Impact of Electronic Alerts on Isolation Precautions for Patients With Multidrug-Resistant Bacteria

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Background: Health care workers’ compliance with isolation precautions for patients colonized or infected with multidrug-resistant bacteria (MRB) is low.

Methods: In a 750-bed, acute care university hospital with a patient information system covering the entire hospital, a database that included all patients with MRB was created and was merged daily with the admission-discharge-transfer application. An electronic alert was generated for all new cases of MRB and for all transfers between wards and all readmissions of patients with MRB. Two successive interventions were implemented based on this alert system. First, alerts were dispatched to medical and staff members in charge of infection control in each ward with requests to order isolation precautions for the patients. Second, alerts were dispatched to the infection control team, who directly ordered implementation of isolation precautions in electronic nursing records. Five audits during a 3-year period were performed to evaluate their effect on health care workers’ compliance with isolation precautions.

Results: Awareness of the MRB status for the nurses in charge of the patients statistically significantly increased from 24.0% at baseline to 59.4% at 1 year after the first intervention. This proportion improved to 93.1% at 1 year after the second intervention. Similarly, the implementation of isolation precautions statistically significantly increased from 15.0% at baseline to 50.5% at 1 year after the first intervention and then to 90.2% at 1 year after the second intervention.

Conclusion: A computer alert system can lead to effective and lasting improvement in the implementation of isolation precautions for patients with MRB in health care institutions.

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HE EMERGENCE OF ANTIMICROBIAL RESISTANCE IN PATHOGENS HAS BECOME A MAJOR PUBLIC HEALTH PROBLEM WORLDWIDE.1,2 Health care-associated infections due to multidrug-resistant organisms are associated with increased morbidity, mortality, and health care costs.3-5 The major routes of dissemination of multidrug-resistant organisms are transmission by direct contacts (through patient-staff interactions) and by indirect contacts (through contamination of environmental surfaces or patient care equipment). Early identification of patients colonized or infected with antibiotic-resistant pathogens and subsequent prevention of spread among patients through barrier isolation precautions are considered to be the most effective ways to control spread of these organisms.6-9 However, the compliance of health care workers with national guidelines6,8 and with local procedures concerning isolation precaution6,9-11 is low. In institutions in which the prevalence of multidrug-resistant bacteria (MRB) is high, poor compliance with isolation precautions may be partially because of loss of information during internal transfers or when patients colonized or infected with multidrug-resistant organisms are readmitted. There is a steady increase in the use of computer information systems in hospitals, but their contribution to improving the adherence of health care workers to infection control procedures has not been widely assessed. The objective of this study was to evaluate the effect of implementing 2 successive electronic alert systems dedicated to patients with MRB on health care workers’ compliance with isolation precautions.

METHODS

HOSPITAL INFORMATION SYSTEM

Hôpital Européen Georges Pompidou, Paris, France, is a 750-bed, acute care university hospital that includes 22 wards (13 medical wards, 6 surgical wards, and 3 intensive care units) with approximately 33 000 admissions per year. A patient information system (DxCare; Medasys, Gil sur Yvette, France), combining an electronic medical record and a computer prescription order entry system, is operational throughout the hospital. The electronic medical record contains most patient clinical information, all labo-

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ratory data from the laboratory information system (including microbiology culture and antibiotic susceptibility results), and the admission-discharge-transfer application.

**MRB CONTROL PROGRAM**

The infection control team, consisting of 1 infection control physician (G.K.), 2 full-time nurses, 1 half-time engineer in microbiology (P.G.), and 2 technicians (M.G. and A.R.), implements the MRB control program, advised by the local infection control committee. A physician and a nurse are in charge of infection control in each ward. According to the local MRB control program, patients with MRB must be placed in single rooms; all staff must wear disposable aprons during care and perform hand rubbing with an alcoholic solution before and after direct or indirect contact with patients with MRB. Gloves are required when contact with blood or body fluids is anticipated. A dedicated MRB poster detailing all barrier isolation precautions must be placed on the door of the patient’s room. Surveillance cultures of nasal swabs (and wound swabs if present) for methicillin-resistant *Staphylococcus aureus* (MRSA) and rectal swabs for multidrug-resistant Enterobacteriaceae (MRE) (particularly extended-spectrum β-lactamase–producing Enterobacteriaceae and extended-spectrum cephalosporinase-producing Enterobacteriaceae) are required for patients discharged from intensive care units and transferred to medical or surgical wards. Screening for MRSA is also required for patients transferred from nursing homes or extended care institutions and for those who have chronic wounds. After sampling, isolation precautions are maintained until MRB culture results are available. If screening or clinical specimens yield positive results, isolation precautions are maintained during the entire patient stay. There are periodic educational meetings for hospital staff, mainly nurses and nursing assistants, in all wards. An audit conducted in 2001 showed that most patients with MRB were not isolated or were incorrectly isolated. Therefore, we decided to develop an electronic alert to improve the implementation of isolation precautions for patients with MRB.

**ELECTRONIC ALERTS**

First, we included a specific MRB tag in the computer program for screening and clinical specimens yielding MRSA or MRE. These MRB were identified according to the guidelines set by the Committee for Antimicrobial Testing of the French Society for Microbiology (http://www.sfm.asso.fr). A specific database for microbiology laboratory findings that included data for all patients colonized or infected with MRB was created and was merged daily with the admission-discharge-transfer application. The system identifies new MRB cases, transfers of patients with MRB from one ward to another, and readmissions to the hospital of patients with MRB. All events prompted the system to generate an alert, including patient identity and pertinent patient identification number, date of MRB identification, and type of MRB (ie, MRSA or MRE). Alerts were automatically generated 24 hours a day and 7 days a week. The system was activated in April 2003 (Figure 1). There was no specific information delivered to staff about the conduct of the study.

During the initial period, alerts were dispatched by e-mail to the infection control team. No active information was delivered by the infection control team to health care workers; consequently, physicians and nurses had to specifically look for the antibiotic susceptibility testing results in the patient’s electronic record, where the MRB tag was added at the end of the antibiogram. Physicians and nurses had open access to this information when connected to electronic medical records. This period was considered the baseline and allowed us to validate the system. Two interventions were then implemented successively.

![Figure 1. Time line of intervention periods and audits (April 2003 to July 2006).](https://archinte.jamanetwork.com/resource/1272690771)

During the first intervention, alerts were dispatched via e-mail to the physicians and nurses in charge of infection control in each ward. These staff members had to look for new e-mails and were then requested to implement isolation precautions for the affected patients.

During the second intervention, alerts were dispatched to the infection control team, who directly ordered implementation of isolation precautions in electronic nursing records. The MRB tag did not pop up when connected on the patient’s screen, but the following message was immediately visible on the screen by the nurse when connected to the electronic nursing record of this patient where he or she had to regularly validate medical prescriptions during day and night shifts: “This patient is an MRB carrier. You must place this patient under isolation precautions according to the local infection control recommendations.”

**AUDITS**

Parallel to these interventions, we conducted 5 successive audits (Figure 1), including a baseline audit, 2 successive audits during the first intervention, and again 2 successive audits during the second intervention. Each audit lasted between 7 and 9 weeks. Following the generation of an alert, an infection control technician checked if the nurse in charge of the patient was aware of the MRB-positive status of the patient and if contact isolation precautions had been implemented. The technician observed if the patient was in a private room, if the MRB poster was on the door of the patient’s room, and if protective equipment (aprons and gloves) was present; if all 3 criteria were fulfilled, the patient was considered to be correctly isolated.

Only inpatients were included. When 2 different MRB were isolated from a single patient during a stay in a single ward, only the first isolation was considered for inclusion in the audit. Our primary outcome was the proportion of patients with MRB correctly isolated according to local guidelines. Our secondary outcome was the proportion of patients with MRB who were correctly identified by nurses. In addition, we recorded the incidence of MRB cases diagnosed at our institution during the 4-year study period.

**STATISTICAL ANALYSIS**

For each audit period, we estimated the proportions and their 95% confidence intervals (CIs) of correctly isolated (identified) patients with MRB using the Rao-Scott method taking intrahospitalization unit correlation into account. We assessed the homogeneity of these proportions between the second and third audits and between the fourth and fifth audits using an adjusted χ² test.14
To assess the effect of the interventions, we used a generalized estimating equations procedure to model the probability of correct isolation (identification) of patients with MRB, considering intrahospitalization unit and intra-audit period correlations. The analysis was also performed in subgroups defined by the type of alerts. We also tested the effect of the type of MRB on the probability of correct isolation (identification) of patients with MRB.

In addition, a Poisson regression model was fitted to determine whether the trend in the yearly incidence rate of MRB cases from 2003 to 2006 diagnosed at our institution was statistically significant. Results were considered statistically significant at $P<.05$. Commercially available statistical software (SAS version 9.1, SAS Institute, Cary, North Carolina) was used for all analyses.

### RESULTS

Six hundred forty-three alerts were generated during the 5 audit periods (Table). Of these 643 alerts, 137 alerts could not be audited because the patients had been discharged before observation (98 alerts), had been transferred to day care units or were outpatients (36 alerts), or had died before observation occurred (3 alerts). As a result, 506 alerts (78.7%) corresponding to 362 patients were included. Of these 506 alerts, 132 (26.1%) corresponded to new cases, 172 (34.0%) to transfers, and 202 (39.9%) to readmissions. The median delay between an alert generation and its audit was 26 hours for the 5 audit periods.

The awareness of the MRB status by the nurses in charge of the patients increased statistically significantly from 24.0% (95% CI, 13.9%-34.1%) at baseline to 66.3% (95% CI, 54.4%-78.3%) immediately after the beginning of the first intervention and was maintained at 59.4% (95% CI, 46.4-72.3) 1 year later ($P = .44$, adjusted $\chi^2$ test of homogeneity between audits 2 and 3). It then increased to 95.1% (95% CI, 91.6%-98.6%) immediately after the beginning of the second intervention and was maintained at 93.1% (95% CI, 88.9%-97.4%) 1 year later ($P = .48$, audit 4 vs audit 5) (Figure 2).

Similarly, implementation of isolation precautions statistically significantly increased from 15.0% (95% CI, 6.2%-23.8%) at baseline to 57.4% (95% CI, 44.2%-70.6%) immediately after the first intervention and was maintained at 50.5% (95% CI, 38.1%-62.9%) 1 year later ($P = .46$, audit 2 vs audit 3). It then increased to 86.3% (95% CI, 80.2%-92.3%) immediately after the second intervention and to 90.2% (95% CI, 84.9%-95.5%) 1 year later ($P = .34$, audit 4 vs audit 5).

Overall, both interventions were highly effective because the odds of correct identification of patients with MRB was multiplied by 5.1 (95% CI, 2.6-9.8) and 50.5 (95% CI, 24.2-105.2) by the second and third interventions, respectively, compared with the baseline period. Similarly, the odds of correct isolation of patients with MRB was multiplied by 5.9 (95% CI, 2.8-12.5) and 37.8 (95% CI, 17.5-81.5) by the second and third interventions, respectively, compared with the baseline period.

Both interventions were effective for new cases and for transfers. Only the second intervention statistically significantly improved correct identification and isolation for readmissions of patients with MRB (Figure 2). The type of MRB had no statistically significant effect on the probability of correct identification or isolation ($P = .09$, MRSA vs MRE; odds ratio, 1.5; 95% CI, 0.9-2.4 for both outcomes).

The incidence rate of patients with MRB decreased from 1.98 (95% CI, 1.79-2.19) cases per 1000 patient-days in 2003 and 1.96 (95% CI, 1.77-2.17) in 2004 to 1.78 (95% CI, 1.61-1.98) in 2005 and 1.54 (95% CI, 1.37-1.72) in 2006. There was a statistically significant linear trend ($P = .01$); compared with 2003, the incidence rate decreased by a factor of 0.97 (95% CI, 0.95-0.99) each year.

### COMMENT

The implementation of electronic alerts dedicated to patients with MRB in the hospital information system resulted in a 1.5-fold increase in the nurses’ awareness of

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**Table. Multidrug-Resistant Bacteria (MRB) Alerts During the 5 Audit Periods**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Audit 1</th>
<th>Audit 2</th>
<th>Audit 3</th>
<th>Audit 4</th>
<th>Audit 5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. included/generated alerts (%)</td>
<td>100/128 (78.1)</td>
<td>101/127 (79.5)</td>
<td>101/133 (75.9)</td>
<td>102/129 (79.1)</td>
<td>102/126 (81.0)</td>
<td>506/643 (78.7)$^a$</td>
</tr>
<tr>
<td>Hospitalization units (minimum-maximum)</td>
<td>31 (1-8)</td>
<td>29 (1-9)</td>
<td>30 (1-7)</td>
<td>31 (1-9)</td>
<td>31 (1-9)</td>
<td>50</td>
</tr>
<tr>
<td>No. of patients per unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of MRB, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methicillin-resistant Staphylococcus aureus</td>
<td>49</td>
<td>45</td>
<td>47</td>
<td>49</td>
<td>40</td>
<td>46</td>
</tr>
<tr>
<td>Multidrug-resistant Enterobacteriaceae</td>
<td>51</td>
<td>55</td>
<td>53</td>
<td>51</td>
<td>60</td>
<td>54</td>
</tr>
<tr>
<td>Type of alert, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New case</td>
<td>20</td>
<td>20</td>
<td>28</td>
<td>33</td>
<td>28</td>
<td>26</td>
</tr>
<tr>
<td>Transfer</td>
<td>33</td>
<td>44</td>
<td>29</td>
<td>28</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>Readmission</td>
<td>47</td>
<td>36</td>
<td>43</td>
<td>39</td>
<td>38</td>
<td>40</td>
</tr>
<tr>
<td>Median delay between alert generation and audit (interquartile range), h</td>
<td>23 (20-44)</td>
<td>28 (23-45)</td>
<td>25 (22-38)</td>
<td>26 (22-46)</td>
<td>26 (22-32)</td>
<td>26 (22-45)</td>
</tr>
</tbody>
</table>

$^a$ One hundred thirty-seven alerts were excluded, including 98 patients who were discharged before audit, 36 patients who were transferred to day care units or were outpatients, and 3 patients who had died before audit.
the patients’ MRB status and in the proportion of correctly isolated patients with MRB. These proportions increased by an additional 50% when a member of the infection control team placed a written order directly in electronic nursing records requiring implementation of MRB isolation contact precautions. The effects of both interventions were sustained after 1 year.

Three lessons can be drawn from this study. First, this study confirms that computerized physician order entry systems with embedded decision support tools can make a valuable contribution to improving clinical practice and are associated with a sustained effect following the intervention. Educational interventions to improve staff adherence to infection control measures have generally had a modest effect; furthermore, the effects decline after the end of the intervention. Also, surveillance rounds by infection control nurses are time-consuming. Some hospitals have implemented similar computer alert systems for patients with MRB. Second, the decision tool was effective for the following 3 types of alerts: new cases of MRB, transfers of patients with MRB from one ward to another, and readmissions of previous patients with MRB (only the second intervention). Patients often remain colonized with MRB for long periods. Consequently, rapid and automatic identification of patients previously identified as MRB carriers when transferred to another ward or readmitted to the hospital may help control MRB spread through the hospital. Early implementation of correct isolation precautions may have an effect specifically on the transmission of MRSA and on the reservoir for patients with MRSA as shown previously by Harbarth et al. In hospitals without such systems, isolation precautions are implemented only when MRB are identified by clinical or screening cultures from hospitalized patients. In our study, 41% of the alerts corresponded to readmissions. This is consistent with the 36% reported by Pittet et al for patients recognized only by an alert system dedicated to patients with MRSA.

Third, the second intervention, involving isolation precaution orders placed in electronic nursing records by the infection control team, had a large beneficial effect. A study of compliance with contact isolation precautions found that having a physician-written order for patient isolation was the only condition that was independently and strongly associated with correct isolation. Recently, a computerized reminder system was found effective in increasing the rates of compliance with isolation recommendations dedicated to readmitted patients with a history of colonization or infection with MRB. It has also been demonstrated in a different context, prescription of vaccination, that writing orders directly in the patient record was more effective than simply reminding health care professionals.

Parallel to the improved compliance with isolation procedures, we observed a statistically significant decrease in the incidence rate of MRB cases at our institution during a 4-year period. However, this temporal association

![Figure 2. Awareness of multidrug-resistant bacteria (MRB) status of patients by nurses and implementation of isolation precautions for patients with MRB during the 5 audit periods according to the type of alert.](https://archinte.jamanetwork.com/)
should be considered cautiously when considering all identified cofactors for patients with MRB. Hospital spread of MRB is affected not only by quality factors (ie, staffing ratios, length of hospital stay, appropriate antibiotic use, isolating or cohorting care of MRB carriers, and adherence of healthcare workers to hand hygiene) but also by patient-related risk factors (ie, age, comorbidities, presence of skin breaks, previous hospital stay, previous antibiotic use, presence of indwelling devices, and presence of nasal S aureus colonization). Therefore, interpreting health outcomes is hampered by the problem of case mix. There is general agreement that it is better to evaluate processes rather than outcomes when assessing the effect of a clinical guidelines implementation strategy. Outcomes have multiple determinants, and it is generally impossible to know what proportion of a given health outcome is determined by processes of care and what is due to patient-related risk factors.24

The main limitation of this alert system dedicated to patients with MRB is that it is restricted to our institution; patients with MRB identified by our system may have been admitted to other hospitals during the study period and not been recognized as potential MRB reservoirs. Implementation of information systems in other hospitals may allow the use of such an alert system for regional or even national hospital networks.

Herein, we have shown that a computer alert system is a useful tool for the detection of previously known patients with MRB. Electronic alerts offer lasting improvement in the implementation of isolation precautions in an individual institution.

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Author Contributions: Dr Kac had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Kac, Grohs, Guillemain, and Meyer. Acquisition of data: Kac, Gueneret, Rodi, Boiron, and Leglise. Analysis and interpretation of data: Kac, Grohs, Durieux, Trinquart, and Meyer. Drafting of the manuscript: Kac, Grohs, Durieux, Gueneret, Rodi, Boiron, Guillemain, and Leglise. Critical revision of the manuscript for important intellectual content: Kac, Trinquart, and Meyer. Statistical analysis: Durieux and Trinquart. Administrative, technical, and material support: Grohs, Boiron, Guillemain, and Leglise. Study supervision: Kac and Meyer.

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REFERENCES