Utilization of the NSQIP-Pediatric Database in Development and Validation of a New Predictive Model of Pediatric Postoperative Wound Complications

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BACKGROUND: Surgical wound classification, introduced in 1964, stratifies the risk of surgical site infection (SSI) based on a clinical estimate of the inoculum of bacteria encountered during the procedure. Recent literature has questioned the accuracy of predicting SSI risk based on wound classification. We hypothesized that a more specific model founded on specific patient and perioperative factors would more accurately predict the risk of SSI.

STUDY DESIGN: Using all observations from the 2012 to 2014 pediatric National Surgical Quality Improvement Program-Pediatric (NSQIP-P) Participant Use File, patients were randomized into model creation and model validation datasets. Potential perioperative predictive factors were assessed with univariate analysis for each of 4 outcomes: wound dehiscence, superficial wound infection, deep wound infection, and organ space infection. A multiple logistic regression model with a step-wise backwards elimination was performed. A receiver operating characteristic curve with c-statistic was generated to assess the model discrimination for each outcome.

RESULTS: A total of 183,233 patients were included. All perioperative NSQIP factors were evaluated for clinical pertinence. Of the original 43 perioperative predictive factors selected, 6 to 9 predictors for each outcome were significantly associated with postoperative SSI. The predictive accuracy level of our model compared favorably with the traditional wound classification in each outcome of interest.

CONCLUSIONS: The proposed model from NSQIP-P demonstrated a significantly improved predictive ability for postoperative SSIs than the current wound classification system. This model will allow providers to more effectively counsel families and patients of these risks, and more accurately reflect true risks for individual surgical patients to hospitals and payers. (J Am Coll Surg 2017; 224:532–544. © 2017 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

Surgical site infection (SSI) has become an important metric as an indicator of quality of care. It can result in significant morbidity and incur much higher costs. The hospital costs associated with an SSI can be up to $25,000 per event.[1-3] Significant time and effort, often by large collaborative groups, have been focused on bundles of care surrounding perioperative care to reduce the incidence of SSIs.

Currently, the most widely used Association of periOperative Registered Nurses (AORN) wound classification system stratifies surgical wounds into 4 classes: Class I, clean; Class II, clean-contaminated; Class III, contaminated; and Class IV, dirty. This classification system is based on the presumed bacterial load of the surgical wound.[4,5] In 1985, the CDC guidelines provided updated, estimated postoperative rates of SSIs to 1% to 5% for clean, 3% to 11% for clean-contaminated, 10% to 17%

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Abbreviations and Acronyms

AUROC = area under the receiver operating characteristic
NSQIP-P = National Surgical Quality Improvement Program-Pediatric
SSI = surgical site infection

for contaminated, and more than 27% for dirty.[3,6] The objectives of this wound classification schema are to allow for better prediction of wounds that have an increased risk for infection, and increase awareness of this possibility of infection for those providing postoperative care. However, a recent collaborative study of pediatric institutions demonstrated inconsistency and inaccuracy in how wounds were being classified.[7] Furthermore, Gonzalez and colleagues[8] and Oyetunji and associates[9] recently demonstrated with National Surgical Quality Improvement Program-Pediatric (NSQIP-P) data that current wound classification systems do not reflect the true risk of SSIs and are inadequate measures for benchmarking surgical care in children.

As the focus in health care shifts to improving the quality of care and value-based care, appropriate risk prediction models that properly benchmark quality will be essential for both providers and payers. The aim of this study was to evaluate the ability of current wound classification systems to appropriately predict postoperative SSIs in children. Furthermore, this study developed multivariate models, based on NSQIP-P data, incorporating important perioperative variables to better predict SSI occurrence postoperatively in pediatric surgical patients.

METHODS

Data source and patients

A retrospective analysis was performed using NSQIP-P data from the 2012 to 2014 Participant Use File. The NSQIP-P collects patient-level clinical data including demographics, comorbidities, laboratory values, and outcomes, and identifies cases by CPT codes. These data are reliable because they are rigorously defined, and collected and recorded by trained surgical clinical reviewers, who undergo training and examination in variable definitions. In addition, the program performs random audits to check for data validity and definition compliance. Cases are systematically sampled across all specialties at each participating hospital, following an 8-day cycle.[10] All cases are followed for 30 days using the medical record or patient outreach to verify the presence or absence of adverse events at the 30-day postoperative time point.

Predictors and outcomes

Factors considered for calculating patient-specific risk of surgical outcomes were demographic, preoperative, and perioperative clinical variables. The final variables were chosen based on previous literature,[6,10-12] predictive value, and clinical face validity. In addition to these patient-specific risk factors, a procedure-specific risk variable was included based on subgrouping of CPT codes. Consequently, out of a total of 218 preoperative and intraoperative variables, 43 variables were selected (Table 1). Four outcomes were then individually modeled: superficial, deep, organ space SSI, and surgical wound dehiscence. The exact NSQIP-P definitions of each outcome of interest are provided in Table 2, as based on the American College of Surgeons NSQIP User Guide for the 2014 Participant Use File.

Development and validation cohorts

All records were randomized into development (50% of records) and validation (50% of records) dataset groups. The cohorts were compared for the variables in question, to determine that they contained no statistical difference in predictor or outcome variables. The predictive (logistic model) equations were estimated from the development dataset and applied to the validation dataset.

Statistical analysis

Each outcome model was evaluated for applicability of all clinical variables listed in Table 1. Univariate analysis of all predictive variables was performed to compare risk factors among patients who did or did not experience each specific outcome. Variables found to be significantly associated with the outcome on univariate analysis subsequently underwent a multivariate logistic regression analysis with a stepwise backward elimination.

Any multivariate model bears concerns of collinearity. In our model, we evaluated adjusted R^2 values of weighed information matrixes of the predictive variables. Specifically, we performed weighted regression of X'WX information matrixes, in which X indicates raw predictors and W is a diagonal matrix of weights that is determined by the fitting algorithm of each iteration. Consequently, the R^2 value demonstrated degree of collinearity (with 0 equaling no collinearity and 1 equaling complete collinearity). This value was also used to determine a degree of tolerance ($1-R^2$). Statistical Analysis System (SAS version 9.4) was used to perform the analyses. Chi-square test was used to analyze categorical variables. A Kruskal-Wallis test was used to evaluate continuous variables. A value of $p < 0.05$ was considered statistically significant.