By Elaine L. Larson, RN, PhD, CIC, Bevin Cohen, BA, Barbara Ross, RN, BSN, CIC, and Maryam Behta, PharmD

The Centers for Disease Control and Prevention recently updated guidelines for isolation precautions and added specific recommendations for the management of multidrug-resistant organisms. However, the extent to which these recommendations are followed is unknown. Although the recommendations are based on studies with high internal validity, the effectiveness of these interventions in clinical practice also is unknown. Evidence of the effectiveness of isolation precautions for preventing transmission of infections caused by multidrug-resistant organisms in acute care settings, with methicillin-resistant Staphylococcus aureus as an example, was reviewed. Despite a lack of experimental data, numerous descriptive and correlational studies and a sound theoretical rationale strongly suggest that barrier precautions play an important role in the prevention of transmission of infections due to multidrug-resistant organisms. Two major problems, however, still exist. First, staff members’ adherence to national recommendations on isolation precautions, although insufficiently described, appears to be inadequate. Second, efficient, reproducible methods for ongoing surveillance of practices such as isolation precautions are not readily available. Automated surveillance systems that provide support for making decisions are promising for this purpose, are likely to result in cost savings, and therefore warrant more widespread development, testing, and implementation.
Although much progress has been made to control preventable infectious diseases, infections remain a major cause of morbidity and mortality. Many of the traditional treatments for common infections are no longer effective because of the fast-growing problem of antimicrobial resistance, first associated with hospitals but increasingly widespread in the community. Antimicrobial resistance is now a global problem of major concern, and experts have urged governments to “take the growing threat of drug-resistant bacteria just as seriously as . . . the threat of bioterrorism.” Since the 1990s, antibiotic resistance has increased 1% to 47% in 7 of 9 of the most common microorganisms that cause infections associated with health care.1,2

Many researchers have examined the effectiveness of specific interventions to prevent and control infection, such as isolation precautions and routine surveillance for resistance, and much is known about which prevention strategies are efficacious. On the basis of this research, the Healthcare Infection Control Advisory Committee (HICPAC) of the Centers for Disease Control and Prevention (CDC) recently updated its guidelines for isolation precautions1,3 and added specific recommendations for the management of multidrug-resistant organisms (MDROs) in health care settings.4 However, the extent to which these recommendations are implemented nationally is unclear.

Furthermore, although the recommendations are based on studies with high internal validity, the effectiveness of these interventions in clinical practice (ie, external validity) is unknown. Unfortunately, no cost-effective system is currently widely available to monitor either the processes (ie, implementation of the recommendations) or the outcomes (ie, rates of infection) of these HICPAC guideline recommendations. Because many infecting and colonizing organisms in critically ill patients are now resistant to multiple drugs and necessitate contact precautions, our purposes in this article are (1) to review evidence of the effectiveness of isolation precautions for preventing transmission of MDRO infections in acute care settings, with methicillin-resistant Staphylococcus aureus (MRSA) as an example, and (2) to describe methods of monitoring adherence to the CDC guidelines on contact precautions for MDROs.

Health Care–Associated MRSA

Since the first isolates of MRSA were identified in the United Kingdom in 1961, MRSA has been a primary cause of health care–associated infections throughout Europe, Asia, Australia, and the United States.5,6 The prevalence of MRSA colonization and infection in US hospitals has increased markedly, both as a proportion of the total number of infections involving S aureus and in absolute terms, with the most dramatic increases occurring since the 1990s.7 In 1980, fewer than 5% of S aureus infections involved methicillin-resistant organisms; the proportion increased to 20% by 1990, 28% by 1995, and 40% by 1999.7 More recent data indicate that MRSA accounts for 49.9% to 63.0% of inpatient S aureus infections in the United States, with variations according to geographic region.8 According to the CDC (http://www.cdc.gov), the highest rates of MRSA infections occur in intensive care units (ICUs) of all types, where the proportion of health care–associated staphylococcal infections resistant to oxacillin or methicillin reached 65% by 2004.

Approximately 70% of hospital isolates of S aureus are now resistant to β-lactam antibiotics, which until recently were the first line of treatment.9 Additionally, 85% of all invasive MRSA infections are associated with health care settings.10 MRSA has been implicated in a variety of infection types and body sites, most notably pneumonia, skin and soft-tissue infections, surgical site infections, and bloodstream infections.9 Invasive interventions and
devices such as endotracheal and tracheostomy tubes and intravenous catheters promote MRSA infection because the bacteria grow readily in biofilms, which build around these devices. Additional risk factors for health care–associated MRSA infection include previous use of antibiotics, increased age, hospital admission within the previous 6 months, chronic hemodialysis, chronic skin breaks, and cancers of the head and neck.\textsuperscript{11,14}

Infections with antimicrobial-resistant organisms are estimated to cost $6000 to $30,000 more than infections associated with antibiotic-sensitive strains.\textsuperscript{15} In 2006, the Infectious Disease Society of America published a “hit list” of 6 resistant organisms that pose a particular threat to public health, the first of which was MRSA.\textsuperscript{16} Because of its public health importance, its high prevalence in all types of health care facilities, and the similarity of its modes of transmission to those of many other MDROs, MRSA is an ideal indicator organism for assessing compliance with isolation precautions. Further, the mode of transmission of MRSA and many other MDROs is most commonly by direct or indirect contact, so data from MRSA would be generalizable to other MDROs.

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**CDC Guidelines**

The CDC’s first published manual of evidence-based guidelines for the prevention of infection, *Guidelines for the Prevention and Control of Nosocomial Infections*,\textsuperscript{17} was published in 1981. Currently, CDC infection control guidelines are developed by HICPAC, Division of Healthcare Quality Promotion of the National Center for Infectious Diseases. Between 1996 and 2007, a total of 8 guidelines were published on topics such as prevention of intravascular-related infections, surgical site infections, and ventilator-associated pneumonia; isolation precautions; infection control in health care personnel; and environmental infection control. The 2 most recent HICPAC guidelines, *Management of Multidrug-Resistant Organisms in Healthcare Settings, 2006*\textsuperscript{6} and 2007 *Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings*\textsuperscript{1} are the latest revisions of guidelines that provide specific practice recommendations for preventing transmission of infection. Each guideline has 4 levels of recommendation: IA (strongly recommended on the basis of well-designed studies), IB (strongly recommended on the basis of some studies and strong theoretical rationale), II (suggested for implementation and supported by suggestive studies or theoretical rationale), and no recommendation (practices with insufficient evidence or lack of consensus). These guidelines are widely accepted as the standard of care for infection prevention and control.

**Efficacy of Isolation Precautions**

Because several terms for isolation precautions have been used over the years, confusion among health care personnel about the components of various types of isolation is likely. In addition, several terms are used interchangeably or are subsets of other terms. Commonly used terms are summarized and defined in Table 1. Although the CDC has recommended the use of standard and/or contact precautions for epidemiologically important MDROs such as MRSA since 1996, no clinical trials have directly compared the efficacy of standard vs contact precautions for control of MRSA infection. Hence, the current recommendations on isolation are ranked as category IB, indicating that they are based on strong theoretical rationale and some studies.

The current guideline cites multiple case reports and evidence from several European countries in which preemptive barrier precautions and/or active surveillance (a “search and destroy” approach) are routinely used and MRSA is still rare, indicating a temporal relationship between precautions and prevention of MRSA infection. As summarized in the 2006 MDRO guideline, however, debate is ongoing about the efficacy of standard or contact precautions for control of MRSA infection, and other organizations have published additional guidelines. Most important of these is a guideline\textsuperscript{18} published in 2003 by the Society of Healthcare Epidemiology of America that emphasizes contact precautions as well as routine use of active surveillance cultures. The slight variations in recommendations between guidelines indicate that the evidence is still equivocal.\textsuperscript{19} Nevertheless, the important features of these various guidelines are generally consistent.\textsuperscript{20}

The literature on MDROs is vast. In a recently published systematic review of studies designed to assess the effectiveness of barrier precautions to reduce transmission of MDROs,\textsuperscript{21} the term *multiple drug resistance* yielded 10,736 articles. When search terms were combined, 250 reports of research related to the role of barrier precautions in preventing transmission of MDROs were found. When outbreak investigations were excluded, in only 29 studies was an attempt made to assess the effectiveness of barrier precautions. Seven of these studies were judged to be of high quality (on the basis of type of design, control for bias and confounding, sufficient...
were initiated for all patients in the unit and results were published since 2006. Although it would be desirable to conduct randomized clinical trials with interdisciplinary teams of experts to strengthen the causal evidence on which practice guidelines are based, such trials may not be feasible because of the current emphasis on “care bundling” (ie, using multiple strategies such as recommended by the Institute for Healthcare Improvement, http://www.ihi.org/ihi), the multifactorial nature of health care–associated infections, and the logistical and ethical challenges of applying traditional randomized clinical trial methods to this clinical problem.24

Therefore, studies are generally positive about the effect of isolation on transmission of MDROs, but are often methodologically flawed, conducted at a single site, and subject to multiple biases.22,23

Several assessments of the relationship between isolation precautions and rates of infection with MRSA or other MDROs have been published since 2006. After an outbreak of MRSA infection in a burn unit, preemptive barrier precautions (gown and gloves) were initiated for all patients in the unit and results were studied for 27 months. The ratio of the rate of infection with MRSA during the barrier precaution period to the rate during the baseline period (before the outbreak) was 0.48 (95% confidence interval, 0.14-1.53; *P* = .10).25 Using a before-and-after quasi-experimental design, Mangini et al26 examined the effect of contact precautions on the incidence of MRSA in a community hospital. The combined rate in the medical and surgical ICUs was 10.0 MRSA infections per 1000 patient days at baseline and 2.5 MRSA infections per 1000 patient days after implementation of contact precautions (*P* = .43). In non-ICU areas, the rates before and after were 1.3 and 0.9 MRSA infections per 1000 patient days, respectively (*P* = .02).

The most important adverse effects of isolation precautions are a decrease in the care and well-being of patients and increased costs.

### Table 1

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
<th>Common elements(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isolation precautions</td>
<td>A general term inclusive of several “levels” of isolation based on modes of transmission</td>
<td>Vary by type of isolation: standard, airborne, contact, or droplet</td>
</tr>
<tr>
<td>Barrier precautions</td>
<td>A general term for activities designed to prevent the spread of health care–associated infection between patients or health care professionals; equipment used is sometimes termed “personal protective equipment”</td>
<td>Wearing of gloves, gowns, masks, goggles; use of sterile drapes, designated or disposable equipment; cohorting of patients with known infections</td>
</tr>
<tr>
<td>Universal precautions, body substance isolation</td>
<td>Terms previously used to indicate that all patients should be considered to be colonized or infected with organisms that could potentially be a risk to others; based on the principle that all body fluids could contain transmissible infectious agents; these terms have been replaced by “standard precautions”</td>
<td>Wearing gloves or other appropriate protective garb when contact with body substances occurs or is anticipated</td>
</tr>
<tr>
<td>Standard precautions</td>
<td>Combines universal and body substance isolation, based on the principle that all body fluids and excretions may contain transmissible infectious agents, whether the patient is symptomatic or not</td>
<td>Wearing gloves, gown, mask, eye protection, or face shield, depending on the anticipated exposure; handling of patient equipment to prevent transmission</td>
</tr>
<tr>
<td>Contact precautions</td>
<td>One of the 3 categories of “transmission-based precautions” (the other 2 are droplet and airborne) recommended by the Centers for Disease Control and Prevention when standard precautions may not be sufficient to prevent spread of microorganisms (eg, fecal incontinence, massive wound drainage, multidrug-resistant strains)</td>
<td>Wearing gown and gloves when in contact with patient or patient’s environment; single group ideally, or ≥3 feet of spatial separation between patients</td>
</tr>
</tbody>
</table>

\(^a\) Based on data from Siegel et al.\(^1\)

\(^b\) Appropriate hand hygiene is a required component of all precautions.
not differ significantly between the 2 phases. These 3 studies had the same design limitations as the studies in the previous systematic review, including small sample sizes, single settings, and lack of control for potential biases and confounding. Nevertheless, the strong theoretical rationale and consistent suggestive study findings indicate that barrier precautions as recommended in the MDRO guideline are likely to reduce transmission of MRSA infection.

**Adverse Effects of Isolation Precautions**

Negative effects of isolation precautions are also well documented. The 2 most important effects are the adverse effect on the care and well-being of patients and increased costs. Patients on isolation precautions may be examined less often by their care providers, receive less care, be more likely to become depressed or anxious, and, most importantly, have more preventable adverse events than do patients who are not isolated. In a recent survey, isolated patients were significantly less likely than nonisolated patients to report that nurses explained things in a way that they understood ($P = .007$).

Herr et al calculated the cost per case of MRSA infection for isolation precautions in year 2000 euros to be €1179.70 (approximately US$1734, Table 2). West et al calculated in 2002 US dollars that the cost just for equipment used for contact precautions for MRSA infection in a community hospital system was $101.76 per patient, and a Canadian group reported that the costs of nursing time and supplies for contact precautions were approximately $61 Canadian daily (approximately US$57). These costs are most likely underestimates because they exclude costs of a private room and may not account for the myriad changes in work processes that occur to accommodate precautions.

Such untoward effects clearly indicate that contact precautions should be used only for the appropriate amount of time; that is, until the patient is no longer a risk for transmission and cultures are negative for MRSA. Unfortunately, the appropriate duration of contact precautions remains an unresolved issue in the latest CDC/HICPAC MDRO guideline because of conflicting evidence on when it is “safe” to discontinue precautions. Some investigators have found that no growth of the resistant organisms on consecutive cultures is a reliable criterion for discontinuing isolation in certain MDRO infections, but others have reported that colonization with MRSA can be prolonged and recurrent, even after treatment.

**Compliance With CDC Guidelines**

Although the Institute of Medicine, Agency for Healthcare Research and Quality, and other agencies have published criteria for guideline development and quality, little information or guidance is available for monitoring adherence to or assessing the clinical impact of guidelines. For example, the Institute of Medicine text on clinical practice guidelines does not discuss monitoring, and devotes only 3 pages to assessment of impact. Similarly, in 1996, the CDC published a document on improving the quality of guidelines. Even though this document described in detail the entire development process, including assessing needs, defining the scope and framework of the guideline, coordinating the review and preparation process, and updating, no guidance was provided on how to monitor compliance, and only 2 of 185 pages were devoted to assessment of impact. Unfortunately, the recommendations in this document were not implemented, and no standard mechanism exists for evaluating the impact of the CDC (or any other) guidelines.

A major challenge in assessing the impact of guidelines is measuring compliance accurately. The CDC guidelines are widely and rapidly disseminated, but awareness and dissemination of a guideline are not necessarily followed by adherence. The CDC recommendations are based on the best available scientific evidence, but field trials are essential to differentiate between efficacy based on high

### Table 2

<table>
<thead>
<tr>
<th>Hygienic measure</th>
<th>Cost per case, € (US$)</th>
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<tbody>
<tr>
<td>Communication/training of personnel</td>
<td>85.05 (125.02)</td>
</tr>
<tr>
<td>Personnel time (eg, donning protective wear, informing patients and visitors)</td>
<td>553.48 (813.62)</td>
</tr>
<tr>
<td>Equipment (masks, gloves, gowns, laundry)</td>
<td>286.61 (421.32)</td>
</tr>
<tr>
<td>Extra supplies and personnel time with patient (eg, meal trays, special disposal equipment and procedures)</td>
<td>109.78 (161.38)</td>
</tr>
<tr>
<td>Disinfection and cleaning measures (time and materials)</td>
<td>67.05 (98.56)</td>
</tr>
<tr>
<td>Patient transportation costs</td>
<td>77.73 (114.26)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1179.70 (1734.16)</strong></td>
</tr>
</tbody>
</table>

* Does not include costs of a private room.
* Based on data from Herr et al and West et al.
* Conversion rate, 1 € = $1.47.
internal validity within controlled trials and effectiveness, which is a result of the extent to which a practice is actually implemented. Unfortunately, compliance is often difficult and costly to measure, and the process of measurement itself results in loss of accuracy; that is, behavior changes as a result of being monitored. Among the efficacy studies we reviewed, only 40% reported monitoring compliance of the intervention being studied. Among the studies in which the intervention was monitored, the compliance rate was 80% or greater in only 16.6%, emphasizing again the challenge of determining the effectiveness of interventions in actual clinical settings. The primary ways to measure compliance with the CDC hand hygiene guideline,\textsuperscript{43} summarized in Table 3, are relevant for the measurement of compliance with isolation precautions as well.

For 13 weeks on 4 clinical units, Eveillard et al\textsuperscript{44} indirectly evaluated compliance with barrier precautions by checking patients’ rooms to confirm the presence of equipment needed (gowns, gloves). They then compared the rate at which appropriate precautions were available with the rate at which precautions were documented in the patients’ records. The use of precautions was documented 3 to 4 times more often than the appropriate equipment was actually available ($P<.001$), evidence that the information recorded on patients’ charts did not reflect actual practice. Similarly, twice monthly for 14 months, infection control staff prospectively assessed isolation precautions in a Canadian tertiary care pediatric hospital.\textsuperscript{45} A total of 623 of 3636 hospitalized patients (17%) were isolated, but primarily for community-acquired infections; 77 of the 623 isolations (12.4%) were for MDRO infections. Although the authors\textsuperscript{45} reported that 74.6% of patients were isolated appropriately, they primarily assessed the presence of signs and equipment but did not observe actual practice.

In a study conducted in a 900-bed teaching community hospital, Manian and Ponzillo\textsuperscript{46} reported that an infectious disease physician and an ICU pharmacist made 1548 observations that involved 21 10 persons entering the room of a patient in isolation. This number included 1504 staff members and 606 visitors. Overall, almost three-fourths (1542 of 21 10, 73%) complied with use of gowns, including 67% (1 19 of 177) of physicians and 78% (914 of 1178) of nurses. In regression analyses, independent predictors of gown compliance among staff

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**Table 3** Methods of measuring compliance with recommendations of the Centers for Disease Control and Prevention for isolation precautions\textsuperscript{a}

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
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<tbody>
<tr>
<td>Direct observation</td>
<td>Gold standard</td>
<td>Labor and resource intensive</td>
</tr>
<tr>
<td></td>
<td>Only method that provides information about by whom and how specific practices are performed</td>
<td>Subject to Hawthorne effect</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Only a small sample of behavior can be observed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Can be subject to bias due to oversampling selected shifts (days) or units (eg, intensive care units) and inadequate sampling of other shifts (nights/weekends)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No standardized observational protocols</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not sustainable or generalizable</td>
</tr>
<tr>
<td>Remote observations</td>
<td>Videotaped observations less subject than other methods to selection bias because camera can monitor at random intervals</td>
<td>Expensive to install and maintain equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Labor costs to review tapes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Can be subject to bias because of camera placement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Issues of patient confidentiality</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not sustainable or generalizable</td>
</tr>
<tr>
<td>Self-report</td>
<td>Low cost</td>
<td>Poor validity</td>
</tr>
<tr>
<td></td>
<td>Involves health care workers in thinking about their behavior</td>
<td></td>
</tr>
<tr>
<td>Volume of products used</td>
<td>Less costly than other methods</td>
<td>No information about which practices are followed, or which staff members are in compliance</td>
</tr>
<tr>
<td>(gowns, gloves, etc)</td>
<td>Overall measure of use</td>
<td>Not possible to assess technique</td>
</tr>
<tr>
<td>Electronic monitoring</td>
<td>Less subject than other methods to observer bias and Hawthorne effect</td>
<td>Expensive initial development</td>
</tr>
<tr>
<td></td>
<td>Most sustainable and generalizable</td>
<td>No information about which practices are followed, or which staff members are in compliance</td>
</tr>
<tr>
<td>Health care–associated</td>
<td>Important as the ultimate goal of compliance</td>
<td>Relationship between isolation and infection may be confounded by other interventions (eg, cleaning the environment)</td>
</tr>
<tr>
<td>infection rates</td>
<td>Data generally available</td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{a} Based on data from Haas and Larson.\textsuperscript{43}
Leading professional associations have recommended automated systems to track and target resistance and interventions.

Standard Methods of Surveillance

Since the classic study of the efficacy of nosocomial infection control in the 1970s, surveillance has been recognized as an essential component of any effective program for prevention and control of infection. In fact, a large proportion of infection control professionals’ time is spent in surveillance activities. The standard surveillance methods for MRSA vary considerably across acute care settings. Generally, data on organisms of interest are gathered manually by infection control professionals from culture reports generated by the clinical microbiology laboratory either in paper or electronic format. A listing of cultures positive for MRSA is often used as the primary data source, as well as rounds on the clinical units and/or reviews of patients’ charts.

Little support for decisions is provided, so the infection control professional must then determine what action to take, with whom to take action, and what to communicate. Once the potential cases of MRSA infections are identified, the infection control professional often reviews the patient’s medical record and speaks with the clinical personnel in the unit to gather additional information and evidence to make a recommendation about the patient’s placement. Because of the growing number of resistant organisms and the lack of resources, surveillance activities are usually targeted to high-risk areas such as ICUs or to specific organisms.

In the traditional system, isolation precautions are usually ordered by a clinician or an infection control professional on the basis of institutional protocols. Similarly, communication of a patient’s qualification for removal from isolation is often made verbally via telephone or during rounds on the patient care units, and decisions about when to discontinue isolation are often made on a case-by-case basis. Manual methods of collecting data such as clinical rounds and review of microbiological and pharmacy reports are time and labor intensive and subject to considerable interobserver variability, even with increasingly clear and consistent definitions provided by the National Health and Safety Network (formerly the National Nosocomial Infections Surveillance system). Further, with traditional manual methods of data collection, databases for rapid detection of MDRO infections cannot be linked to assessment of patients’ risk factors and severity of illness.

Automated Surveillance Systems

Since the 1980s, the potential for information linking and analysis has become more realistic, and automated systems offer the potential for monitoring and intervening much earlier than would be possible with manual data collection. Despite the potential of automated systems for rapid data linking and dissemination, and the fact that more than 90% of acute and long-term care facilities report having systems to track infections, the current status of surveillance systems to track health care–associated infections is not well described. It appears, however, that most surveillance is still manual. “Homegrown” automated systems developed within individual facilities have been reported, but few descriptions of their actual use for supporting clinical decisions have been published. Despite initial costs of system development, automated systems in the long run are projected to be cost saving.

Several proprietary systems for monitoring infection control processes are available, and a few have undergone some field testing. These proprietary systems as well as locally developed systems have been used primarily for monitoring rates of health care–associated infection and patterns of antimicrobial use; a few have been used to generate clinical alerts, primarily to improve prescribing of antibiotics. In general, studies of these systems have reported more appropriate and judicious use of antimicrobial agents. For example, a computer-assisted antimicrobial management program developed by Intermountain Health Care (a group long known for its innovative and groundbreaking use of technology...
in health care) has been associated with reductions in antibiotic use, related adverse events, and costs.73-79

To our knowledge, a link between automated surveillance systems and reductions in resistance rates has not yet been reported.80 This finding is not surprising because patterns of antibiotic use, once established in an institution, will most likely be slow to change. Nevertheless, leading professional associations (Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America) have recommended automated systems to enhance tracking and targeting of resistance and interventions.88

Despite their promise, however, automated systems for supporting decisions for clinical practices such as isolation precautions have not yet been widely implemented and disseminated. Only 13% of 150 infection control professionals in a 2007 survey reported that they use such technology. The failure to adopt automated technologies has been associated with organizational factors such as type of health care system and institution size and location. Larger systems and for-profit hospitals are more likely to adopt automated systems, and such systems have been associated with more positive operating revenue.85

Although automated alerts to control MDRO infections have been suggested since the 1990s, only a few investigators have assessed the results of such applications. Pittet et al used computer-generated reports to alert infection control staff when a patient with an MRSA infection was admitted. The infection control staff then contacted the patient’s physician. Although this intervention was associated with a reduction in the time to obtain follow-up cultures and an increase in the proportion of patients with an MRSA infection identified at admission, it was resource intensive and time consuming.86 In a systematic literature review of randomized and nonrandomized controlled trials to evaluate the effects of computerized clinical decision support systems, Garg et al found positive changes in provider behavior in 16 of 21 studies (76%) in which use of reminder systems was examined. Improved performance was associated with systems that use automatic prompts rather than prompts that require user activation; 73% of trials with automatic prompts were successful vs 47% of trials with prompts that required user activation (P = .02).

A French research team used an informational flyer that was attached to each microbiology report of a culture positive for MRSA.86 Adherence to isolation precautions was assessed by observation for 3 months before and after implementation of the flyer. Observers were not blinded to the study aims, and no information was provided about interobserver reliability. A total of 89 patients with MRSA infection were observed during the control period, and 76 were observed during the intervention period. The presence of the appropriate signage, use of gowns and dedicated materials, and proportion of patients infected with MRSA assigned to private rooms all increased significantly (all P < .04) during the implementation period.88

In another French study in a 750-bed teaching hospital, Kac et al investigated use of an electronic system to alert staff members about the need for isolation precautions among patients infected with MDROs. When alerts were sent to members of the infection control team, who then ordered isolation precautions on electronic nursing records, awareness of the MDRO status among the nursing staff increased from 24.0% at baseline to 93.1% after 1 year. Implementation of isolation precautions increased from 15.0% at baseline to 90.2% after 1 year. Significant improvements were sustained over the several years of the study. Kho and colleagues developed and tested a computerized physician reminder for contact precautions for patients infected with MDROs and reported an increase in the proportion of eligible patients isolated, from 33% to 89% from before to after the intervention (P < .001), but no changes in rates of infection. The same research team created a citywide electronic network to track and respond in a standardized way to patients admitted with a history of infection with MRSA or vancomycin-resistant enterococci.85

The potential for information linking and analysis has become more realistic, and automated systems offer the potential for much earlier intervention.

Essential Elements of Surveillance Systems

Many of the systems to date have been promising, but have lacked some important features. In order to improve clinical practice, an automated surveillance system must have a number of characteristics. It must (1) have the capability to prospectively retrieve and link data elements from a variety of relevant sources; (2) be highly sensitive, specific, and precise; (3) account for patient confidentiality; (4) be user friendly with intuitive alerts and data retrieval interfaces; (5) provide information for clinical decision making at the point of use and in real time; (6) be generalizable, accessible, and reproducible across health care systems; (7) include clinical indications (in addition to cases identified only
through laboratory cultures); (8) be customizable for the changing needs of institutional and regulatory reporting requirements; (9) provide features for use by clinicians and members of the patient care team in addition to infection control professionals; and (10) be cost-effective. Development of such systems is expensive, and the systems would be cost-effective only if they were associated with improved monitoring and adherence to infection prevention practices and, as a result, a reduction in the costs of health care–associated infections. The need is therefore great for additional research on the costs of automated systems and an objective analysis of cost-benefit issues for programs such as those described in Table 4.

FINANCIAL DISCLOSURES
None reported.

SEE ALSO
For more about multidrug-resistant pathogens, visit the Critical Care Nurse Web site, www.ccnonline.org, and read the article by Montefour and colleagues, “Acinetobacter baumannii: An Emerging Multidrug-Resistant Pathogen in Critical Care” (February 2008).

REFERENCES

<table>
<thead>
<tr>
<th>System</th>
<th>Purposes (from Web sites)</th>
<th>Published field tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>AICE Millennium (<a href="http://www.icpa.net/aice.html">www.icpa.net/aice.html</a>)</td>
<td>Monitor and analyze health care–associated infections, investigate outbreaks, analyze patients’ risk factors, and benchmark data</td>
<td>None found</td>
</tr>
<tr>
<td>EpiQuest (<a href="http://www.epiquest.com">www.epiquest.com</a>)</td>
<td>Identify, analyze, and monitor historic and current infectious trends; tracking of patient, health care admissions, and incidence trends</td>
<td>None found</td>
</tr>
<tr>
<td>MedMined (<a href="http://www.cardinal.com/medmined">www.cardinal.com/medmined</a>)</td>
<td>Infection data, data-mining technologies, best-practice recommendations to address emerging issues, alerts for use of antimicrobials</td>
<td>Significantly higher sensitivity and specificity than SENIC chart review and NNIS surveillance methods</td>
</tr>
<tr>
<td>QC Pathfinder (<a href="http://www.vecnamedical.com/medical/qcpathfinder.shtml">www.vecnamedical.com/medical/qcpathfinder.shtml</a>)</td>
<td>Uses real-time microbiology laboratory, pharmacy, surgical, radiology, critical care, and other data feeds and advanced analysis to monitor and detect infections</td>
<td>None found</td>
</tr>
<tr>
<td>SafetySurveillor (<a href="http://www.premierinc.com/quality-safety/tools-services/performance-suite/infectioncontrol.jsp">www.premierinc.com/quality-safety/tools-services/performance-suite/infectioncontrol.jsp</a>)</td>
<td>Web-based tool; subscription accessed over a secure Internet server for managing infection control surveillance; prevention and reporting efforts including control charts and Sentinel event alerts</td>
<td>User-defined control charts were more sensitive than routine methods for identification of clusters of infection</td>
</tr>
<tr>
<td>Theradoc (<a href="http://www.theradoc.com">www.theradoc.com</a>)</td>
<td>Surveillance tools and clinical alert system linked to electronic patient records to report test results, medication orders, and patient data in real time</td>
<td>Used during 2002 Olympic Games, Salt Lake City, to monitor potential public health problems</td>
</tr>
</tbody>
</table>


93. Wright MO, Perencevich EN, Novak C, Hebben JD, Standa-
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Elaine L. Larson, Bevin Cohen, Barbara Ross and Maryam Behta

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