Detecting Delayed Microbiology Results After Hospital Discharge: Improving Patient Safety Through an Automated Medical Informatics Tool

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We developed a computerized medical informatics tool to identify patients who had a culture performed on a sterile body site specimen during their hospitalization that subsequently turned positive after hospital dismissal. During a 13-month period, 533 patients had a positive culture identified by our Computer-Based Antimicrobial Monitoring (CBAM) program after hospital dismissal, and 112 (21%) of these culture results necessitated an intervention and communication with the primary health care professional. Thirty-two (29%) of positive cultures were from the blood. Thirty-eight (34%) of the CBAM interventions with available outcome data resulted in initiation of, change in, or prolongation of outpatient antimicrobial therapy. The CBAM program serves an important role in optimizing patient care and communication with the health care professional during the transition from inpatient to outpatient management.

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CBAM = Computer-Based Antimicrobial Monitoring; ID = infectious diseases

Cultures for bacteria, fungi, viruses, and mycobacteria require days to weeks to produce positive results. For many hospitalized patients, culture results are not available at the time of dismissal. In fact, approximately 41% of patients discharged from the hospital have pending laboratory test results,^{1,2} and the most common results requiring urgent action come from pending microbiology tests. Results of a delayed positive culture commonly require initiation of or change in antimicrobial therapy^{1,3}; however, only a fraction of pending microbiology tests are actually documented on the hospital dismissal summary.³

Strategies are therefore needed to improve both the recognition of delayed test results and the communication of such results to the appropriate health care professional providing care to the patient. Computerized information systems are gaining increasing recognition as a valued tool for reducing medical errors. Computerized tools that can improve communication of laboratory information and assist with monitoring of pending laboratory tests are 2 main strategies that show how information technology can reduce medical errors and prevent adverse patient outcomes.⁴ An automated alerting system for inpatient critical laboratory results has been shown to reduce the time until appropriate treatment is subsequently prescribed.⁵ However, no published studies have evaluated the utility of automated alerting systems for microbiology test results that are pending at the time of hospital discharge.

The Computer-Based Antimicrobial Monitoring (CBAM) system used at Mayo Clinic in Rochester, MN, is an automated, rules-based medical informatics system that monitors antimicrobial and microbiology information among hospitalized patients in near real time. Its objectives are to improve patient care through the reduction of medical errors, enhancement of education for the health care professional, and improvement of hospital cost savings. Each CBAM algorithm or “rule” contains a set of clinical criteria that identifies situations in which the review and/or intervention by an infectious diseases (ID) physician or ID pharmacy specialist may be beneficial to patient care. More than 60 CBAM rules utilize information from a number of integrated electronic data sources, including patient demographic information, calculated metabolic values, laboratory and microbiology data, and medication information. When appropriate, the patient’s primary hospital physician is contacted to discuss the specific clinical issue and optimal antimicrobial and/or other infection management measures as needed.

At our medical center, CBAM has had a significant influence in the optimization of hospital inpatient care, including identification of untreated or suboptimally treated infections, incorrect antimicrobial dosing, adverse drug-to-drug interactions, and suboptimal hepatorenal or serum drug level monitoring. During a 16-month period in 2003-2004, approximately 83% of CBAM interventions resulted in improvements to inpatient care pertaining to antimicrobial and/or infection management.⁶ However, an important limitation of CBAM has been the inability of the system to identify clinical infection and antimicrobial management concerns for outpatients or for those recently dismissed from the hospital.

To assess the significance of overlooked culture results from patients recently dismissed from the hospital and the potential benefits from clinical intervention, we developed a new CBAM rule to identify cultures collected during a patient’s hospitalization that subsequently turned positive after hospital dismissal. We then determined the

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outcomes of interventions by the ID physicians and ID pharmacy specialist working with CBAM.

METHODS

A new CBAM rule was developed to identify patients recently hospitalized at 2 Mayo Clinic-affiliated hospitals (Saint Marys Hospital and Rochester Methodist Hospital, with a combined capacity of >2000 beds) in Rochester, MN, who had a culture collected from a sterile body site other than urine during hospitalization that subsequently turned positive for microbial growth after hospital dismissal. Urine cultures were excluded because of the high frequency of bacteruria and funguria without correlating infection and the difficulties in urine culture interpretation without actual patient evaluation. The rule identified or “flagged” patients who met all of the following criteria: (1) a tissue or fluid sample from a sterile body site (other than urine) was collected from the patient during hospitalization and submitted for culture; (2) the patient was dismissed from the hospital (defined by date and time) and is alive; (3) the patient’s hospital dismissal occurred *before* the culture was identified and reported as positive from the laboratory for microbial growth; (4) the tissue or fluid culture was identified as positive within 7 days of the patient’s hospital dismissal; and (5) the organism identified in culture is not likely a contaminant from the laboratory or patient’s skin (eg, single colony or blood culture bottle of coagulase-negative *Staphylococcus*, *Propionibacterium acnes*, *Corynebacterium* species)

Although a relatively short incubation for some slow-growing organisms, a 7-day duration was chosen initially for CBAM of pending cultures after hospital dismissal to best pilot this new CBAM rule. Flagged patients by CBAM had their medical and laboratory records reviewed by an ID physician assigned to CBAM to determine whether (1) the positive culture result was clinically relevant or contributing to disease, (2) the patient was prescribed appropriate antimicrobial therapy on hospital dismissal, and (3) any additional diagnostic (eg, echocardiogram, radiologic imaging, etc) or additional therapeutic measures were needed. If the CBAM-ID physician had any clinical concerns regarding possible suboptimal infection management, the patient’s primary care physician was contacted by the CBAM-ID physician with the corresponding delayed positive culture results and, if needed or requested, given appropriate antimicrobial treatment recommendations and other supporting clinical advice. For the more complex or serious infections and antimicrobial-related issues, a formal ID outpatient consultation was also recommended.

The intervening CBAM-ID physician then documented the nature of the intervention and subsequent recommen-

dations (if given) into a designated “CBAM report” section. To assess the outcomes of CBAM-ID physician interventions, we reviewed their comments and recommendations in the CBAM reports as well as the electronic medical records of CBAM-flagged patients to determine whether such recommendations were subsequently implemented by the patient’s primary health care professional. The CBAM intervention was considered significant if it resulted in a change in a patient’s plan of care. The determination of whether specific recommendations by the CBAM-ID physician were implemented by an outpatient health care professional could be made only when such recommendations and changes were documented in the patient’s Mayo Clinic outpatient medical record by the patient’s health care professional.

RESULTS

Between August 4, 2009, and August 30, 2010, 1865 patients were identified who had a positive culture result from a sterile body site and who were eventually dismissed from Mayo Clinic-affiliated hospitals (Figure). Among these patients, the CBAM rule identified 548 patients who had a culture collected from a sterile body site during hospitalization that subsequently turned positive after hospital dismissal. The ID physicians assigned to CBAM during the study period were able to review the medical and laboratory information of 533 (97%) of these patients. From this group, 112 patients (21%) with cultures that turned positive after hospital dismissal were identified as necessitating CBAM-ID physician intervention and communication with the primary health care professional.

Among the 112 patient interventions performed by the CBAM-ID physician, 32 (29%) were for positive blood cultures (Table 1). Among CBAM-ID physician communications with primary health care professionals that resulted in subsequent alterations in their patients’ post-hospitalization management and that also were clearly documented by those health care professionals in the electronic medical record, 38 (34%) resulted in initiation, alteration, or prolongation of antimicrobial therapy. Among all CBAM interventions, there were no instances in which recommendations by the CBAM-ID physician were not followed or resulted in a subsequent alternative inappropriate antimicrobial change.

Not all CBAM-ID physician interventions necessitated a change in therapy. Twenty-one interventions (19%) resulted in no change in outpatient management given that acceptable therapy had already been provided after discussion by the CBAM-ID physician with the primary health care professional. The outcomes in patient management from the remaining 53 CBAM interventions (47%) could not be determined because of insufficient or absent outpatient documentation in the Mayo Clinic

FIGURE. Patients reviewed by Computer-Based Antimicrobial Monitoring (CBAM) rule. ID = infectious diseases.

patient medical record. This was a common occurrence in patients subsequently managed outside of the Mayo Clinic system because outpatient documentation by non-Mayo Clinic health care professionals is not typically accessible through our electronic medical record.

DISCUSSION

With this new CBAM rule coupled with ID physician review, approximately one-third of patients recently dismissed from the hospital with a delayed positive culture

result had a subsequent modification in antimicrobial therapy. A few examples are listed in Table 2. We think that this finding underscores the clinical relevance of delayed post-hospitalization culture results to patient care. Although a positive culture from any sterile site should be addressed, positive blood cultures necessitate more time-expedient and appropriate clinical communication to ensure optimal antimicrobial intervention. Multiple studies illustrate how inadequate early antimicrobial therapy for bloodstream infections leads to poor patient outcomes.⁷⁻⁹ Untreated or suboptimally treated *Staphylococcus aureus*,

TABLE 1. **Blood Cultures That Turned Positive After Patients' Hospital Dismissal**

Aerobic gram-positive cocci	
<i>Staphylococcus aureus</i>	5
Viridans group streptococci	4
<i>Staphylococcus lugdunensis</i>	1
<i>Aerococcus</i> species	1
Aerobic gram-negative bacilli	
<i>Escherichia coli</i>	3
<i>Moraxella</i> spp	2
<i>Schwanella</i> spp	1
<i>Bergeyella zoohelcum</i>	1
Anaerobes	
<i>Clostridium</i> spp	3
<i>Dialister pneumosintes</i>	2
<i>Bacteroides fragilis</i>	1
<i>Fusobacterium necrophorum</i>	1
<i>Actinomyces</i> spp	1
<i>Veillonella</i> spp	1
<i>Peptostreptococcus</i>	1
<i>Prevotella</i> spp	1
<i>Actinobaculum schaalii</i>	1
Fungi	
<i>Candida albicans</i>	1
<i>Candida parapsilosis</i>	1
Total	32

Staphylococcus lugdunensis, or *Candida* species bloodstream infections (more than one-third of delayed blood culture results in the current study) can be a crucial factor toward adverse patient morbidity or mortality.

Anaerobic blood cultures typically require prolonged incubation periods, and thus results may not be available during short patient hospitalizations. The presence of anaerobic bacteria in the bloodstream (more than one-third of delayed blood culture results in the current study) may also suggest a more complex and often polymicrobial infection depending on the source and bacteria species.

CBAM is not the only mechanism available to notify primary health care professionals of delayed positive culture results. Many hospital microbiology laboratories, including those at Mayo Clinic, will attempt to contact the hospital

physician or service about a positive culture from a sterile body site. This system works relatively well for hospitalized patients but poses challenges for those who have been discharged. One problem with delayed positive culture results is that health care professionals taking care of patients in the hospital are commonly not the same health care professionals who follow up in the outpatient setting. Our laboratory technicians do not have access to patient medical records and do not know whom to contact beyond the inpatient health care professional who originally ordered the culture. Even when the inpatient health care professional is contacted by the microbiology laboratory regarding the delayed positive culture result, that information is commonly not communicated to the appropriate primary outside health care professional or to the patients themselves. Additionally, the laboratory technicians may not be qualified to render opinions to the inpatient physician or service regarding the specific clinical relevance or application of positive culture results.

Many community and academic hospitals utilize physician hospitalists and residents to care for inpatients, and the communication between the inpatient health care professionals and outpatient primary health care professionals is often compromised.¹⁰ Resident work hour limitations and frequent patient “sign-offs” to other health care professionals further complicate accurate communication and documentation of pending laboratory results at the time a patient is dismissed from the hospital. During the transition from inpatient to outpatient status, it can be difficult for both the hospital health care professionals following up on pending cultures and the laboratory technicians to determine which person is best suited to address important microbiology test results.

In addition to microbiology, laboratory, and pharmacy data, an important component to the CBAM system is the direct access to inpatient and outpatient Mayo Clinic electronic medical records. The ability to review the actual medical records of patients dismissed from the hospital enables the CBAM-ID physician to both understand the specific

TABLE 2. **Clinical Examples of CBAM Identification of Post-hospital Delayed Positive Culture Results^a**

Primary inpatient diagnosis during hospitalization	Post-hospital dismissal positive culture result	Time to positive culture result after patient hospital dismissal ^b	Clinical intervention
85-year-old man with pulmonary infiltrate	Blood culture: <i>Staphylococcus lugdunensis</i>	2 d	Change in antimicrobial therapy, evaluation for endocarditis and other sources
48-year-old woman with cervical spine metallic plate erosion into esophagus	Paraspinal soft tissue culture: <i>Candida krusei</i>	6 h	Change in antifungal therapy (part of combination antimicrobial program)
76-year-old man, recent Whipple's surgical procedure	Blood culture: <i>Staphylococcus aureus</i>	3 d	Readmitted to hospital, antimicrobial change, evaluation for intra-abdominal postoperative infection and possible secondary endocarditis
90-year-old man with bladder cancer	Blood culture: <i>Bacteroides fragilis</i>	6 h	Modification of antimicrobial therapy and investigation of possible intra-abdominal source

^a CBAM = Computer-Based Antimicrobial Monitoring.

^b Note: time between culture acquisition and positive growth is longer than time between hospital dismissal and positive culture growth.

clinical application of a patient's positive culture result and the identity of the patient's outpatient health care professional. Both the direct and time-efficient notification by CBAM-ID staff to outpatient health care professionals and the opportunities to discuss culture interpretation and management recommendations through expert telephone consultation are why CBAM has a unique and clinically advantageous role at Mayo Clinic. This is not to say that an ID physician is required for this type of medical informatics program to be effective because recognition of delayed positive culture results after hospital dismissal is the primary goal. However, the ID physician can provide additional clinical expertise via a "curbside" or virtual consultation to assist the primary health care professional.

For this rule, CBAM identifies only the post-hospital positive culture results, whereas the CBAM-ID physician is required to interpret the clinical relevancy within the context of each patient's diagnosis and plan of care. Not all delayed positive culture results or interventions by the CBAM-ID physician require initiation of or change in antimicrobial therapy. Indeed, 421 (79%) of the CBAM-flagged patients reviewed by the CBAM-ID physician did not require intervention or communication with the primary health care professional (Figure); 21 (19%) of the CBAM-ID physician interventions and discussions with primary health care professionals did not involve any change in patient management. These results often reflected an attentive primary health care professional who was aware of the positive culture result and had already implemented an appropriate management plan. Patient-specific information outlined by the primary health care professional, including palliative care, chronic suppression, or specific patient wishes, commonly led to alternative and appropriate antimicrobial treatment plans. In addition, delayed growth of bacteria from some tissue sites may have been expected (eg, repeatedly positive bacterial growth from surgically debrided tissues or fastidious bacteria from a known polymicrobial infection) and did not warrant a change in management.

Because of insufficient subsequent outpatient documentation in the patient medical record, 47% of the CBAM-ID physician intervention outcomes could not be accurately determined. This was often due to the large numbers of nonregional (eg, out-of-state and international) patients at our medical center who are managed by non-Mayo Clinic health care professionals. Although the CBAM-ID physician would routinely contact outside health care professionals regarding delayed positive culture results (as documented in a CBAM note), we did not have access to outside, non-Mayo Clinic patient medical records or the identity of many outside health care professionals to confirm whether CBAM-ID physician interventions and recommendations were carried out. Considering the high number of post-hospitalized pa-

tients managed outside of the Mayo system, we think that the overall number of patients who had their treatment plan appropriately influenced by CBAM intervention was significantly higher.

Our study has several limitations. As previously mentioned, our inability to access non-Mayo Clinic outpatient records of patients recently dismissed from our hospitals limited a more accurate and comprehensive determination of CBAM intervention impact. We were also not able to contact most outside non-Mayo health care professionals to retrospectively confirm results of CBAM intervention. These are areas for CBAM system improvement that are currently in development. Additionally, some outpatient modifications in antimicrobial therapy (eg, extension of duration of therapy or outpatient therapy) may have been done without documentation in the medical records. We acknowledge that 7 days can be a relatively short incubation for some slow-growing organisms, including mycobacteria and some fungi. After the current study was completed, we extended the time that the CBAM program monitors pending culture results from 7 days to 1 month after hospital dismissal.

We think that our CBAM program provides for both a considerable hospital-based quality improvement initiative and enhanced patient safety. In addition to positive culture results, we are looking to expand this particular CBAM program to identify other important delayed hospital microbiology test results such as polymerase chain reaction on specific microbes, fungal antigens, and select microbial serologies. Whether through CBAM or other informatics programs, it is imperative that safeguards are in place to identify and communicate delayed microbiology information to the appropriate health care professional.

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