Improving Surveillance and Prevention of Surgical Site Infection in Pediatric Cardiac Surgery

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Background Postoperative cardiovascular surgical site infections are preventable events that may lead to increased morbidity, mortality, and health care costs.
Objective To improve surgical wound surveillance and reduce the incidence of surgical site infections.
Methods An institutional review of surgical site infections led to implementation of 8 surveillance and process measures: appropriate preparation the night before surgery and the day of surgery, use of appropriate preparation solution in the operating room, appropriate timing of preoperative antibiotic administration, placement of a photograph of the surgical site in the patient's chart at discharge, sending a photograph of the surgical site to the patient's primary care physician, 30-day follow-up of the surgical site by an advanced nurse practitioner, and placing a photograph of the surgical site obtained on postoperative day 30 in the patient's chart.
Results Mean overall compliance with the 8 measures from March 2013 through February 2014 was 88%. Infections occurred in 10 of 417 total operative cases (2%) in 2012, in 8 of 437 total operative cases (2%) in 2013, and in 7 of 452 total operative cases (1.5%) in 2014.
Conclusions Institution of the surveillance process has resulted in improved identification of suspected surgical site infections via direct rather than indirect measures, accurate identification of all surgical site infections based on definitions of the National Healthcare Safety Network, collaboration with all persons involved, and enhanced communication with patients' family members and referring physicians. (*American Journal of Critical Care.* 2016;25:e30-e37)

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Postoperative cardiovascular surgical site infections (SSIs) are preventable harmful events that may lead to increased morbidity, mortality, and health care costs. In children undergoing cardiac surgery, SSIs account for up to 1 in 4 of all health care–related infections.[1] The reported incidence of SSI in children undergoing cardiac surgery is 1.4% to 6.3%.[1,2] Risk factors for SSI in children include younger age, duration of cardiopulmonary bypass, use of perioperative devices, use of parenteral nutrition, and more postoperative blood transfusions.[2,3] Of interest, in a study by Sohn et al,[2] multiple severity illness scores, Risk Adjustment for Congenital Heart Surgery category, and longer duration of postoperative treatment with antimicrobial agents were not associated with SSIs. However, Sohn et al noted that 36% of SSIs were identified after discharge from the hospital.

Surgical wound surveillance is typically performed by using indirect methods, including review of patients' charts for epidemiological data, use of laboratory tests, examination of databases (hospital and national), surveys of surgeons, and communication with other health care providers. The National Healthcare Safety Network (NHSN) of the US Centers for Disease Control and Prevention is the nation's most widely used system for tracking health care–associated infections.[4,5] Certain criteria[6] must be met for an SSI to be considered a superficial SSI according to the NHSN definition, and only SSIs for pediatric cardiac surgical cases involving open chest procedures on the valves or septum are tracked. Thus, not all congenital cardiac defects and operations are included in the database.[7] The Society of Thoracic Surgeons Congenital Heart Surgery Database is a clinical database in which the procedures are coded by an attending surgeon using international nomenclature and are validated by the database manager.[8] Marked differences exist in identification, completeness, and verification in administrative and billing databases vs clinical databases or registries,[9] leading to potentially inaccurate reporting of SSI rates.[10] Because of the inconsistency in the reporting of SSIs, we sought to provide more consistent and valid reporting of SSIs within the Heart Center, Nationwide Children's Hospital, Columbus, Ohio. The purpose of this quality initiative was to improve surgical wound surveillance and reduce SSIs in all infants and children undergoing cardiac surgery.

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Methods

Ethical Issues

This quasi-experimental quality improvement work involved development of a process to improve surgical site surveillance, improve perioperative surgical site care, and increase identification of SSIs. No randomization of patients was used. Medical records were accessed by health care staff and quality improvement team members as part of normal responsibilities. Because the project does not meet the definition of research, approval by the institutional review board was not required.

Surgical wound surveillance is typically performed by using indirect methods.

Setting

The Heart Center operates within the confines of the hospital structure with 2 hybrid operating rooms, 2 hybrid catheterization suites, dedicated cardiac anesthesiologists and cardiac intensivists, 3 cardiothoracic surgeons, a 20-bed pediatric cardiac intensive care unit, and a 24-bed pediatric step-down cardiology unit. Approximately 400 cardiovascular surgeries are performed each year.

Planning the Intervention

Before 2012, the Heart Center followed the Ohio collaborative bundle for the prevention of SSIs, which consisted of using chlorhexidine gluconate (CHG) wipes the night before surgery, CHG wipes the day of surgery, chlorhexidine skin preparation in the operating room (for all patients <2 months old), and appropriate timing and dosage of perioperative antibiotics. Also before 2012, SSI surveillance relied on indirect identification via epidemiology followed by discussion with health care providers on just the NHSN-reportable cases. The Heart Center sought to track the total incidence of SSIs, not just SSIs in NHSN-reportable cases, because approximately half of the center's cardiothoracic surgeries were not reportable. A multidisciplinary team was recruited to explore the issues associated with surveillance of

SSIs. The team included physicians (cardiology and cardiac surgery), advanced nurse practitioners (APNs), nurses, and members of the quality improvement team. The multidisciplinary team evaluated the SSI identification process that was in place: indirect surveillance measures with communications with other health care providers on the NHSN-reportable cases only. On the basis of this evaluation, the multidisciplinary team developed SSI surveillance process measures that included communication and collaboration among the key persons involved, standardized guidelines, specific documentation and follow-up, education of staff and patients' family members, and data and compliance analysis.

Intervention

In July 2012, process and surveillance measures based on the NHSN guidelines for prevention of SSIs[4] and the Children's Hospital Solutions for Patient Safety[11] were introduced. The measures included surveying all cardiothoracic surgical sites for 30 days after surgery or during the primary hospital stay[4]; a standardized preoperative inpatient and outpatient skin preparation protocol with either CHG or Sage Comfort Bath (Sage Products LLC), depending on the patient's age[4,11]; education of outpatients' families and inpatient hospital staff on CHG or Sage Comfort Bath bathing requirements[11,12]; standardized perioperative antibiotic (cefazolin) dosing, timing, and redosing (based on the patient's weight and gestational age)[4,11-13]; and multidisciplinary meetings after detection of every suspected SSI to discuss root cause and potential interventions. In early 2013, use of standardized silver-impregnated dressings, which are removed on postoperative day 7, was added for all postoperative surgical sites.

A multidisciplinary team was recruited to explore the issues associated with surveillance of surgical site infections.

All suspected SSIs identified were reviewed in multidisciplinary meetings. Providers at the meetings included the attending cardiology physician or cardiac surgeon, a cardiothoracic surgery APN, a cardiac anesthesiologist, a nurse, and representatives of the epidemiology and quality improvement services. All available documentation was reviewed as well as the suspected SSI meeting tool (Figure 1) for each potential SSI. Each suspected SSI was evaluated according to the NHSN definition for superficial incisional, deep incisional, and organ space SSIs and further classified as reportable or nonreportable on the basis of the NHSN 2012 criteria.[6] Both reportable and nonreportable SSIs were tracked within the Heart Center.

The first plan-do-study-act (PDSA) cycle (July 2012 through August 2012) included compliance monitoring of 4 interventions: standardized skin preparation with CHG or Sage Comfort Bath according to the patient's age for both inpatients and outpatients on the night before surgery and the morning of surgery,[4,11] standardized perioperative dose and timing of antibiotic administered,[4,11] and standardized protocol for skin preparation in the operating room.[4]

The second PDSA cycle (September 2012 through November 2012) included introduction and compliance monitoring of each cardiothoracic surgery surgical site and documentation in the electronic medical record by the APN at discharge. Low compliance for the second PDSA cycle led to a third PDSA cycle with specific methods for documenting surveillance and follow-up. The third cycle (December 2012 through February 2013) included introduction and compliance monitoring of placement of photographs of surgical sites at the time of hospital discharge into the electronic medical record; forwarding of photographs to the primary care physician for continuity of care; use at the postoperative follow-up visit of the data collection tool for postoperative wound surveillance created to identify superficial incisional SSIs that might be difficult to distinguish from wound dehiscence, erythema, or stitch abscess (Figure 2); and surveillance by the APN of the surgical site at postoperative day 30 via an e-mailed photograph from the patient's parents or via direct visualization during clinic visit and documentation of the surveillance in the electronic medical record.

The current surgical site surveillance includes 8 measurable interventions:

1. Use of standardized skin preparation the night before surgery.[4,11] This preparation includes bathing with soap, shampooing the hair, and then a CHG wipe down of neck, chest, and abdomen if the patient is more than 2 months old or a wipe down with Sage Comfort Bath if he or she is less than 2 months old.
2. Use of standardized preparation the day of surgery.[4,11] This measure includes a second CHG wipe down of neck, chest, and abdomen the morning of surgery for patients more than 2 months old or wipe down with Sage Comfort Bath if he or she is less than 2 months old.
3. Use of the appropriate preparation solution in the operating room.[4] Patients less than 2 months old are wiped down with alcohol followed by use of a preparation of povidone-iodine. Patients more than 2 months old are wiped down with CHG. The preparation solution on the skin is allowed to air dry.
4. Preoperative antibiotic is administered within 1 hour of incision, and additional doses are given as appropriate throughout the procedure.[4,11]

SUSPECTED SURGICAL SITE INFECTION (SSI) - CARDIOTHORACIC

NHSN REPORTABLE: ❑ YES ❑ No/Reason:

Patient:		**MR #:**	**DOB/Age:**
Procedure Date:	**Infection Date:**	**Days post procedure to SSI:**	
Infection Type: ❑ Superficial Incision SSI ❑ Deep Incision SSI ❑ Organ/space SSI **Definition Criteria Met:**			
Culture Done: ❑ Yes ❑ No **Pathogen:**			
Previous SSI? ❑ Yes ❑ No **If Yes, provide previous pathogen:**			
Infection Information:			
Diagnosis:			
Procedure:			
Hospital admit date: **Unit:**	**After procedure admitted to:**		**Hospital discharge date:**
Follow-up date(s):			
Surgery Details			
Surgeon:		**Co-Surgeon:**	**OR Suite #:**
Anesthesia Staff:	**Scrub Nurse:**	**Other Staff:**	
Pre-op antibiotic/time:	**Incision time:** **Start:** **End:**	**Intra-op Antibiotic re-dosing/time:**	
Post-op antibiotic/time:			
❑ Primary closure ❑ Delayed closure ❑ Days until closure:	**Implants:** ❑ Yes ❑ No	**Wound Class:**	**First temperature in PACU:** **Lowest intraoperative temperature:**

Compliance with bundle and surveillance elements

Individual Element	Compliant?	Comments
CHG wipes used the night before OR?	❑ Yes ❑ No ❑ N/A	
CHG wipes used the day of OR?	❑ Yes ❑ No ❑ N/A	
CHG skin prep used and air dried?	❑ Yes ❑ No ❑ N/A	
Pre-op antibiotic given at appropriate time?	❑ Yes ❑ No ❑ N/A	
Intra-op antibiotic given at appropriate time?	❑ Yes ❑ No ❑ N/A	
Post-op antibiotic given at appropriate time?	❑ Yes ❑ No ❑ N/A	
Picture obtained before discharge or POD30?	❑ Yes ❑ No ❑ N/A	
Picture sent to PMD at discharge?	❑ Yes ❑ No ❑ N/A	
APN follow up picture at POD30?	❑ Yes ❑ No ❑ N/A	

Were all prevention bundle elements met? ❑ **Yes** ❑ **No**

Did any significant issues occur during the procedure? ❑ Yes ❑ No
Any significant patient factors that may have contributed to this infection? ❑ Yes ❑ No
RCA/Meeting Summary Findings:
RCA Attendees included:

Figure 1 Meeting tool.

Abbreviations: APN, advanced practice nurse; CHG, chlorhexidine gluconate; DOB, date of birth; intra-op, intraoperative; MR, medical record; N/A, not applicable; NHSN, National Healthcare Safety Network; OR, operating room; PACU, postanesthesia care unit; PMD, primary physician; POD, postoperative day; post-op, postoperative; RCA, root-cause analysis.

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Post-Op Infection Assessment
QI Data Collection

Complete this document and submit form to Surveillance Coordinator

Patient ID Sticker

Reporting Unit _____
Date of Report ____/____/____
Date of Surgery ____/____/____
Emailed Picture ____/____/____

Superficial Infection:

(check all that apply)

_____ Purulent Drainage
_____ Organism Isolated
_____ Pain or Tenderness
_____ Localized Swelling
_____ Erythema
_____ Wound Open by Surgeon

COMMENTS:

_____
_____
_____

Suspected SSI: ___ Yes ___ No

❑ Documentation is in EPIC

_____ CT Surgery Initials

Definition of a Superficial Incisional SSI:

1. Occurs within 30 days after the operative procedure; AND
2. Involves only skin and subcutaneous tissue of incision; AND
3. Meets ONE of the following:
- *Purulent drainage from superficial incision*
- *Organism isolated from aseptically obtained culture of fluid or tissue from superficial incision*
- *At least one of the following signs/symptoms of infection: pain/tenderness, localized swelling, redness or heat, AND superficial incision are deliberately opened by surgeon, and are culture-positive or not cultured*
- *Diagnosis of superficial incisional SSI by surgeon/attending*

Figure 2 Data collection tool for postoperative wound surveillance.

Abbreviations: CI, cardiothoracic; EPIC, the hospital's electronic medical record system; ID, identification; post-op, postoperative; QI, quality improvement; SSI, surgical site infection.
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5. A photograph of the surgical site is placed in the patient's electronic medical record at the time of discharge. Photographs are taken by using an institutional approved, encrypted iPod touch (Apple Inc). Photographs do not include patient identifiers. Parents sign a consent form upon admission giving permission for the photographs to be taken, placed in the electronic medical record, and shared with the primary care physician and referring cardiologist.

6. A photograph of the surgical site is sent to the patient's primary care physician and referring cardiologist via the US Postal Service.

7. An APN follows up surveillance of the surgical site by using the data collection tool for postoperative wound surveillance (Figure 2).

8. A photograph of the surgical site taken on postoperative day 30 is placed in the patient's electronic medical record. The photograph is taken by the APN at the 30-day follow-up clinical visit or is taken by the parents and e-mailed to the APN if the patient does not return for the 30-day postoperative clinic visit.

Method of Evaluation and Analysis

Compliance with use of appropriate preoperative skin preparation and standardized operating room

skin preparation is monitored for NHSN-reportable cases only. All other measurable interventions of the surgical site surveillance are monitored for all operative cases, not just the NHSN-reportable ones. In addition, beginning in January 2013, interdisciplinary meetings were held for all suspected SSIs, not just NHSN-reportable cases.

Results

Number of SSIs

In 2012, among a total of 417 operative cases, 181 were NHSN reportable, and 15 suspected SSIs occurred. As the result of the interdisciplinary meetings performed for each suspected SSI, 3 sites were determined to have no infection, and 2 had wound dehiscence. Therefore, 10 of the suspected SSIs were defined as SSIs according to the NHSN definition. Of the 10 SSIs identified, only 5 were NHSN reportable (2% of the 417 cases; Figure 3).

In 2013, among a total of 437 operative cases, 213 were NHSN reportable, and 9 suspected SSIs occurred. Of the 9 suspected SSIs, 1 was determined to be a stitch abscess. Therefore, of the 8 SSIs identified, 8 were defined as SSIs according to the NHSN definition (2% of the 437 total operative cases). Of the 8 SSIs identified, 4 were NHSN reportable (Figure 3).

In 2014, among a total of 452 operative cases, 260 were reportable to the NHSN, and 10 suspected SSIs occurred. Among the 10 suspected SSIs, 7 were defined as SSIs according to the NHSN definition (1.5% of 452 total operative cases). Of the 7 SSIs identified, 4 were NHSN reportable (Figure 3).

Compliance

Mean overall compliance with the 4 process and surveillance measures included in the first PDSA cycle was 81%. Mean compliance with the individual components was 77% for appropriate preoperative skin preparation for both inpatients and outpatients on the night before surgery, 82% for appropriate preoperative skin preparation for both inpatients and outpatients on the morning of surgery, 99% for use of standardized perioperative antibiotic dose and timing, and 66% for use of the standardized operating room skin preparation protocol.

Overall compliance with the second PDSA cycle was only 22%; most likely because of the lack of specific methods for documenting surveillance and follow-up. Overall compliance improved with the 4 process and surveillance measures included in the third PDSA cycle; mean compliance was 56%. Mean compliance was 71% for placing a photograph of the surgical site at time of hospital discharge into the electronic medical record, 55% for providing a photograph to the patient's primary care physician for continuity of care, 59% for follow-up by APN with the data collection tool for postoperative wound surveillance, and 39% for surveillance of the surgical site at postoperative day 30 via an e-mail photograph from the patient's parents or via direct visualization during a clinic visit with documentation in the electronic medical record.

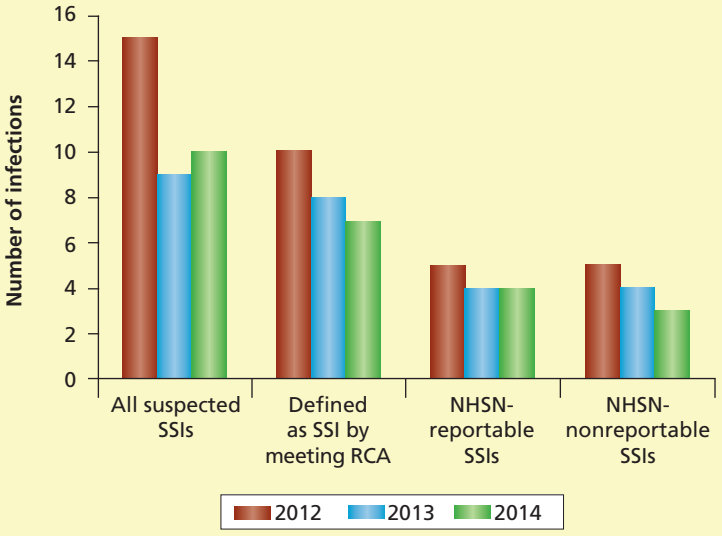

Figure 3 Total number of surgical site infections (SSIs), by year.

Abbreviations: NHSN, National Healthcare Safety Network; RCA, root-cause analysis.

Mean overall compliance with 8 process and surveillance measures was 88% for the period March 2013 through February 2014. Mean compliance with individual components was 90% for use of appropriate preparation the night before surgery, 94% for use of appropriate preparation the day of surgery, 99% for use of appropriate surgical preparation solution in the operating room, 99% for appropriate timing for administration of preoperative antibiotic, 90% for placement of a photograph of the surgical site in the patient's electronic medical record at time of discharge, 92% for sending a photograph of the surgical site to the patient's primary care physician and referring cardiologist, 73% for follow-up of the surgical site by using the data collection tool for postoperative wound surveillance, and 72% for placing a photograph of the surgical site at postoperative day 30 in the patient's electronic medical record.

Discussion

Limitations in NHSN-Reportable SSIs

SSIs in children undergoing cardiac surgery are an important cause of health care related–infections, accounting for up to 1 in 4 of all such infections.[1] The reported incidence of SSI in children undergoing cardiac surgery is 1.4% to 6.3%.[1,2] However, the NHSN does not consider operations that are performed at the bedside or in a procedure room in

a neonatal, pediatric, or cardiac intensive care unit. Nor does it consider operations with delayed sternal closure, or procedures not classified by the *International Classification of Diseases, 9th Revision, Clinical Modification* codes, which are defined by the *ICD-9* Coordination and Maintenance Committee of the National Center for Health Statistics and the Centers for Medicare and Medicaid Services.[7] Therefore, the NHSN does not consider the following procedures: hybrid stage 1 procedure for treatment of hypoplastic left heart syndrome, insertion of pulmonary artery bands, or establishment of Blalock-Taussig shunts. In 2012 and 2013, less than 50% of our operative procedures were reportable according to the NHSN. Thus NHSN underestimates the population at risk for SSIs. We sought to include all of our operative patients in our surveillance of surgical sites, not just those with sites that are NHSN reportable. This change in practice alone would considerably expand our opportunities to learn from each SSI and implement changes if indicated.

The process and surveillance measures introduced were based on the NHSN guidelines for prevention of SSIs[4] and the Children's Hospital Solutions for Patient Safety.[11] Because of the challenge of appropriate identification and classification of potential SSIs, the following processes were also implemented: multidisciplinary meetings on all suspected SSIs, placement of a photograph of the surgical site in the patient's electronic medical record at the time of discharge, sending a photograph of the surgical site to the patient's primary care physician and referring cardiologist, use of the data collection tool for postoperative wound surveillance for follow-up (Figure 2), and placement in the patient's electronic medical record of a photograph of the surgical site obtained on postoperative day 30. Additional strategies, such as screening for colonization by methicillin-resistant *Staphylococcus aureus* and use of mupirocin (Bactroban) ointment, were not implemented because they are not part of the NHSN guidelines for prevention of SSIs[4] or the Children's Hospitals' Solutions for Patient Safety.[11]

> Instituting the surveillance process improved identification of suspected surgical site infections.

Indirect vs Direct Surveillance

With our current surveillance system, an attempt was made to have direct visualization of each postoperative patient's surgical site at least at hospital discharge and at 30 days after the surgery. This step is important because 36% of SSIs are identified after discharge from the hospital.[2] If the possibility of an SSI is a concern at any time, our multidisciplinary meetings provide a thorough evaluation of the surgical site with the aid of the data collection tool (Figure 1) and photographs of the surgical site. This process of information gathering and discussion is intended to accurately identify via direct surveillance and define all SSIs according to the NHSN definition of SSIs (superficial incisional, deep incisional, and organ space). From January 2012 through May 2014, a total of 16 of 26 suspected SSIs (62%) actually met the NHSN definition of a SSI. The most common diagnoses that were not considered SSIs were wound dehiscence, erythema, and stitch abscess.

Surveillance and Process Measures Unique to the Institution

Physicians, APNs, pharmacists, nurses, respiratory therapists, and staff from the quality improvement service worked together to review events and suggest interventions in a factual, blameless, nonthreatening environment. Having multiple disciplines involved in the review process is beneficial, because members of different disciplines look at the event from different points of view. The meetings are organized by the Heart Center quality improvement representative; the goal is to have the meeting within 1 week of the event. The meeting for an SSI begins with a chart review and input from the patient's caregiver on contributing clinical or situational factors. The goal of each meeting is to define the suspected SSI as a true SSI vs a wound dehiscence, erythema, or stitch abscess according to the NHSN definition of an SSI; identify factors that may have contributed to the infection; and suggest interventions, with consensus agreement of the meeting's participants, to prevent recurrence.

Because of the difficulty in appropriately assessing surgical wounds and differentiating between wound dehiscence, erythema, stitch abscess, and true SSI, the interventions of obtaining photographs at the time of discharge from the hospital and at 30 days follow-up and use of the data collection tool for postoperative wound surveillance were instituted. The intent was to provide a guide, the data collection tool, and consistency in evaluation of all surgical sites and to have documentation (ie, the photographs) for comparison and review over time. The photographs are also useful teaching tools in the differentiation between wound dehiscence, erythema, stitch abscess, and true SSI.

Pitfalls of the Individual Components

Each component of the process and surveillance measures had its own set of problems with either implementation or compliance. For example,

appropriate use of preoperative preparation was difficult to monitor in outpatients because reliance on reports from the patients' family members was required. Appropriate use of preparation the day of surgery and use of a standardized surgical preparation solution was more accurately monitored because this step was performed in the hospital for all patients. However, compliance with this measure was still less than 100%. Whether this finding was due to lack of charting in the electronic medical record or actual lack of proper preparation of the surgical site is difficult to determine.

Obtaining physicians' acceptance for standardization of surgical site preparation was initially a challenge, because each surgeon had specific, individual preferences. Once the physicians' acceptance was obtained, compliance with this measure increased to 100%. The appropriate timing of administration of the preoperative antibiotic was easily monitored because it was linked to administration of anesthetics. Shah et al[14] reported that children for whom antibiotics were administered incorrectly had a 1.7-fold increased risk for SSIs compared with children who received antibiotics within the time recommended in the guidelines. Obtaining photographs of the surgical site for the patient's electronic medical record and the referring physician continues to be a challenge because of the need for compliance with the Health Insurance Portability and Accountability Act. Photographs require parental consent, must lack any patient identifiers, and must be obtained with an institutionally approved, encrypted iPod touch. The main reason for less than 100% compliance has been lack of consent from a patient's family because of religious or other reasons.

Finally, the component with the lowest compliance was the 30-day follow-up of the surgical site, mainly because of the out-of-town patients who could not return to our clinic for the 30-day follow-up appointment. An attempt was made to rectify this problem by asking families to send photographs, but, not surprisingly, obtaining family compliance has been challenging.

Conclusion

Institution of the surveillance process has resulted in improved identification of suspected SSIs via direct rather than indirect measures, accurate identification of all SSIs on the basis of the NHSN definitions, collaboration with all persons involved, and enhanced communication with patients' family members and referring physicians.

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FINANCIAL DISCLOSURES

None reported.

eLetters

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