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ORIGINAL ARTICLE

Enhanced Surgical Site Infection Surveillance Following Hysterectomy, Vascular, and Colorectal Surgery

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OBJECTIVE. To evaluate the use of inpatient pharmacy and administrative data to detect surgical site infections (SSIs) following hysterectomy and colorectal and vascular surgery.

DESIGN. Retrospective cohort study.

SETTING. Five hospitals affiliated with academic medical centers.

PATIENTS. Adults who underwent abdominal or vaginal hysterectomy, colorectal surgery, or vascular surgery procedures between July 1, 2003, and June 30, 2005.

METHODS. We reviewed the medical records of weighted, random samples drawn from 3,079 abdominal and vaginal hysterectomy, 4,748 colorectal surgery, and 3,332 vascular surgery procedures. We compared routine surveillance with screening of inpatient pharmacy data and diagnosis codes and then performed medical record review to confirm SSI status.

RESULTS. Medical records from 823 hysterectomy, 736 colorectal surgery, and 680 vascular surgery procedures were reviewed. SSI rates determined by antimicrobial- and/or diagnosis code-based screening followed by medical record review (enhanced surveillance) were substantially higher than rates determined by routine surveillance (4.3% [95% confidence interval, 3.6%–5.1%] vs 2.7% for hysterectomies, 7.1% [95% confidence interval, 6.7%–8.2%] vs 2.0% for colorectal procedures, and 2.3% [95% confidence interval, 1.9%–2.9%] vs 1.4% for vascular procedures). Enhanced surveillance had substantially higher sensitivity than did routine surveillance to detect SSI (92% vs 59% for hysterectomies, 88% vs 22% for colorectal procedures, and 72% vs 43% for vascular procedures). A review of medical records confirmed SSI for 31% of hysterectomies, 20% of colorectal procedures, and 31% of vascular procedures that met the enhanced screening criteria.

CONCLUSION. Antimicrobial- and diagnosis code-based screening may be a useful method for enhancing and streamlining SSI surveillance for a variety of surgical procedures, including those procedures targeted by the Centers for Medicare and Medicaid Services.

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Healthcare providers, quality-improvement groups, consumers, payers, and legislators have become increasingly invested in efforts aimed at preventing healthcare-associated infections (HAIs), including surgical site infections (SSIs). Prevention of SSI has been targeted by the Department of Health and Human Services as a national priority.¹ Several ongoing national quality-improvement efforts are focused on SSI prevention, including the Surgical Care Improvement Project (SCIP), a collaborative SSI prevention effort led by the Centers for Medicare and Medicaid Services (CMS) and other organizations focused on quality improvement. In addition, the updated CMS Inpatient Prospective Payment System will

require hospitals seeking full CMS reimbursement to submit SSI outcome measures for colorectal and abdominal hysterectomy procedures through the Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN), and hospitals' SSI outcomes are likely to be included in the metrics used by CMS to determine eligibility for full reimbursement.

To prevent SSI and to assess the benefits of prevention programs, infection-prevention staff must accurately and efficiently monitor SSI rates; however, conventional SSI surveillance methods have some major limitations. The SSI surveillance definitions and methods that are most commonly

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utilized by infection preventionists in US hospitals are those of the CDC's NHSN. Although NHSN definitions are standardized, methods for case finding and data accessibility can vary substantially between hospitals and involve labor-intensive application of infection definitions to large numbers of patients by highly trained personnel. Because these definitions require a review of medical records and include some data elements that are prone to subjective interpretation, SSI surveillance is both resource intensive, potentially diverting scarce infection-prevention resources away from other HAI prevention activities, and subject to interobserver variability.

For these reasons, the development of alternative or adjunctive surveillance strategies that are efficient and relatively objective is an important step toward advancing SSI prevention. Our previous work has demonstrated the superior sensitivity of screening algorithms that utilize automated data from administrative and inpatient pharmacy databases compared with routine prospective surveillance for SSI detection following a variety of surgical procedures including coronary artery bypass graft procedures and total hip and knee arthroplasty.^{2,3} The goal of this study is to evaluate the use of this SSI surveillance method for other operations targeted by the SCIP, including hysterectomy, colorectal, and vascular procedures.

PATIENTS AND METHODS

Study Design and Study Population

We conducted a retrospective cohort study that included patients aged 18 years and older who underwent hysterectomy, vascular surgery, or colorectal surgery procedures between July 1, 2003, and June 30, 2005, at 5 hospitals affiliated with the CDC Prevention Epicenters, a research consortium funded by the CDC. Participating hospitals were eligible to submit data for study procedures if during the study period they had performed prospective SSI surveillance using NHSN definitions for those procedures. Three hospitals contributed data for all 3 procedure types, 1 hospital contributed colorectal and vascular data, and 1 hospital contributed only hysterectomy data. Patients were included if they had been assigned an International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM) procedure code for a hysterectomy, vascular, or colorectal procedure included in SCIP specifications.⁴ Research personnel retrospectively reviewed the medical records of all patients who had been classified as having an SSI through routine surveillance. In addition, research personnel reviewed the medical records of a random sample of approximately 200 patients without a known SSI who underwent study procedures at each center, by sorting procedures performed on patients without a known SSI in chronological order by operative date and then selecting procedures for review at evenly spaced intervals.

Data Collection

Medical record review at all study sites was limited to inpatient medical records. Patient records were retrospectively reviewed

for clinical evidence of SSI, according to NHSN criteria, during the initial hospitalization for surgery and during any subsequent hospitalizations at the same hospital and within the surveillance time period specified by NHSN definitions (ie, 30 days for procedures not involving implantation of prosthetic material and 365 days for procedures involving implants). Any SSI identified solely in the outpatient setting was excluded from the analysis. In addition, records were reviewed for the presence or absence of specific ICD-9-CM diagnosis codes suggestive of SSI (postoperative infection: 998.5, 998.51, 998.59; implant or graft infection: 996.60; vascular procedures: 996.62) for the index hospitalization or any subsequent hospitalization within the surveillance time period.

Pharmacy data were reviewed to determine whether intravenous or oral antimicrobial agents were administered on or after a patient's second postoperative day and during any subsequent hospitalization during the appropriate surveillance time period. Antimicrobial exposure intervals were calculated as the number of days from the first day through the final days of antimicrobial use, excluding the day of operation and the first postoperative day in order to omit antimicrobials administered for perioperative prophylaxis. It was not required that patients receive antimicrobial agents on each day or the same agent throughout the interval. For example, a patient who received cefazolin on postoperative days 3–5, no antimicrobials on days 6 and 7, and an oral fluoroquinolone on days 8–11 was considered to have had an antimicrobial exposure interval of 9 days. We also identified patients who received any oral or parenteral antimicrobial therapy during a subsequent hospitalization in the same hospital within the appropriate surveillance time period. Data regarding the use of antiviral and antifungal agents were excluded.

At the onset of the study, 2 reviewers examined 10% of the medical records selected for review in order to validate data collection methods. All centers were required to achieve interobserver kappa scores of 0.60 or greater before proceeding with additional data collection. All information was entered into a Microsoft Access database. All patient identifiers were removed before data sets were submitted to the study coordinating center. The study protocol was approved by the institutional review boards of each participating center.

Data Analysis

Using previously described methods, we identified the antimicrobial exposure thresholds with the best combinations of sensitivity and specificity when fitted to a receiver operating characteristic (ROC) curve.⁵ We selected a random sample of operative procedures from the pool of procedures performed on patients without known SSI at each hospital, and we examined the results of medical record reviews for these patients to estimate the numbers for each of the cells in the 2-by-2 tables assessing SSI status versus the presence or absence of screening criteria based on the sampling fraction for that hospital. For example, if we reviewed the records of one-fifth

TABLE 1. Sensitivity (Sens; %) and Positive Predictive Value (PPV) of Routine Surveillance and Screening by Antimicrobial Exposure and Diagnosis Codes for Identification of Surgical Site Infection (SSI) Following Hysterectomy, Colorectal Procedures, and Vascular Procedures

Surveillance method	Hysterectomy		Colorectal procedures		Vascular procedures	
	Sens	PPV	Sens	PPV	Sens	PPV
Routine surveillance	59	99	22	93	43	73
SSI diagnosis code during the index hospital stay and/or readmissions	55	64	45	39	72	31
Antimicrobial exposure above threshold during index hospital stay and/or any antimicrobials during readmission	85	32	86	20	90	11
Antimicrobial exposure during any readmission	70	51	51	18	84	13
Antimicrobial exposure above threshold during index hospital stay and/or any antimicrobials during readmission and/or SSI diagnosis code for index hospital stay or readmission	92	31	88	20	90	10

of all vascular surgery procedures performed on patients without a known SSI at hospital A, then the numbers within each of the cells of the 2-by-2 SSI status versus screening criteria tables were multiplied by 5 and then added to the results for hospital A procedures with known SSI, generating overall 2-by-2 table results for all vascular procedures performed at hospital A. These results were used to estimate the sensitivity and positive predictive values (PPVs) of routine prospective surveillance, screening based on antimicrobial exposure, diagnosis codes suggestive of infection, and combinations of these. We chose as screening criteria for each procedure type the combination of antimicrobial exposure thresholds and/or diagnosis codes suggestive of SSI with the highest sensitivity and PPVs of 20% or greater.

The total number of SSIs not previously detected through routine surveillance was estimated by multiplying the rate of SSI identified by review of the medical records of the random sample of patients not known to have an SSI based on routine surveillance by the number of patients in the entire cohort who were not known to have an SSI. This estimate was added to the number of SSIs identified through routine surveillance to calculate a revised SSI rate. Statistical testing was performed, using SAS statistical software, version 9.2 (SAS Institute).

RESULTS

Hysterectomy

During the study period, 3,079 hysterectomies were performed at the 4 medical centers that implemented routine prospective SSI surveillance for these procedures (range, 161–1,496 procedures per hospital). Eighty-two SSIs were detected through routine surveillance, including 43 superficial incisional, 11 deep incisional, and 28 organ/space SSIs. A retrospective review of the medical records of the random sample of 741 patients who were not previously known to have an SSI identified 15 additional SSIs (10 superficial incisional, 2 deep incisional, and 3 organ/space SSIs). By extrapolating these results to the entire study population, we

estimated a total of 143 SSIs. A total of 80% of SSIs were detected after initial patient discharge.

The sensitivity of routine surveillance for the detection of SSI after hysterectomy was 59% (range among the 4 hospitals, 0%–69%). Screening with SSI diagnosis codes during the initial surgery hospitalization or a rehospitalization during the surveillance period had similar sensitivity (55%) and a PPV of 64% to detect SSI. Criteria of an antimicrobial exposure threshold of 3 days or more and/or receipt of at least 1 day of antimicrobials during subsequent rehospitalizations had a substantially higher sensitivity of 85% and a PPV of 32% to detect SSI. Adding assignment of an ICD-9-CM diagnosis code for infection to antimicrobial-based screening increased sensitivity to 92% (range among the 4 hospitals, 89%–100%) and caused a minimal decrease in PPV, to 31% (Table 1). Screening for patients who had an antimicrobial exposure threshold of 3 days or more and/or receipt of at least 1 day of antimicrobials during a rehospitalization and/or receipt of an ICD-9-CM diagnosis code for infection (subsequently referred to as enhanced surveillance) provided a revised SSI rate of 4.3% (95% confidence interval, 3.6%–5.1%), compared with an SSI rate of 2.7% with routine surveillance (Figure 1). The SSI rates by infection depth with routine versus enhanced surveillance were 1.3% versus 3.2% for superficial incisional SSI, 0.4% versus 0.8% for deep incisional SSI, and 0.9% versus 1.6% for organ/space SSI. A total of 14% of all hysterectomy procedures met the antimicrobial-plus diagnosis code–based screening criterion.

Colorectal Procedures

A total of 4,748 colorectal procedures were performed at the 4 participating medical centers during the study period (range, 300–1,666 procedures per hospital). Routine surveillance identified 109 SSIs, although 7 cases that were designated as SSI during routine surveillance were reclassified as no SSI on review of the records. The remaining 102 SSIs included 44 superficial incisional, 18 deep incisional, and 40

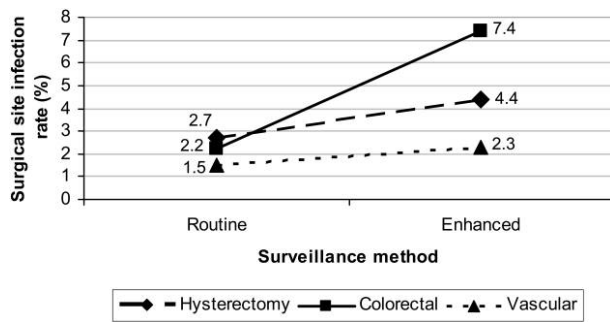


FIGURE 1. Rates of surgical site infection (including superficial incisional, deep incisional, and organ/space infections) determined with routine surveillance versus antimicrobial and/or diagnosis code–based (enhanced) screening following vascular procedures, colorectal procedures, and abdominal and vaginal hysterectomies.

organ/space SSIs. Research personnel reviewed a random sample of 643 patients who were not previously known to have SSI and found 41 additional SSIs (25 superficial incisional, 1 deep incisional, and 15 organ/space SSIs). By extrapolating these results to the entire study population, we estimated a total of 398 SSIs. A total of 43% of SSIs were detected after initial hospital discharge.

The sensitivity of routine surveillance for the detection of SSI after colorectal procedures was 22% (range among the 4 hospitals, 8%–89%). Screening for SSI diagnosis codes during the initial surgery hospitalization or during readmissions had a higher sensitivity for detecting SSI (45%) than did routine surveillance, although this method still missed more than half of all SSIs. Screening for receipt of 7 days or more of antimicrobials during the index hospitalization and/or at least 1 day of antimicrobials during a rehospitalization during the surveillance period had a substantially higher sensitivity of 86% and a PPV of 20%. When analysis of diagnosis codes was added to the antimicrobial criteria, sensitivity improved to 88% without affecting the PPV of 20% (Table 2). Screening that included a review of the records of patients who had an antimicrobial exposure threshold of at least 7 days and/or received at least 1 day of antimicrobials during a rehospitalization and/or were assigned an ICD-9-CM diagnosis code for infection (enhanced surveillance) resulted in a revised SSI rate of 7.1% (95% confidence interval, 6.7%–8.2%), compared with an SSI rate of 2.0% with routine surveillance (Figure 1). The SSI rates by infection depth with routine versus enhanced surveillance were 0.8% versus 4.1% for superficial incisional SSI, 0.3% versus 0.5% for deep incisional SSI, and 0.8% versus 2.8% for organ/space SSI. Thirty-seven percent of all patients undergoing colorectal procedures met the antimicrobial- plus diagnosis code–based screening criterion.

Vascular Procedures

A total of 3,332 vascular procedures were performed during the study period at the 4 participating medical centers (range,

580–3,332 procedures per hospital). Routine surveillance identified 68 SSIs, although 20 of these were reclassified as no SSI on review of the records. The remaining 48 SSIs included 16 superficial incisional, 22 deep incisional, and 10 organ/space SSIs. The 20 instances of SSI misclassification during routine surveillance occurred at 3 of the 4 hospitals, mainly involving cases originally classified as superficial incisional SSIs. Research personnel reviewed a random sample of 612 patients who were not previously known to have SSI and detected 11 additional SSIs (6 superficial incisional, 4 deep incisional, and 1 organ/space SSI). By extrapolating these results to the entire study population, we estimated a total of 107 SSIs. A total of 85% of SSIs were detected after initial hospital discharge.

Routine surveillance detected 43% (range among the 4 hospitals, 32%–63%) of SSIs after vascular procedures. Screening for SSI diagnosis codes during the index surgery hospitalization period or during readmissions within the surveillance period had higher sensitivity to detect SSI than did routine surveillance (72%) and a PPV of 31%. Screening for receipt of at least 1 day of antimicrobials during rehospitalization was more sensitive (84%) but had a low PPV of 13%. The addition of diagnosis codes to the antimicrobial exposure criterion improved sensitivity to 90%, but at the cost of further lowering PPV (Table 2). Screening for patients who received an ICD-9-CM diagnosis code for infection (enhanced surveillance) provided a revised SSI rate of 2.3% (95% confidence interval, 1.9%–2.9%), compared with an SSI rate of 1.4% with routine surveillance (Figure 1). The SSI rates by infection depth with routine versus enhanced surveillance were 0.5% versus 0.9% for superficial incisional SSIs, 0.7% versus 1.1% for deep incisional SSIs, and unchanged at 0.3% for organ/space SSIs. Eight percent of patients undergoing vascular procedures met the diagnosis code–based screening criterion.

DISCUSSION

HAI surveillance is essential to guide and assess the effectiveness of infection-prevention strategies. Increasingly, states are requiring that hospitals report HAI rates; many of these states require that these data be entered into the NHSN system. Hospitals are also now required to report SSI data to the NHSN for full CMS reimbursement, and hospital-specific SSI rates will become available for public scrutiny. The need for complete and accurate surveillance, however, must be balanced with competing demands, including resources necessary for implementing other HAI prevention efforts. To avoid the paradoxical negative impact of increasing surveillance requirements, it is essential that healthcare facilities explore methods of streamlining surveillance. The completeness and consistency of traditional surveillance methods can be limited by interobserver variability in classifying infections, inconsistent access to information required for the application of surveillance definitions, and fluctuations in the intensity of surveillance efforts over time due to competing

TABLE 2. Surgical Care Improvement Project (SCIP) Procedures and Enhanced Surgical Site Infection Screening Criteria with the Best Combinations of Sensitivity and Positive Predictive Value (PPV) for Detecting Surgical Site Infections

Surgical procedures	Screening criteria	Percentage of patients who met screening criteria
Coronary artery bypass graft operations ²	1. ≥ 9 days of antimicrobials during the index surgery hospitalization AND/OR 2. Any antimicrobials during any readmission within the surveillance period AND/OR 3. Infection diagnosis code for the index hospitalization or a readmission	19.6
Total knee arthroplasty ³	1. Infection diagnosis code for the index hospitalization or a readmission	2.7
Total hip arthroplasty ³	1. Infection diagnosis code for the index hospitalization or a readmission	3.6
Hysterectomy	1. ≥ 3 days of antimicrobials during the index surgery hospitalization AND/OR 2. Any antimicrobials during any readmission within the surveillance period AND/OR 3. Infection diagnosis code for the index hospitalization or a readmission within the surveillance period	13.7
Colorectal procedures	1. ≥ 7 days of antimicrobials during the index surgery hospitalization AND/OR 2. Any antimicrobials during any readmission within the surveillance period AND/OR 3. Infection diagnosis code for the index hospitalization or a readmission within the surveillance period	36.9
Vascular procedures	1. Infection diagnosis code for the index hospitalization or a readmission within the surveillance period	7.5

infection-prevention and infection-control priorities. This variability can limit the ability to compare SSI outcomes between institutions and even within a hospital over time.

Diagnosis codes that are relatively specific for SSI can be used to improve the poor performance of claims-based SSI surveillance that has been reported in some studies.^{6,7} Antimicrobial administration for patients who have recently undergone surgical procedures can indicate clinicians' suspicions of SSI and may in some cases accurately reflect the presence of an infection even when microbiologic sample cultures are not obtained. Both antimicrobial- and diagnosis code-based screening criteria depend on data that are automated in many hospitals and that could be utilized with minimal effort to identify for targeted review the subset of surgical patients most likely to have SSI. Following hysterectomy procedures, for example, antimicrobial- and diagnosis code-based screening identified the 14% of patients in which 92% of all SSIs occurred.

Prior studies have identified combinations of antimicrobial exposure thresholds and diagnosis codes that are useful for identifying SSI following a variety of surgical procedures including coronary artery bypass graft operations, total hip and knee arthroplasty, breast procedures, and cesarean deliveries (Table 2).^{2,3} The results of this study similarly suggest that

the use of diagnosis codes and/or quantitative measurement of antimicrobial exposure can be a useful surveillance screening strategy following hysterectomy, colorectal, and vascular operations (Table 2). For these procedures, antimicrobial- and/or diagnosis code-based screening criteria were more sensitive than routine surveillance and detected many SSIs

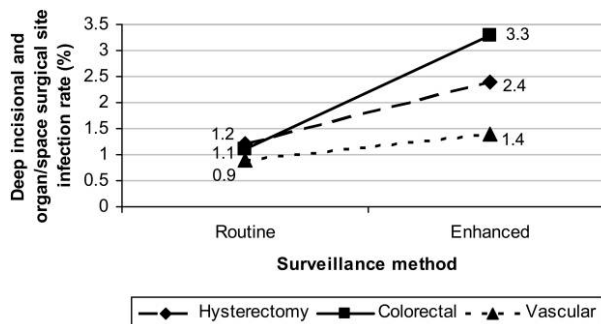


FIGURE 2. Rates of deep incisional plus organ/space surgical site infections determined using routine surveillance versus antimicrobial and/or diagnosis code-based (enhanced) screening following vascular procedures, colorectal procedures, and abdominal and vaginal hysterectomies.

missed by routine surveillance, including deep incisional and organ/space SSIs (Figure 2).

Although the PPV of antimicrobial- and/or diagnosis code-based screening ranged from a low of 20% for colorectal procedures to a high of 31% for hysterectomy and vascular procedures, focusing on the 8%–37% of postsurgical patients whose cases met screening criteria would enable infection preventionists to identify 1 true case of SSI out of every 3 hysterectomy, every 5 colorectal, and every 3 vascular procedures reviewed. Antimicrobial- and/or diagnosis code-based screening performed before medical record review could potentially both improve the completeness and consistency of SSI surveillance and streamline surveillance efforts.

Our study has a number of limitations. First, our strategy of reviewing all previously identified SSIs and extrapolating the results to other procedures by using a review of only a sample of these procedures may have impacted the accuracy and generalizability of screening criteria results.

Second, the goal of this study was to assess overall performance of screening criteria, and our ability to assess interhospital variability in screening criteria performance is limited because sensitivity, specificity, and PPV estimates were based on pooled results. In addition, the 5 study sites were affiliated with academic medical centers, and additional evaluation may be required to assess the generalizability of this surveillance method for use in community hospitals or resource-limited settings.

Furthermore, coding and antimicrobial prescribing practices may vary over time. In particular, diagnosis codes that negatively impact a hospital's reimbursement may lead medical record coders to avoid the use of these codes. The results of this study are based on procedures performed between 2003 and 2005, and increased scrutiny of SSI outcomes since that time may have impacted coding and antimicrobial administration practices as well as the accuracy and completeness of SSI surveillance in hospitals. The effectiveness of diagnosis code- and antimicrobial-based screening criteria therefore must be periodically reassessed over time.

Finally, this method uses only the information that is available in inpatient data systems and does not identify patients with SSIs that were detected and treated exclusively in the ambulatory setting or at hospitals other than the hospital where the operation was performed. Other strategies, such as those that utilize claims data submitted to insurers (eg, CMS or managed-care organizations), may provide alternative approaches for assessing postsurgical complications across the continuum of health care.^{8–11}

Antimicrobial- and diagnosis code-based screening appears to be a useful method for enhancing and streamlining SSI surveillance for a variety of surgical procedures, including the procedures targeted by the SCIP, and it provides a substantially different picture of the overall burden of SSI than does routine surveillance. As US hospitals progress toward adopting health-care information technology, it may become more straight-

forward for infection preventionists to incorporate inpatient pharmacy and administrative data into automated SSI surveillance algorithms that could also be utilized by NHSN and state health departments to further standardize, validate, and augment the quality of national SSI surveillance data.

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