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Major Article

# Validation of an electronic tool for flagging surgical site infections based on clinical practice patterns for triaging surveillance: Operational successes and barriers

T. Pindyck MD, MPH [a,*], K. Gupta MD, MPH [b,c], J. Strymish MD [b,d], K.M. Itani MD [b,c], M.E. Carter MSPH [e,f,g], Y. Suo MS [e,f,g], M.T. Bessesen MD [h,i], J. Topkoff RN, MS [h], A.S. Steele MSN, RN, CIC, CNOR [j], A.E. Barón PhD [k], A.V. Gundlapalli MD, PhD [e,f,g], W. Branch-Elliman MD, MMsc [b,d]

[a] *Department of Family Medicine Preventive Medicine Residency Program, University of Colorado Anschutz Medical Campus, Aurora, CO*
[b] *VA Boston Healthcare System, Boston, MA*
[c] *Boston University School of Medicine, Boston, MA*
[d] *Harvard Medical School, Boston, MA*
[e] *VA Salt Lake City Healthcare System, Salt Lake City, UT*
[f] *IDEAS Center 2.0, Salt Lake City, UT*
[g] *University of Utah School of Medicine, Salt Lake City, UT*
[h] *Eastern Colorado VA Healthcare System, Denver, CO*
[i] *Department of Medicine, University of Colorado Anschutz Medical Campus, Aurora, CO*
[j] *U.S. Department of Veteran Affairs, VA St. Louis Healthcare System, St. Louis, MO*
[k] *Department of Biostatistics and Informatics, Colorado School of Public Health, University of Colorado Anschutz Medical Campus, Aurora, CO*

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***Background:*** Surveillance is an effective strategy for reducing surgical site infections (SSIs); however, current identification methods are resource-intensive. Therefore, we sought to validate an electronic SSI triaging tool for detection of probable infections and identify operational barriers and challenges.

***Methods:*** A retrospective cohort study was conducted among all Veterans Affairs Surgical Quality Improvement Program (VASQIP)–reviewed surgeries at 2 Veterans Affairs medical centers from October 1, 2011-September 30, 2014. During the postoperative period, clinical and administrative variables associated with SSI (relevant microbiology order, antibiotic order, radiology order, and administrative codes) were extracted from the electronic medical record and used to score the probability (high, intermediate, and low) that an SSI occurred. VASQIP manual chart review was used as the gold standard of comparison.

***Results:*** VASQIP manual review identified 118 SSIs out of 3,700 surgeries (3.2%). There were 2,041, 1,428, and 231 surgeries that met criteria for low, intermediate, and high probability for SSI. The tool's area under the curve was 0.86 (95% confidence interval, 0.82-0.89). The sensitivity among low-probability surgeries was 92.4%, and the specificity among high-probability surgeries was 95.1%.

***Conclusions:*** The electronic SSI tool has the potential to be used for triaging VASQIP surveillance toward the high-probability surgeries and to avoid manual review of surgeries with low probability of SSI.



* Address correspondence to Talia Pindyck, MD, MPH, Department of Family Medicine Preventive Medicine Residency Program, University of Colorado Anschutz Medical Campus, 13001 E 17th Place, Mailstop B119, Aurora, CO 80045.
*E-mail address:* talia.pindyck@ucdenver.edu (T. Pindyck).

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## BACKGROUND

Surgical site infections (SSIs) are among the most common health care–associated infections,[1,2] accounting for up to 20% of all health care–associated infections in hospitalized patients.[3] SSIs increase morbidity, mortality, medical costs, and are used as a quality benchmark.[4-6]

Surveillance is an effective strategy for deploying infection prevention resources and ultimately reducing SSIs. However, currently available methods have significant limitations. Isolated clinical markers, such as microbiology results, have low sensitivity.[7-9] Complex detection algorithms are hampered by narrow generalizability and complexity.[10,11] Because SSI is a rare outcome, random sampling with manual review is low-yield, resource-intense, and impractical in many settings. An additional limitation of manual review programs is the inherent subjectivity of the method.[12-15] Automated SSI triaging tools based on readily available clinical and administrative variables are an attractive alternative because they have the potential to expand current surveillance capacity consistently and accurately across medical institutions.[16]

The Veterans Affairs Surgical Quality Improvement Program (VASQIP), which applies recent Centers for Disease Control and Prevention's National Healthcare Safety Network (NHSN) surveillance definitions to identify SSI, includes detailed manual review of a selection of surgical procedures by a trained nurse reviewer. Sampling is based on a validated method that targets major cases and limits review of minor cases, such as hernia repairs.[17] An alternative strategy for conducting SSI surveillance is the use of clinical variables—part of the usual diagnosis and treatment of SSI and other health care associated infections—to guide detection and subsequent case review. Using clinical practice patterns to guide surveillance activities has been a successful strategy for identifying other health care–associated infections, such as clinical methicillin-resistant *Staphylococcus aureus* infections.[18]

A simple and easily automated triaging tool for identifying SSI based on clinical variables associated with the diagnosis and treatment of SSI, including antimicrobial use, was previously developed at a single Veterans Affairs (VA) medical center.[19] Based on an initial case-control study, this surveillance tool demonstrated excellent operating characteristics (area under the curve [AUC], 0.87).[19] In the setting of expanding our SSI surveillance for quality assurance purposes,[20] we operationalized this tool to expand surveillance at 2 VA medical centers. The purpose of this study was to validate the tool and determine operational barriers to using a practice pattern–based approach to SSI detection.

## METHODS

### *Medical center overview*

The study cohort included 2 geographically distributed level 1 VA facilities: VA Eastern Colorado Healthcare System (Denver VA) and VA Boston Healthcare system (Boston VA). They perform approximately 4,000 and 5,000 operating room surgical procedures annually, respectively, including major cardiothoracic, abdominal, orthopedic, and vascular surgeries.

### *Cohort development and case definition*

All surgeries that were manually reviewed for the presence of SSI by VASQIP during the period from October 1, 2011-September 30, 2014 were included. The VASQIP determination was compared with the probability score from the electronic triaging tool.

### *Data collection*

Data were extracted from the VA Heath Information Systems electronically. Type of surgical procedure was determined based on VASQIP entry. Electronically extracted variables included demographic (age and sex), potentially relevant microbiology culture orders (examples of labels include swab, tissue, fluid, abscess fluid, connective tissue, and bone; blood, urine, sputum, and methicillin-resistant *Staphylococcus aureus* nasal surveillance swabs were specifically excluded), first antimicrobial order within the postoperative window, radiology orders, and ICD-9 or current procedural terminology codes determined a priori to be potentially indicative of SSI diagnosis. A random sample of the electronically extracted data was validated using manual chart review blinded to electronic flag to evaluate the accuracy of electronically extracted variables.

### *SSI triaging tool*

Clinical and administrative variables included in the previously constructed electronic tool were ICD-9 or CPT code indicative of SSI, first new antibiotic order, relevant microbiology culture order, and computed tomography (CT) or magnetic resonance imaging (MRI) radiology examination during the NHSN-defined postoperative data extraction period (30 days). Antibiotic orders placed within 24 hours after a surgical procedure were excluded from the triaging tool, given the accepted time frame for perioperative prophylaxis according to former Surgical Care Improvement Project measures.[17]

### *Statistical analysis*

#### *SSI triaging tool*

The practice pattern–based SSI detection tool was applied to all VASQIP-reviewed surgical procedures during the study period, using a weighted point system based on previously published data (antimicrobial order, 2 points; wound, tissue, or fluid specimen logged in microbiology laboratory, 1 point; CT or MRI order, 1 point; ICD-9 or CPT code, 5 points).[19] Surgeries with a score of zero were classified as low probability, 1-3 points were classified as intermediate probability, and ≥4 points were classified as high probability of SSI.[19] True SSI cases flagged in the low-probability category (false negatives) and high-probability noncases (false positives) at 1 facility were reviewed to ascertain reasons for discordance between the electronic algorithm and the gold standard manual review.

The sensitivity and specificity of each cut point were calculated and examined, and the area under the receiver operator characteristic curve was obtained. Positive likelihood ratios (LRs+) and negative likelihood ratios (LRs–) were calculated to determine the probability of SSI changes for each cut point. LR+ > 10 indicated a large increase in the likelihood of disease, and LR– < 0.1 indicated a large decrease in the likelihood of disease.

$$LR+ = \frac{sensitivity}{1-specificity} \qquad LR- = \frac{1-sensitivity}{specificity}$$

Receiver operator characteristic curves were calculated to assess operability of the probability score. To ensure that algorithm accuracy was not overestimated, confidence intervals for AUC values were obtained via bootstrapping with 1,000 repetitions. Multivariable logistic regression was also used to confirm the independent contribution of each of the 4 clinical variables in predicting SSI in this larger sample set.

Given that procedure-related infections typically do not occur in the first 24 hours after a surgical intervention,[21,22] and concern that microbiology orders logged during this time frame might be related to preexisting, nonprocedure-related infections, a sensitivity analysis on the window period for the microbiology order flagging