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Major article

## Automated tracking and ordering of precautions for multidrug-resistant organisms



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### Key Words:

Multidrug-resistant organism  
*Clostridium difficile*  
Isolation  
Precautions

**Background:** The transmission and infection risk associated with multidrug-resistant organism (MDRO) carriers necessitates surveillance and tracking to provide proper contact precautions. As MDROs increase in scope, automated electronic health record (EHR) systems may help with surveillance demands.

**Methods:** We created a system for MDROs and *Clostridium difficile* tracking that automated the following 3 main surveillance and tracking activities: monitoring of microbiology results and initiation of chart-based flags, ordering of contact precautions on admission, and ensuring appropriate removal of precautions.

**Results:** Automation saved 43 infection preventionist hours per 1,000 admissions, in addition to previously unquantified hours spent reviewing MDRO history for every admission. Automatic retiring of certain MDRO flags ensured removal of contact precautions after a specified time. A point-prevalence assessment for eligibility for discontinuation found that all precautions were appropriate, with none eligible for removal. By integrating microbiology data, EHR tracking flags, and automated orders, this system assured rapid and comprehensive placement of patients into contact precautions without requiring oversight by infection prevention personnel.

**Conclusion:** We show that automated systems embedded within EHRs can ensure tracking and application of appropriate contact precautions while simultaneously producing tremendous time savings for infection prevention programs.

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Tracking of endemic and emerging multidrug-resistant organisms (MDROs) and *Clostridium difficile* in hospitalized patients to ensure appropriate use of contact precautions is important for protecting patients by preventing transmission. Of nearly 70,000 health care-associated infections (HAIs) reported by U.S. hospitals to the National Healthcare Safety Network in 2009–2010, nearly 20% were associated with MDROs.<sup>1</sup> This included approximately 6,000 methicillin-resistant *Staphylococcus aureus* (MRSA) HAIs, 6,000 multidrug-resistant (MDR) gram-negative bacteria (GNB) HAIs, and 2,000 vancomycin-resistant *Enterococcus* (VRE) HAIs.<sup>1</sup>

Carriage of these important pathogens is associated with high risk of later infection.<sup>2</sup> For this reason, hospitals are required to implement a surveillance program for MDROs and the infections

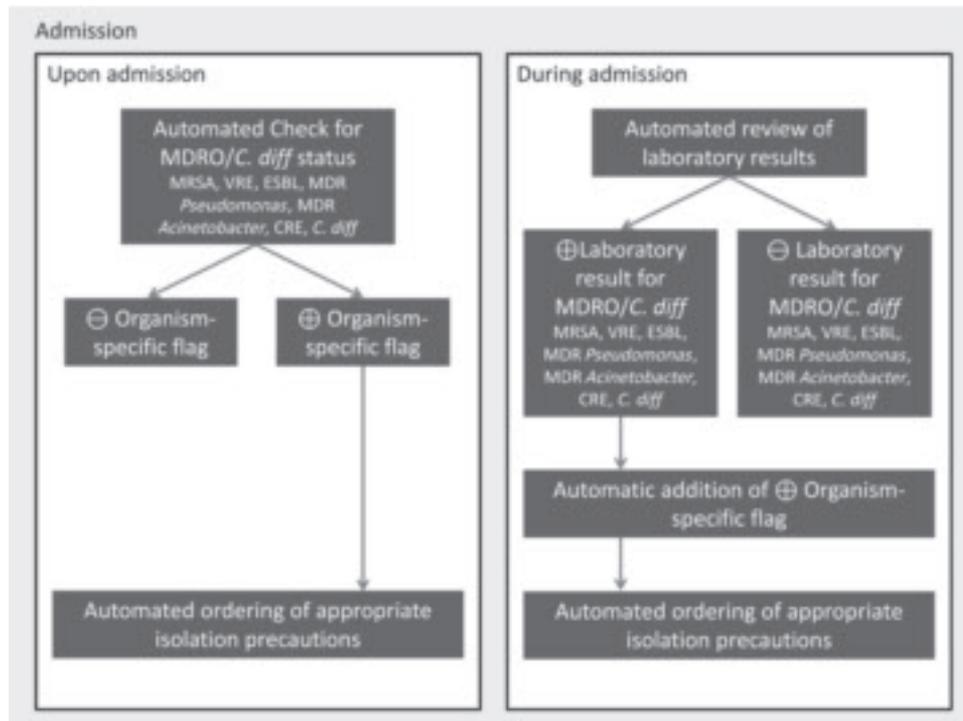
they cause.<sup>3</sup> Surveillance programs allow for the identification of patients with infection or carriage of significant organisms; therefore, contact precautions can be properly applied to help prevent MDRO spread.

MDRO surveillance and assuring contact precautions is time and labor intensive for infection prevention programs. Effort is needed to not only assess newly positive laboratory results but to also track prior history of MDRO carriage and recent *C difficile* infection that may still be associated with diarrhea.<sup>4</sup> Furthermore, infection prevention programs must ensure that MDRO carriers receive single rooms, if available, and appropriate precautions on admission. Finally, infection prevention programs often track and promote the removal of precautions when appropriate criteria are met.

The Joint Commission requires infection prevention measures to include, but not be limited to, MRSA, VRE, MDR GNB, and *C difficile*.<sup>3</sup> The increasing number of MDROs amplifies the time and labor required for these infection prevention activities. As additional MDR GNB continue to emerge, including MDR *Acinetobacter*,

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Conflicts of interest: None to report.



**Fig 1.** Flow diagram demonstrating the system's automated functions. *C. diff*, *Clostridium difficile*; CRE, carbapenem-resistant Enterobacteriaceae; ESBL, extended-spectrum  $\beta$ -lactamase; MDR, multidrug resistant; MDRO, multidrug-resistant organism; MRSA, methicillin-resistant *Staphylococcus aureus*; VRE, vancomycin-resistant *Enterococcus*.

MDR *Pseudomonas*, extended-spectrum  $\beta$ -lactamase producers, and carbapenem-resistant Enterobacteriaceae (CRE), the time associated with preventing their spread will continue to rise.

The effort required for surveillance can be magnified further by mandatory screening laws, such as those that exist in 8 states for MRSA.<sup>5</sup> This type of active MRSA surveillance testing program is recommended by the Society for Healthcare Epidemiology of America and the Infectious Diseases Society of America when basic practices of contact precautions and cleaning fail to produce effective control.<sup>6</sup> To maintain institution-level infection prevention priorities while also fulfilling such mandates, infection prevention programs must streamline tracking processes.

In the face of these increasing demands, automated electronic health record (EHR) systems can decrease MDRO surveillance workload. Additionally, such systems can improve patient safety by providing a fail-safe way to ensure assignment of single rooms and ordering of contact precautions for appropriate patients. One study found that an automated, pop-up suggested order for contact precautions, which could be approved by admitting physicians with 1 click, increased contact precautions for eligible patients from 33% to 89% and decreased median time to precautions from 16.6 to 0 hours.<sup>7</sup> Another system sent automated requests for contact precautions directly to the infection prevention team for all new or readmitted MDRO cases and increased contact precaution orders from 50.5% to 90.2% after 1 year.<sup>8</sup> Given these results, The Joint Commission, Society for Healthcare Epidemiology of America and Infectious Diseases Society of America, and Healthcare Infection Control Practices Advisory Committee guidelines suggest that hospitals implement laboratory-based alert systems that identify patients with newly identified MDRO carriers and readmitted or transferred patients who are previously known carriers.<sup>5,9-11</sup> The use of informatics to identify and promote isolation of MDRO cases can provide 24-hour automated and fail-safe solutions. Our goal was to develop a fully automated system that linked microbiology and historical data to inpatient orders for contact precautions for

appropriate patients deemed to harbor transmissible pathogens without the need for physician or infection preventionist intervening action.

## METHODS

We created a system for MDRO and *C difficile* tracking that signaled new and historical status in real time by automatically generating a flag (visual alert in the header banner of the EHR) and automatically generated orders for appropriate inpatient precaution (Fig 1). This prominent placement allowed all health care workers viewing the patient's EHR to easily see the patient's MDRO and *C difficile* status. This system automated the following 3 main areas of infection prevention surveillance and tracking activities: real-time monitoring of microbiology laboratory results and initiation of active MDRO and *C difficile* EHR flags, timely ordering of contact precautions, and appropriate inactivation of EHR flags and removal of precautions. The system was implemented at the University of California, Irvine Medical Center, a 410-bed tertiary care academic medical center with a level I trauma center, regional burn center, and comprehensive cancer center. This project was performed for hospital operations and quality improvement. Therefore, institutional review board approval was not obtained.

### Laboratory monitoring and health system tracking

The automated system continuously surveyed newly finalized microbiology results for positive tests for significant organisms. These organisms included MRSA, VRE, CRE, extended-spectrum  $\beta$ -lactamase pathogens, MDR *A baumannii*, and *C difficile*. When the EHR system detected a finalized positive laboratory test result, it automatically checked whether an organism-specific flag was already present and added the flag, if needed. For this and all automated actions, if the action was already in place, a duplicate action was suppressed.

The system used MDRO and *C difficile*-specific flags to reflect a patient's health history for a pathogen-specific period of time. For gram-positive MDROs and CRE, the flags were an enduring record of the patient's positive test result that persisted in the EHR across all patient outpatient visits and inpatient admissions. MDR GNR and *C difficile* flags expired after 60 days.

#### Ordering of contact precautions

The system used the presence of active MDRO flags to automate inpatient orders for contact precautions on patient admission. Hospital registration staff also used MDRO and *C difficile* flags to guide indication for single room placement. For *C difficile* specifically, because precautions are based on diarrheal symptoms, any readmission within 60 days of an initial flag resulted in an automated order for precautions (contact precautions plus hand washing with soap and water, denoted as spore precautions in our facility), along with an automated prompt to nurses or physicians to discontinue the order if diarrheal symptoms were not ongoing.

#### Discontinuation of precautions and inactivation of pathogen flags

To ensure that MDRO and *C difficile* precautions were continued according to guidelines, discontinuation criteria were displayed for review when physicians attempted to discontinue a precaution order. If the physician determined that it was appropriate to discontinue the order, the system allowed the discontinuation. For example, this process allows physicians to discontinue precautions for *C difficile* in a patient when symptoms resolve.

Discontinuing a precaution order for a current visit did not serve to inactivate a flag. Deactivation of flags, which controlled readmission precaution orders, was strictly monitored and controlled by the infection prevention program. Deactivation of flags was managed in 1 of the 4 following ways. (1) For CRE, there was no clearance protocol, and the flag could not be deactivated in accordance with national guidance.<sup>12</sup> (2) For MRSA and VRE, only the infection prevention program could inactivate the flag if criteria for clearance were met according to hospital protocols. (3) Clinicians could remove flags if they had been entered in error or if a rule out precautions order was entered and the patient tested negative (eg, *C difficile*). (4) For all other organisms, flags were inactivated after 60 days. When a flag was inactivated, an entry for the prior history of the organism was automatically placed into the EHR under the patient's medical history in case clinicians would preferentially select different therapies (eg, antibiotics) based on that knowledge.

To assist with timely removal of contact precautions, the system produced reports of MRSA and VRE carriers who might be eligible for clearance according to MDRO-specific protocols. These reports were actively reviewed on a weekly basis to identify patients eligible to have their MDRO flag status changed to inactive.

## RESULTS

#### Laboratory monitoring and health system tracking

In 2012, the system automatically reviewed daily positive laboratory results for 110,212 patient days and cross-checked these results with historical MDRO and *C difficile* flags to determine whether 2,375 positive results represented incident cases. Of these test results, the system identified 832 patients who already had an organism-specific flag, requiring no action. The remaining 1,543 results represented either new incident cases or cases not previously known to the system, which triggered organism-specific flags and header displays. Automation of these 3 actions (monitoring

**Table 1**

Estimated infection prevention time savings from automated actions, 2012

Action	Result
Tracking and detection	
Review of daily positive laboratory results (110,212 patient days)	600 h saved
Review of historical MDRO and <i>Clostridium difficile</i> results (2,375 laboratory positive tests)	200 h saved
Adding medical record flag, if needed (1,543 incident cases)	50 h saved
Automatic precaution order on admission	
Based on history (via organism-specific flag) (19,793 admissions)	New functionality, prior time commitment undefined*
MDRO clearance eligibility report	New functionality, prior time commitment undefined*

MDRO, multidrug-resistant organism.

\*Infection prevention program activities were ad hoc as patients were identified. Comprehensive evaluation for all admitted patients was not performed.

positive laboratory results, assessing for newly positive cases, and adding flags for tracking) saved a total of 850 hours of infection preventionist time annually (Table 1). This translated to 43 hours of infection preventionist time saved per 1,000 admissions.

#### Ordering of contact precautions

The system ordered precautions or verified the presence of a similar precaution order for another pathogen for the 1,543 newly detected cases. The automated ordering of precautions for inpatients occurred immediately after laboratory results were finalized, without a delay for manual order submission.

In addition to creating orders for newly positive patients, the system reviewed the historical MDRO or *C difficile* status for nearly 20,000 annual admissions and autogenerated precaution orders as appropriate. This process obviated hours of manual review and documentation by infection prevention staff.

#### Discontinuation of precautions and inactivation of pathogen flags

The system identified cases to be reviewed for clearance in an automated MDRO clearance eligibility report. For MRSA and VRE, the system searched flagged patient records for progress toward achievement of clearance criteria, such as how many of the 3 negative laboratory test results at least 6 months after the last positive culture for MRSA had been obtained, and listed these eligible and near-eligible patients and the number of negative cultures required to clear them in the report. These cases were then reviewed weekly for clearance per protocol by infection prevention staff.

In 2013, a point-prevalence review of this automated system was conducted to determine whether the system was missing patients who were eligible for discontinuation of MRSA or VRE contact precautions. It found that 17% (49/288) of adult inpatients had contact precaution orders, 63% (31/49) of which were for MRSA or VRE. All precautions were appropriate, with none eligible for removal after review. Therefore, the MDRO clearance report ensured that precautions were efficiently and necessarily applied.

## DISCUSSION

We identify an automated method for ensuring comprehensive identification, tracking, and ordering of contact precautions for carriers of high-priority pathogens, including MDROs and *C difficile*. By integrating microbiology data, EHR tracking flags, and automated orders, this process effectively assured rapid and comprehensive

placement of patients into contact precautions without requiring oversight by infection prevention personnel. This is important because verification of contact precautions by infection prevention personnel is often limited to weekday working hours and can be delayed by more urgent infection control needs.

In addition, automation of these processes results in tremendous time savings for infection prevention programs. We show that automated systems can effectively perform these highly labor-intensive and repetitive tasks. In this study, we saved an estimated 43 hours of infection prevention time per 1,000 admissions. These hours can be repurposed to front-line assessment and campaigns to prevent HAIs, activities which are more appropriate uses of infection prevention expertise. Furthermore, the number of reported hours saved in this study is substantially underestimated. Beyond the 850 hours saved annually, we were unable to quantify the prior resources consumed by identifying those admitted with a history of MDROs and confirming the presence of appropriate precautions. These resources included not only additional infection preventionist time, but also the time of highly skilled nurses and physicians.

As EHR systems become increasingly functional, complex algorithms that can provide real-time links between laboratory results, admitting processes, and infection prevention strategies can be realized. The processes described here represent activities common to all U.S. hospitals. Given that there are 35.1 million hospitalizations in the United States each year, saving 43 hours/1,000 admissions amounts to >1.5 million hours of infection preventionist time saved for manual assurance of contact precautions.<sup>13</sup> This automated system is broadly applicable to all hospitals tracking MDROs and *C difficile*. Adoption by EHR vendors to include this as a prepackaged functionality would greatly assist surveillance and the application of hospital contact precautions in high- and intermediate-resourced countries.

The automated systems ensured that precautions were both appropriately applied and removed. Automated ordering prevented missed precautions, which might be caused by errors, such as admitting providers not noticing a flag or health care workers missing history of infection on manual review. Automation also improved appropriate weekend and after-hours facilitation of isolation precautions. In addition to applying precautions, the system facilitated identification of patients eligible for discontinuation of precautions through an automated report. This has the potential to reduce costs through eliminating waste from excess personal protective equipment<sup>14</sup> and through decreasing staff time in donning personal protective equipment, and it also contributes to increased patient satisfaction.<sup>15</sup>

The system not only tracked critical pathogens and initiated appropriate precautions, but it logged a complete history of a patient's status in harboring these organisms. All flags were pathogen specific, with start dates and discontinuation dates, if applicable, logged in the system. Importantly, discontinued flags were replaced with an automated entry into the health record of a history of that pathogen, which served to alert clinicians who wished to alter antibiotic therapy because of that knowledge, for example for preoperative antibiotics or treatment of active infection in which those organisms are common causative agents.

The limitations of this study include our inability to fully quantify the time savings attributable to this automated system. In

addition, we were unable to determine the number of patients for whom contact precautions were missed prior to the automated system. Therefore, the time estimates and impact to preventing transmission are likely to be greater than estimated in this study. Second, we do not evaluate whether the increased ordering of contact precautions enhanced compliance; however, it is unlikely that this would be impacted. Efforts to ensure appropriate adherence remain a necessity. Third, although this automated system generates reports to evaluate possible discontinuation of precautions, our current protocols for discontinuation were sufficiently complex to prevent complete automation. As more streamlined protocols are tested and validated, we will be able to add this functionality into this system.

In conclusion, we show that automated systems embedded within EHRs can protect patients by ensuring that appropriate contact precautions are ordered as soon as the need arises. These systems result in substantial time saved for clinicians and infection prevention programs.

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