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Point-of-Care Electronic Prompts: An Effective Means of Increasing Compliance, Demonstrating Quality, and Improving Outcome

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BACKGROUND: Incentives based on quality indicators such as the Surgical Care Improvement Project core measures (SCIP 1) encourage implementation of evidence-based guidelines consistently into clinical practice. Information systems with point-of-care electronic prompts (POCEPs) can facilitate adoption of processes and benchmark performance. We evaluated the effectiveness of POCEPs on rates of antibiotic administration within 60 minutes of surgical incision and effect on outcome in a prospective observational trial.

METHODS: SCIP 1 compliance and the corresponding outcome variable (surgical site infection [SSI]) were examined prospectively over 2 consecutive 6-month periods before (A) and after (B) POCEPs implementation at a regional health system. Secondary analysis extended the observation to two 12-month periods (A′ and B′). A 2-year (C and D) sustainability phase followed.

RESULTS: The 19,744 procedures included 9127 and 10,617 procedures before (A) and after (B) POCEPs implementation, respectively. POCEPs increased compliance with SCIP indicators in period B by 31% (95% CI, 30.0%–32.2%) from 62% to 92% ($P < 0.001$) and were associated with a sustainable, contemporaneous decrease in the incidence of SSI from 1.1% to 0.7% ($P = 0.003$; absolute risk reduction, 0.4%; 95% CI, 0.1%–0.7%). Secondary and sustainability analysis revealed that compliance rates remained >95% with mean SSI rates lower for all periods compared with pre-POCEPs SSI rates (0.8%, 0.7%, and 0.5% vs 1.1%; $P < 0.001$).

CONCLUSIONS: POCEPs increased compliance with SCIP indicators by >30% and were associated with a 0.4% absolute risk reduction in the incidence of SSI. POCEPs may be useful to modulate provider behavior and demonstrate intraoperative quality and value. (Anesth Analg 2011;113:869–76)

Translating scientific evidence into clinical practice remains a health care system challenge. In an effort to improve the quality and diminish the cost of health care in the United States, the 2010 Patient Care and Affordable Care Act establishes a Hospital Value-Based Purchasing Program under which value-based incentive payments will be made to providers that meet performance standards for a given fiscal year.[1] The Center for Medicare and Medicaid Services has identified administration of perioperative antibiotics (part of the Surgical Care Improvement Project—SCIP)[2] as one of the value-based performance standards in the Value-Based Purchasing Program.[1] Antibiotic administration within 60 minutes of surgical incision is associated with a decreased rate of bacteremia, surgical site infections (SSIs), and improved outcome.[2–4] Despite the body of scientific evidence demonstrating the effectiveness of this low-cost intervention, administration rates within the appropriate time window remain inconsistent at 25% to 95%.[2,5,6]

Anesthesia information management systems (AIMS) require a substantial initial capital investment, but such systems may ultimately maximize value-based incentive payments to anesthesiology departments and hospitals. As part of AIMS, point-of-care electronic prompts (POCEPs) can be customized to meet performance standards and improve the quality and value of perioperative care. Specifically, POCEPs could be used to elicit a specific behavior or response from a system or provider in a specific setting, encouraging adherence to evidence-based practice guidelines. The effectiveness of POCEPs implementation on rates of compliance with SCIP 1 and the effect on SSI were evaluated in a prospective observational trial.

METHODS

POCEPs Development

The Lehigh Valley IRB determined that the study was exempt from IRB review. The Department of Anesthesiology at a regional academic community health system (Lehigh Valley Health Network, Allentown, PA) was designated to be accountable for clinical compliance with the Center for Medicare and Medicaid Services' perioperative core measure: antibiotic administration within 60 minutes

Author affiliations are provided at the end of the article.

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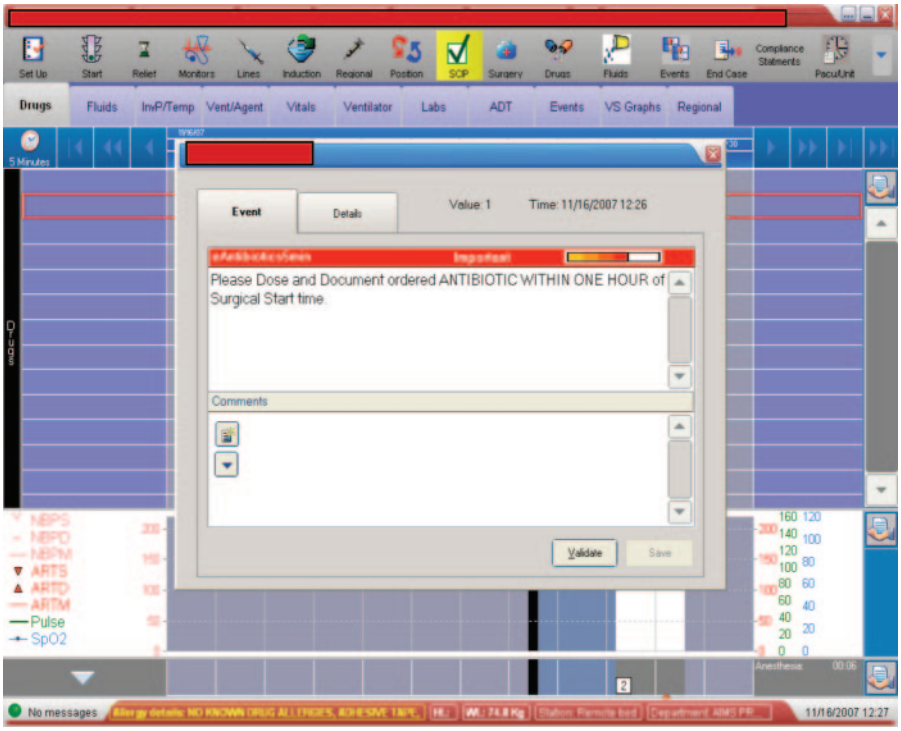

Figure 1. Live screen shot of a point-of-care electronic prompt (POCEP) as seen in intraoperative anesthesia information management systems (AIMS) medical record. A POCEP appears in real time in an AIMS within 5 minutes of operating room admission. Validation of the prompt is required before entry of any additional data. The prompt will continue to appear every 20 minutes.

of surgical incision, also known as SCIP 1 (Surgical Improvement Project Core Measure 1), for all indicated surgical cases within the health network. Despite initiatives to increase awareness and education, network-wide compliance rates with SCIP 1 remained low and inconsistent. Because of the failure of traditional methods to improve compliance, a small group of department staff developed a system of clinical reminders that would appear in our existing intraoperative AIMS. In conjunction with software developers, we developed and customized our electronic clinical prompt to meet our clinical objectives and suit our workflow.

POCEPs were embedded within our existing intraoperative automated AIMS (iMDsoft, Needham, MA). POCEPs were designed to appear on the patient's computer screen record within 5 minutes of operating room admission (patient in-room status) (Fig. 1). Further data entry in the record by the provider was not permissible until the prompt was acknowledged, although physiologic information continued to accrue in the background. Prompts were programmed to reappear thereafter every 20 minutes (second prompt appearing at 25 minutes after in-room status), unless an antibiotic (dose and time) was entered manually as having been administered to the patient on the computerized record or a "no antibiotic event" was chosen.

Compliance was defined as documentation that physical administration of antibiotics occurred within ≥1 ≤60 minutes of surgical incision (for vancomycin ≥1 ≤120 minutes of incision) or validation not to comply based on the following criteria: (1) no antibiotic indicated, (2) prior documented antibiotic administration, or (3) delayed administration indicated (after acquisition of surgical cultures). Antibiotics were documented and administered by the provider validating the electronic prompt, in all cases either the attending anesthesiologist or certified registered nurse anesthetist, in consultation with the operating attending surgeon. Compliance rates were extracted from the AIMS through the use of an internal query function at the end of each evaluation period and determined to be compliant (yes/no).

Evaluation Period

No organizational initiatives or educational efforts aimed at improving compliance with SCIP 1 were introduced during the evaluation period. Approximately 120 anesthesia providers (anesthesiologists and certified nurse anesthetists) staffed the various site locations. All patients undergoing surgical procedures at a major health network teaching hospital and its affiliated ambulatory surgical center were evaluated for compliance, except those undergoing obstetrical, endoscopic, percutaneous catheterization, or interventional radiologic procedures.

The primary evaluation periods straddled the date of POCEPs implementation (December 1, 2006) by 6 months pre- and post-prompts. Patients' records were evaluated over 2 consecutive 6-month periods: period A (June 1, 2006 to November 30, 2006) and period B (December 1, 2006 to May 31, 2007) to determine compliance with SCIP 1.

A secondary analysis examined compliance and SSI rates over 12 months before and after POCEPs implementation: period A′ (December 2005 to November 2006) and period B′ (December 2006 to November 2007). Finally, a sustainability phase followed, which examined compliance and SSI rates in surgical patients for 2 years after the secondary analysis, periods C and D (calendar years 2008 and 2009, respectively).

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Surgical Site Infections

SSIs were determined in accordance with definitions established by the Centers for Disease Control (CDC) and Prevention for the National Nosocomial Surveillance (NNIS) System[7] and the National Healthcare Safety Network (NHSN).[8] An operative procedure was defined as an event occurring in an inpatient admission setting with a trip to the operating room where the surgeon makes at least 1 incision through the skin or mucous membrane, including laparoscopic approach, and closes the incision before leaving the operating room.

Trained infection control professionals performed active surveillance on all patients suspected of having an SSI after an operative procedure. Sources of data were derived from daily rounds of the inpatient wards, review of microbiology laboratory records, discussion with physicians, and patient chart review. CDC/NHSN criteria[a] were used to define an SSI. Postdischarge surveillance was limited to review of microbiology cultures from outpatient and emergency department visits. In addition, patients readmitted with any surgical wound were identified and investigated. SSIs were followed for 30 days from the date of the operative procedure for nonimplant procedures and 1 year if an implant was inserted and there was evidence that the SSI was related to the operative procedure (infection site, organism, documented evidence of other sources of infection, etc.). All surgical patients were evaluated and standard SSI rates were reported monthly, as per institutional protocol. SSI rates were defined as the number of SSIs divided by the total monthly surgical volume. Aggregate SSI data for periods A and B (6 months pre- and post-POCEPs), A′ and B′ (12 months pre- and post-prompts), and period C (calendar year 2008) and D (calendar year 2009) were calculated from the standard monthly SSI rates reported by Infection Control. All Infection Control personnel were blinded to the purpose of data acquisition or periods of comparison.

Statistical Analysis

Infection rates were calculated as number of infections per 1000 surgical procedures. Data were tested for normalcy and homoscedasticity and did not require any statistical transformation. χ^2 analyses were used to test overall compliance and incidence of SSI between both groups. Finally, *P* and X-bar control charts using SPSS 15.0 (IBM SPSS Statistics, Chicago, IL) were constructed to evaluate noncompliance proportions and mean SSI rates over time, respectively. Sigma was set at 1 SD; rule violations were defined as any of the following:

More than $+3\ \sigma$
Two points of the last 3 above $+\ 2\ \sigma$
Four points of the last 5 above $+\ 1\ \sigma$

Demographic variables including age, sex, duration of surgery (in relation to national norms), American Society of Anesthesiologists (ASA) score, and NNIS score were also compared between both groups (A and B). No statistical transformations were warranted for the clinical demographic variables. χ^2 analysis was used to test for distribution of sex between groups. Kendall τ-c statistic was used to test for symmetry of distribution of ASA and NNIS scores between time periods A and B. Independent *t* tests were used to examine mean infection rate, age, and surgical duration between patients in periods A and B. Analysis of variance and ad hoc analyses of Dunnett T3 were used to examine mean infection rate among periods A, B, C, and D. Bivariate and hierarchical χ^2 and logistic regression model analyses were used to evaluate compliance and SSI rates by location, inpatient/outpatient surgery, surgical service, and individual surgeon. Hierarchical analyses included overall χ^2 test analyzing the association of compliance with pre- and post-prompts. The χ^2 was then hierarchically layered by inpatient versus outpatient surgery, location, followed by surgical service, and then by individual surgeon using the cross-tabulations χ^2 analysis module in SPSS 15.0. This analysis was then confirmed using overall logistic regression models testing the likelihood of overall compliance pre- and post-prompts. This model was then adjusted for inpatient versus outpatient surgery, location, followed by surgical service, and then for individual surgeon using the multinomial logistic regression module in SPSS 15.0. Alpha was set at 0.05 with 95% confidence intervals.

Table 1. Preoperative Risk Factors for SSI for Period A and B Patients

Indicator	Period A (%), *n* = 9127	Period B (%), *n* = 10,617	*P* value
Age, mean (SD), y	53.2 (23.6)	53.8 (21.1)	0.109
Female sex	4000 (49.8)	4128 (50.5)	0.125
ASA physical status			0.099
I	754 (9.4)	767 (9.4)	
II	3280 (40.9)	3372 (41.4)	
III	2694 (33.6)	2879 (35.3)	
IV	1270 (15.8)	1120 (13.7)	
V	17 (0.2)	12 (0.1)	
NNIS score			0.202
0	3147 (41.7)	3295 (42.3)	
1	3330 (44.1)	3451 (44.3)	
2	994 (13.2)	1002 (12.9)	
3	76 (1.0)	37 (0.05)	
Time in operating room, mean (SD), min	93.6 (81.2)	95.9 (83.6)	0.074

Incidence of surgical site infection (SSI)-related risk factors in patients evaluated in periods A and B, before and after point-of-care electronic prompts implementation, respectively.
NNIS = National Nosocomial Surveillance.

RESULTS

Primary Analysis: 6 Months Pre- and Post-POCEPs

A total of 19,744 surgical procedures were evaluated for SCIP 1 compliance. The 6-month comparison period immediately before and after implementation of POCEPs included 9127 and 10,617 surgical procedures, respectively. Surgical patients in period A and period B were well matched for known nationally validated risk factors associated with SSI (Table 1).

SCIP compliance and postoperative SSI rates within the health delivery network before and after the implementation of POCEPs are displayed in Figures 2 and 3, respectively. Overall, network-wide compliance with documentation and

[a]Identifying Healthcare-Associated Infections (HAI) in NHSN. Available at: http://www.cdc.gov/nhsn/PDFs/pscManual/2PSC_IdentifyingHAIs_NHSNcurrent.pdf. Accessed May 13, 2011.

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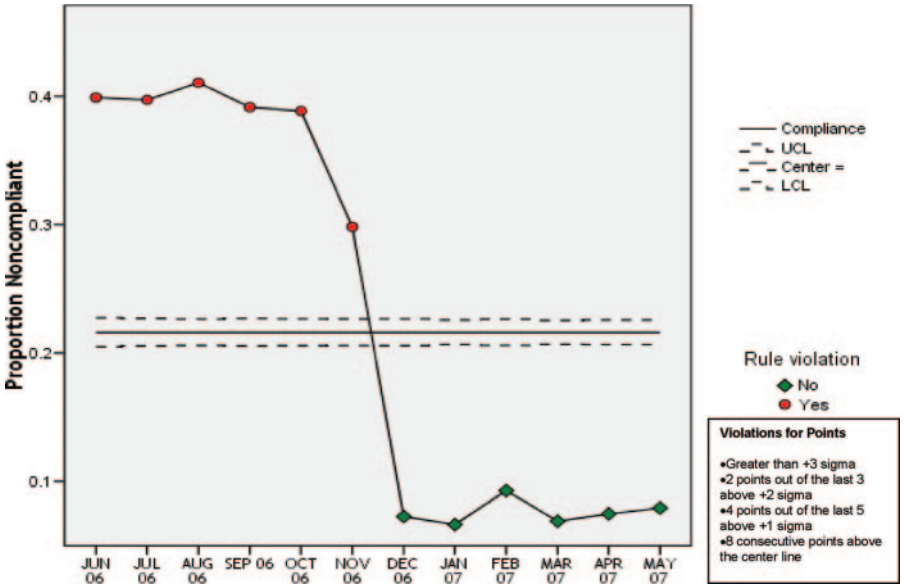

Figure 2. Control chart of antibiotic compliance rates. The compliance rates of the health network before and after implementation of point-of-care electronic prompts in the anesthesia information management system for periods A′ and B′. UCL = upper control limit; LCL = lower control limit.

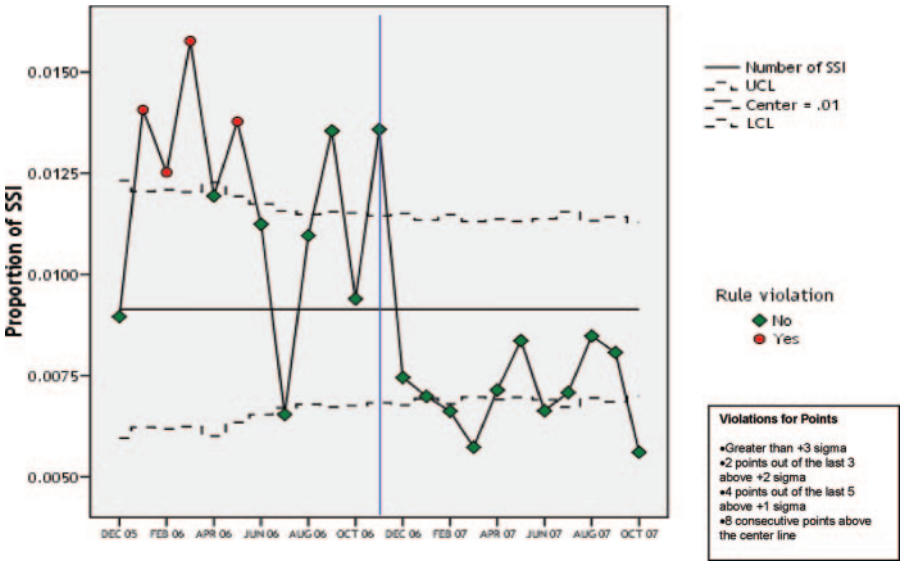

Figure 3. Control chart of surgical site infection (SSI) incidence. The incidence of SSI of the health network before and after implementation of point-of-care electronic prompts in the anesthesia information management system for periods A and B. UCL = upper control limit; LCL = lower control limit.

administration of antibiotics within 60 minutes of surgical incision increased by 31% (95% CI, 30%–32.2%) from 62% to 92% ($P < 0.001$) for the 6-month period immediately before and after prompts implementation (periods A and B, respectively). POCEPs implementation was associated with a sustainable, contemporaneous reduction in the absolute risk (0.4%; 95% CI, 0.1%–0.7%) and relative risk (35.1%; 95% CI, 12.9%–51.7%) of SSI, corresponding to a decrease in the overall rate of SSI from 1.1% to 0.7% ($P = 0.003$) observed in periods A and B, respectively.

Extended Analysis: 12 Months Pre- and Post-POCEPs and 2-Year Sustainability

A secondary analysis extended the observation period to 12 months pre- and post-POCEPs (A′ and B′) and then for 2 additional years (C and D) to account for seasonal variability in the comparison periods and to demonstrate sustainability of the post-POCEPs' effect.

The analysis for periods A′ and B′ demonstrated compliance patterns (Fig. 4) and SSI rates (Fig. 5) consistent with the primary results demonstrated in periods A and B. Hierarchical and bivariate analyses showed a consistent pattern of increased compliance and decreased SSI rates adjusting for total surgery volume, inpatient versus outpatient surgery ratios, location, surgical service, and individual surgeon. Although overall surgical volume increased over each 12-month period analyzed, period A′ ($n = 20{,}944$), period A + B ($n = 19{,}744$), B′ ($n = 22{,}174$), C ($n = 23{,}340$), and D ($n = 23{,}528$), outpatient/inpatient surgical ratios remained stable over all time periods with 58%, 55%, 56%, and 55% corresponding to periods A′, B′, C, and D, respectively.

A total of 69,042 surgical cases were observed in all of the post-POCEPs periods. Compliance rates remained consistently >95% throughout all post-POCEPs observation periods (at 97.9%, 96.4%, and 97.1% for periods B′, C, and D, respectively).

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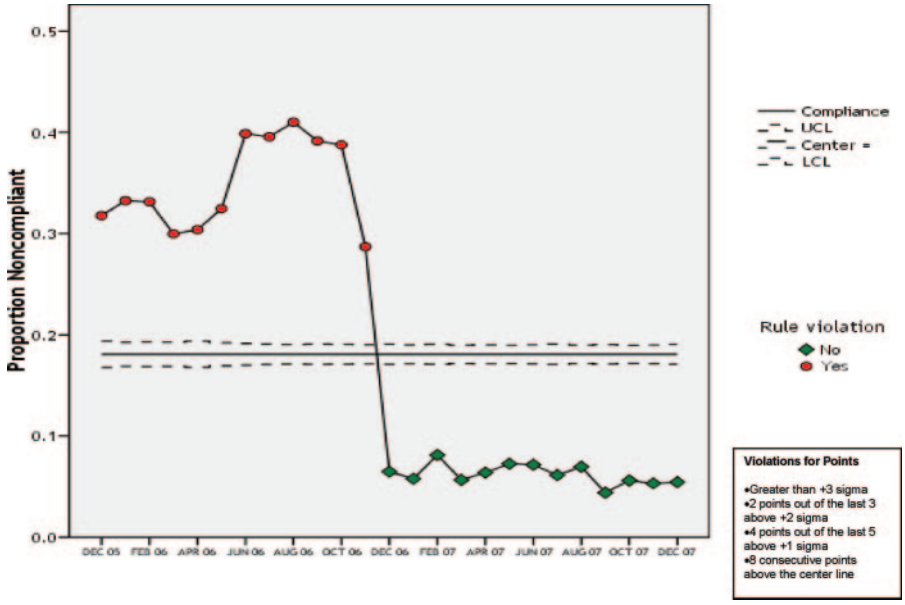

Figure 4. Sustainability of antibiotic compliance rates. The compliance rates of the health delivery network 1 year before and 1 year after implementation of point-of-care electronic prompts. UCL = upper control limit; LCL = lower control limit.

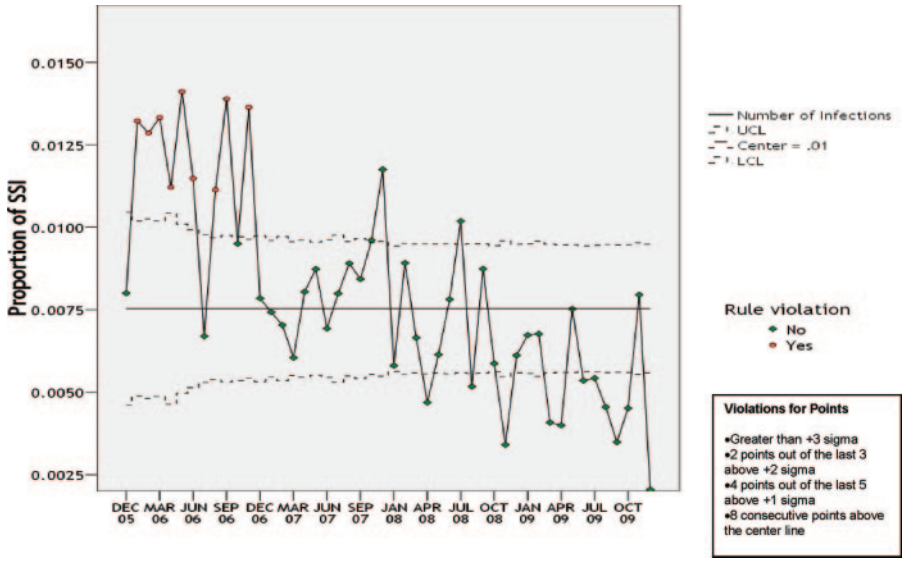

Figure 5. Sustainability of SSI rates. Control chart of the incidence of surgical site infection (SSI) rates of the health delivery network before and after the implementation of point-of-care electronic prompts in the anesthesia information management system over 4 years. UCL = upper control limit; LCL = lower control limit.

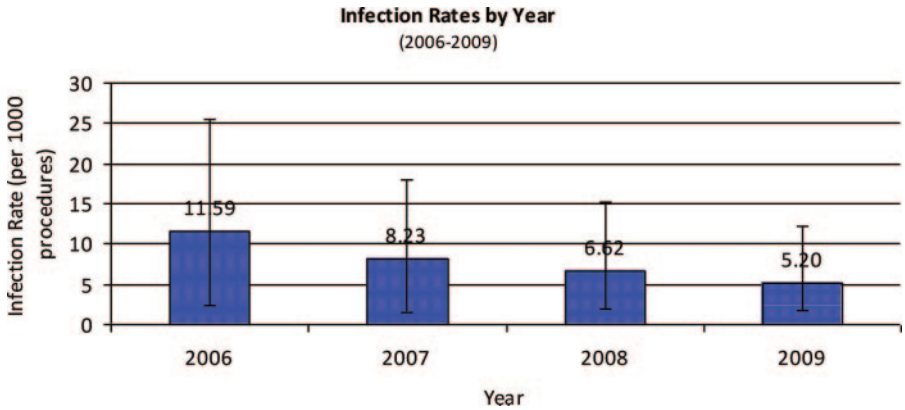

Figure 6. Annual surgical site infection (SSI) rates. The incidence of SSI rates corresponding to calendar year.

Figure 6 displays the SSI rates of the study periods corresponding to their approximate calendar year: A′ (2006), B′ (2007), C (2008), and D (2009). Analysis of variance and ad hoc analysis showed statistically significant differences in mean SSI rates between period A′ and all other periods (periods B′, C, and D: $P = 0.004$, $P < 0.001$, and $P < 0.001$, respectively) and may reflect the sustainability of the POCEPs′ effect on SSI rates. No significant differences in

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compliance or SSI rates were observed between any consecutive time periods since POCEPs implementation.

DISCUSSION

Electronic prompts have been reported to increase compliance with a variety of best-practice recommendations including venous thromboembolism prophylaxis,[9] asthma care,[10] and medication prescribing patterns.[11] POCEPs have also been shown to be "useful" for implementation of complex algorithms[12] and to alert providers of impending danger or risk that would be difficult to discern by other means or easily neglected because of human oversight.[13,14] Despite these encouraging reports, the systematic disregard of prompts by providers[15] and alert fatigue[16] have also been described.

In the operating room, the introduction of POCEPs has thus far had a consistent beneficial effect on compliance with evidence-based practices. Improvements in rates of adherence to clinical recommendations have been reported for antibiotic administration by 2 centers using POCEPs.[17,18] Consistent with these reports, our data confirm the effectiveness of electronic prompts to increase rates of appropriate perioperative antibiotic administration, but go an important step further in demonstrating an association between increased antibiotic administration compliance rates and a decreased incidence of SSI.

Quality Indicators and Outcome

Although the investigators predicted an improvement in compliance rates with POCEPs implementation, the association with lower rates of SSI was less anticipated. Although unexpected, the findings are consistent with published reports demonstrating that antibiotic prophylaxis reduces SSIs in controlled settings.[19,20] More importantly, these results suggest that improved adherence to process can measurably affect outcome in an unprotocolized clinical milieu.

Establishing an association between quality indicators and outcome outside the domain of the rigorously controlled environment of clinical trials has proven surprisingly challenging.[21–24] A recent retrospective cohort study evaluating 405,720 patients between July 1, 2006 and March 31, 2008 from 398 hospitals in the United States for whom SCIP performance was recorded and submitted for public report on the Hospital Compare web site demonstrated that none of the individual infection prevention SCIP process measures was associated with a lower probability of infection.[24] SCIP compliance rates from that published report were self-reported by hospitals and predominantly abstracted from nonelectronic and secondary administrative data sources. Although our sample size is smaller, our compliance data were derived from primary electronic clinical data and suggest that increasing compliance with a single process measure (SCIP 1) was associated with decreased incidence of infection.

Impact of SSI and AIMS

Conservative estimates suggest that the national economic burden of SSI exceeds $3 billion annually, and that SSI is a primary contributor to in-hospital mortality.[25] Forty million surgical procedures are performed in the United States annually. From those, approximately 780,000 patients will develop a postoperative surgical wound infection,[26] and 20,000 will die as a direct consequence.[25] Evidence suggests that the current national surgical infection rate (2.6%) can be reduced by 40% to 60% annually by adherence to recommended SCIP 1 guidelines.[27]

Vis-à-vis the extant technological sophistication in health care today, poor adherence[28,29] with effective low-cost, evidenced-based interventions seems inexplicable. Poor compliance with quality indicators may result from multifarious factors.[30] Efforts aimed at changing provider behavior by relying on or promoting an increase in vigilance, safety, or education, have historically had limited success[31] in producing the high compliance rates necessary to approximate expected industry standards (>95%).[32] Our data suggest that computerized clinical reminders, presented at a point in time during which the process measure can be physically executed, are a highly effective modality in eliciting behavior change in a "real world" clinical setting.

Investment in AIMS can be substantial, ranging from $250,000 to >$2 million, commensurate with scale and complexity of the system.[33] Demonstrating a return on investment in tangible dollars directly arising from the implementation of AIMS (via the creation of efficiencies or decreased cost of reporting, etc) has been challenging.[34] If, however, economic incentives are realigned to encourage value, then the return on investment in AIMS becomes quantifiable. The data suggest that interactive prompts imbedded in such technologies can consistently affect human behavior and create value by improving quality while reducing health care cost. A calculation based on the presented data suggests that POCEPs implementation may have been responsible for the 26 fewer SSIs during the latter 6-month study period.

Weakness and Bias: Rates of Compliance

Factors other than POCEPs may have been related to the improved rates of compliance with SCIP 1 obtained in period B. Although no other organizational initiatives focused on SSI prevention or antibiotic compliance were conducted during the observation period, a Joint Commission site visit occurred during period A. It is possible that additional factors related, but not directly attributable, to POCEPs may have influenced provider behavior sufficiently to account for the increase in compliance obtained after POCEPs implementation.

Furthermore, the process of POCEPs implementation rather than the POCEPs themselves may have influenced providers. However, the sustainability of the high rates of compliance over the ensuing 3 years does not support this conclusion. Nevertheless, desensitization is a potential phenomenon in human factors, and extended evaluation periods will be necessary to fully evaluate the impact of electronic prompts on behavior and outcome over longer periods of time.

Weakness and Bias: SSI Outcome

Postdischarge surveillance to identify SSIs was limited to the review of positive microbiological culture results. A positive culture result in an outpatient with a history of a

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surgical procedure initiated further investigation by infection control professionals to identify criteria that matched the CDC/NHSN definition of an SSI. Alternatively, if an outpatient received empirical treatment in the physician's office and a culture was not submitted for microbiological testing, it may have been missed as a potential SSI. The absence of a means to identify SSI postdischarge when cultures were not collected may have resulted in the underreporting of SSIs.

Although observation period B had an increase in overall surgical volume, no new surgical service lines, changes in inpatient/outpatient surgical ratios, or assimilations of geographic populations were introduced during the study period. In addition, no change in preoperative risk factors or patient acuity occurred over the consecutive 12-month observation period in the primary analysis. Nevertheless, significant differences in known risk factors for SSI between the 2 evaluated groups may still exist and account for the decrease in SSI rates.

Furthermore, although a strong association between SCIP 1 compliance and SSI rate has been demonstrated, a cause and effect relationship cannot be unequivocally inferred from the data. It is conceivable that additional factors that have not been accounted for may be related to, or responsible for, the reduction in SSIs obtained in period B.

Future Application

The assessment of behavior-modulating interactive electronic technology is in its infancy. Considering the relative scarcity and limited collective experience with POCEPs, broader clinical applicability of these "electronic coordinators" of care is unknown. The clinical application of POCEPs in this trial features a rigorously validated quality measure (antibiotic administration) related to outcome. Furthermore, the described POCEPs-coordinated intervention algorithm is very basic and linear. These factors coupled with the relatively homogeneous clinical setting of the operating room present an ideal environment for testing electronically driven algorithms. It is impossible to predict whether POCEPs will be effective when exported to other settings where the complexity of the encounters and clinical pathways increases. The current data also support collateral investigations of POCEPs as a potential tool to benchmark quality and demonstrate value.

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Contribution: Study concept and design and critical revision of the manuscript for important intellectual content.
Attestation: Dr. McLoughlin had full access to all study data and takes responsibility for the data integrity and the accuracy of the data analysis.

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