobial consumption and resistance, and may help to create new approaches to the prevention of HCAI.[58–61] They also allow the development of clinical decision support tools for antibiotic stewardship and screening algorithms of patients at high risk of carrying MDROs, and can serve as data sources for complex epidemiological simulation and modelling

Table I
Application to infection control of innovative, interdisciplinary research and work activities in the USA

Topic area	Application	Examples	Impact
Information technology	Novel electronic HCAI surveillance methods	Efficient identification of post-discharge surgical site infections with the use of automated pharmacy dispensing information, administrative data, and medical record information[58]	Increased efficiency with rapid feedback to wards
Quality improvement methods	Real-life implementation of best practices in infection control	Multifaceted intervention for quality improvement in a network of intensive care units[138]	Sustained reduction of adverse patient outcomes
Behavioural sciences and qualitative research	Infection control interventions based on behavioural change strategies	Prevention of urinary tract infections through a bundle approach linked with qualitative research methods[139,140]	Better understanding about why hospitals use or do not use a range of available preventive practices

HCAI, healthcare-associated infection.

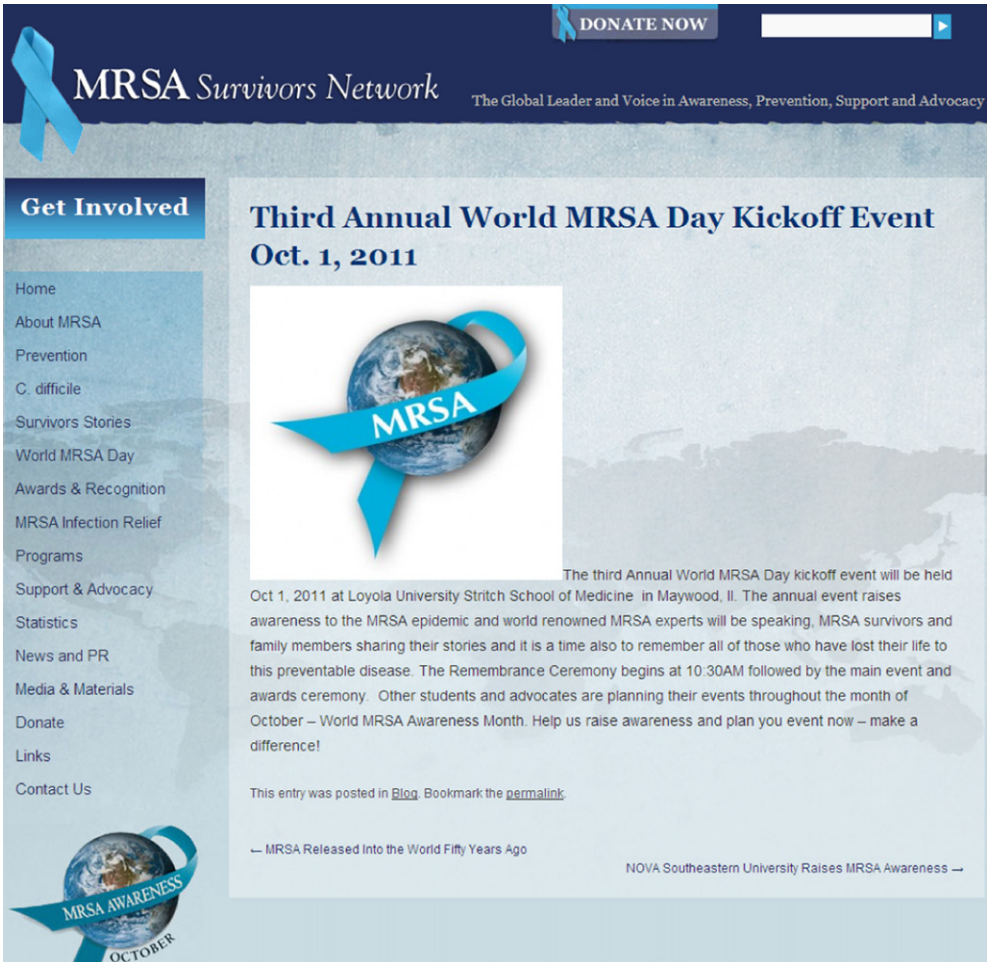

Figure 3. Screen shot of the website of the MRSA Survivors Network, a US-based patient group attempting to increase awareness about meticillin-resistant *Staphylococcus aureus*-related issues.

studies on the impact and transmission of HCAIs and MDROs.[62–65]

Useful lessons from Europe

The second part of this review summarizes relevant experiences and important advances in infection prevention in Europe as well as useful lessons for colleagues outside continental Europe.

Surveillance and assessment of the burden of HCAI

During the past decade, the basic principles of hospital epidemiology, aimed at measuring the necessity and effect of strategies to prevent HCAIs, have been successfully introduced into most European countries.[66] Surveillance and control of HCAIs based on epidemiological concepts are now an established component in many healthcare institutions throughout Europe.[55,67,68] Nevertheless, large regional differences remain; a survey performed in 2001 showed that infection control programmes in many European hospitals still suffer from major deficiencies in human resources and policies.[69] Furthermore, there remains debate about the challenges and disadvantages associated with current surveillance methods of monitoring HCAIs, as summarized in Table II.[70]

There has been much progress made, especially in the field of HCAI prevention, following the establishment of the European Centre for Disease Prevention and Control (ECDC, Stockholm) in 2005, although some experts have criticized its limited staffing level, laboratory facilities and regulatory power.[71] Working with European researchers, expert group meetings have led to informative exchanges of knowledge and ideas.[1,72] Key components of the ECDC's activity are HCAI and MDRO surveillance, which are now well-established themes within the Centre's core agenda and budget.[73] The European 'Council Recommendation' on patient safety, which includes control of HCAI, shows the high priority attached to this area within the political context.[73]

Without doubt, HCAIs are associated with adverse patient outcomes.[74] However, most US-based studies on the burden of HCAI have frequently ignored the time-varying nature of exposures and have amplified confounding.[75–77] Consequently, the most frequently applied approaches (i.e. matched cohort study; linear regression analysis) tend to overestimate the excess morbidity and mortality related to HCAI compared with more suitable methods based on multistate modelling techniques that take into account the timing of in-hospital

Table II
Challenges and disadvantages associated with current surveillance methods of monitoring HCAIs

Disadvantages and limitations	Possible solutions and comments
May yield excessive data, labour intensive, time-consuming	Electronic files and data collection, software support, and data manager included in the surveillance staff could help to reduce the workload
Expensive	Estimated yearly costs of HCAIs are higher than the costs of surveillance and dedicated control staff
May miss clusters or outbreaks in non-surveyed areas or populations	Establishing alert mechanisms (e.g. microbiology laboratory alerts)
Overall infection rate not valid for inter-hospital comparison	For some measurements, availability of appropriate case-mix risk adjustment systems and external comparative data can improve external benchmarking
Collects data only for targeted patients or units – limited information about endemic rates in the entire hospital	Performance of hospital-wide prevalence surveys could complement prospective HCAI surveillance data and help to determine high-risk patient groups
Poor inter-rater reliability in applying standard definitions and variable implementation of case-finding strategies	Strategies that make use of existing electronic data sources for creating process and outcome measures may reduce errors

HCAI, healthcare-associated infection.

events.[64,78,79] These newer statistical methods are applied mostly in European research projects, whereas US-based research has not yet embraced this methodological breakthrough.[80–83] Clearly, appropriate statistical methods are important for the analysis of excess length of stay and costs associated with HCAI because informed decisions and policy developments may depend on them.[84] Exaggeration of excess costs may lead to unintentional errors in the economic analysis of intervention programmes.[22]

Control of antimicrobial consumption and resistance

During the last two decades, Europe has made substantial progress in combating MDROs and in control of antibiotic overuse.[85,86] Innovative strategies and consensus guidelines have been issued.[72,87,88] A wide array of epidemiological studies has been undertaken in European countries at national or hospital level, helping to better understand the efficiency and problems of MDRO control in Europe.[89–91] For instance, in a multicentre study by Meyer *et al.* performed between 2001 and 2008 in 53 German ICUs, carbapenem use almost doubled despite no significant change in total antibiotic use.[92] The exponential increase of third-generation cephalosporin resistance in *Escherichia coli* and other Enterobacteriaceae reported in this study led to switching empirical therapy to carbapenems to treat infections, with the subsequent emergence of carbapenem-resistant *Klebsiella pneumoniae*, carbapenemase-producing Gram-negative pathogens and imipenem-resistant *Acinetobacter baumannii*. This scenario may affect many ICUs in Europe in the near future, with resistance trends and antibiotic consumption rates influenced by different factors, including ICU characteristics (medical, surgical, general), local antibiotic policies and physicians' level of education.[93]

Innovative antibiotic stewardship has been a hallmark of European research activities during the last decade.[94,95] For instance, numerous recent publications from Europe have assessed the application of algorithms based on procalcitonin as a biomarker of bacterial infection for antibiotic stewardship. Several high-quality clinical trials investigating the diagnostic performance and clinical effectiveness of procalcitonin have been published.[96–99] Another recent stewardship success story to report from Europe relates to changes in antibiotic treatment guidelines in the UK, related to the increase in *Clostridium difficile* and multi-resistant enterobacteriacae.[100–102] Nevertheless, Europe's antimicrobial stewardship policies remain heterogeneous; whereas there is great progress in stewardship in some countries, other countries certainly lag behind.

Promotion of alcohol-based hand hygiene and skin disinfection

Despite its strong leadership role in epidemiological research, the USA still trails behind most European countries with the promotion of bedside, alcohol-based, waterless hand disinfection, considered widely to be among the most important tools to prevent the spread of nosocomial MDROs.[103] In Europe, large-scale hand hygiene promotion campaigns have been conducted in a majority of countries.[104] In the USA, the misconception that sink-based hand washing with antimicrobial soap is superior to alcohol-based hand disinfection dominated until recently. In fact, the latter practice allows much faster hand hygiene during patient care and achieves higher compliance rates.[105,106] Although alcohol-based hand antisepsis has been shown to be superior to hand washing in all important microbiological and technical aspects, the use of alcohol-based hand antisepsis remained limited in US hospitals until the beginning of this century. This is somewhat ironic given that the original observations of Semmelweis were actually related to hand disinfection rather than hand washing with soap and water.[107]

Another misconception is still predominant outside Europe regarding the role of alcohol in skin disinfectants, since alcohol has frequently been overlooked in evidence assessments.[108] For instance, in a large randomized clinical trial, Darouiche *et al.* were able to quantify differences in efficacy between two compounds (2% chlorhexidine gluconate and 70% isopropyl alcohol versus an aqueous solution of 10% povidone–iodine) for presurgical skin preparation.[109] Results from this study cannot be extended to most European settings as they are based on a comparison with a non-alcoholic iodine compound and centred upon a surgical population with relatively high wound

infection rates. As outlined recently by Maiwald and Chan, the perceived efficacy of chlorhexidine is often based on evidence for the efficacy of the chlorhexidine–alcohol combination.[108]

Multicentre interventional research studies

Several European countries and groups of researchers have helped to increase the evidence base in infection control.[66] Recent examples include multicentre randomized, clinical studies conducted in The Netherlands and France on the prevention of ventilator-associated pneumonia, surgical site infection, and central line-associated bloodstream infection that have gained widespread attention by addressing essential questions of HCAI control.[110–112] Furthermore, research funding has increased during the past decade. The European Commission in particular has shaped the research agenda by allocating more than €200 million since 1999, addressing in particular the growing public health threat of antimicrobial resistance.[66] Funded projects included molecular, clinical, and epidemiological studies organized mostly by large-scale, multidisciplinary consortia that have advanced our knowledge and have underlined the leadership role of Europe in this field.[113–115]

As mentioned above, the complex, multifaceted nature of HCAI makes the planning and realization of randomized trials difficult, if not unrealistic, in many instances.[66] Therefore, interrupted time-series analyses are a suitable alternative for quasi-experimental research in infection control.[116,117] These studies should follow rigorous methodological standards, as outlined in an authoritative guideline issued by European experts, called the 'ORION statement'.[118] Of note, the uptake and inclusion of these innovative, but rather complex statistical methods have been quicker and more thorough in European compared with North American research publications.[119–122] Figure 4 shows an example of a recent publication applying interrupted time-series methodology to an interventional cohort study on MRSA control.[123]

Environmental control

Traditional, environment-based hospital hygiene has long been considered a weak science, usually arising from the creation of a global hypothesis, which is poetically elaborated upon by its creator without any appeal to patient-orientated facts that would be capable of confirming or refuting it.[10,11] There are many examples of environment-focused studies in hospital hygiene that reveal the missed opportunity of introducing some controlled, patient-orientated outcome into the study design.[124] For instance, a remarkably

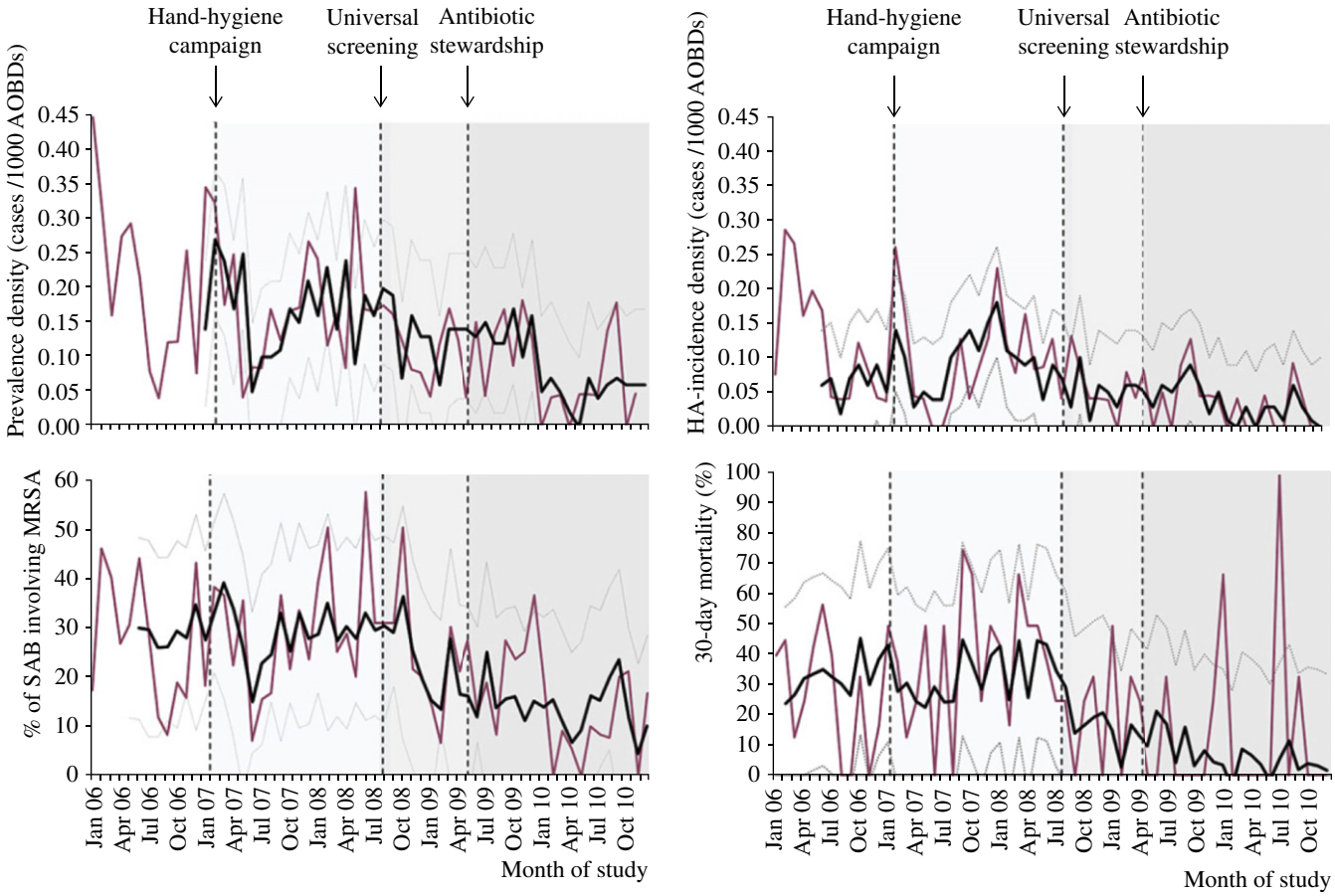

Figure 4. Observed trends (red lines) and multivariate transfer model predictions (sum of lagged explanatory variables; black lines) for prevalence density, hospital-associated (HA) incidence density, 30-day mortality in meticillin-resistant *Staphylococcus aureus* (MRSA) bacteraemia and percentage *Staphylococcus aureus* bacteraemia (SAB) involving MRSA, Aberdeen Royal Infirmary, Scotland, 2006–2010. AOBDs, acute occupied bed-days. Grey lines, 95% lower and upper confidence limits.[123]

well-performed longitudinal study about the control of *Legionella pneumophila* in a hospital water system could have gained clinical importance and generalizability if surveillance data regarding the rate of hospital-acquired legionellosis had been added.[125—127]

Despite these limitations, the role of the environment as potential reservoir of MDROs has recently gained new momentum.[128,129] Several studies from Europe have highlighted the importance of thorough cleaning practices to avoid transmission of MDROs that are capable of surviving in the environment for extended periods.[130—133] With respect to hospital cleaning, a broad consensus exists now among European experts that high standards are essential.[73] This message has also been well received in the USA, where several descriptive and interventional studies addressed the challenge to decrease environmental contamination with MDROs and *Clostridium difficile*.[134—137] Nevertheless, the impact of environmental contamination on HCAI rates and the cost-effectiveness of surface disinfection as opposed to detergent-based cleaning remains a scientifically unresolved issue, despite a growing body of literature.[73]

Conclusions

Although prospective, randomized trials are one important method of answering narrow healthcare epidemiology questions, they cannot capture the nuanced, real-world impact of diverse and divergent cultural and practical approaches to infection prevention across international boundaries.[36] Cross-country comparison of epidemiological data and infection control practices, a technique that is frequently used in the social sciences, allows an ecological approach that can complement interventional infection control studies based on individual patient-level data.

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Conflict of interest statement

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