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Major article

Toward the rational use of standardized infection ratios to benchmark surgical site infections

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Background: The National Healthcare Safety Network transitioned from surgical site infection (SSI) rates to the standardized infection ratio (SIR) calculated by statistical models that included perioperative factors (surgical approach and surgery duration). Rationally, however, only patient-related variables should be included in the SIR model.

Methods: Logistic regression was performed to predict expected SSI rate in 2 models that included or excluded perioperative factors. Observed and expected SSI rates were used to calculate the SIR for each participating hospital. The difference of SIR in each model was then evaluated.

Results: Surveillance data were collected from a total of 1,530 colon surgery patients and 185 SSIs. C-index in the model with perioperative factors was statistically greater than that in the model including patient-related factors only (0.701 vs 0.621, respectively, $P < .001$). At one particular hospital, for which the percentage of open surgery was lowest (33.2%), SIR estimates changed considerably from 0.92 (95% confidence interval: 0.84-1.00) for the model with perioperative variables to 0.79 (0.75-0.85) for the model without perioperative variables. In another hospital with a high percentage of open surgery (88.6%), the estimate of SIR was decreased by 12.1% in the model without perioperative variables.

Conclusion: Because surgical approach and duration of surgery each serve as a partial proxy of the operative process or the competence of surgical teams, these factors should not be considered predictive variables.

An effective way to reduce surgical site infection (SSI) has been through surveillance of SSI rates.[1] By comparing SSI rates among surgeons and institutions, an impression of past performance can be gained to motivate future changes in the design and implementation of infection control practices. However, success relies on the quality of risk adjustment, and inadequate models may lead to erroneous interpretations of adjusted SSI rates.

Risk adjustment models for SSI rates have traditionally used risk stratification with either the National Nosocomial Infections Surveillance System (NNIS) basic risk index,[2] which includes surgical wound class, American Society of Anesthesiologists (ASA) score, and duration of surgery; or the modified risk index,[3]

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a composite of endoscopic surgeries. Since 2010, however, the National Healthcare Safety Network (NHSN, formerly NNIS) transitioned from SSI rates based on an index to an SSI standardized infection ratio (SIR)[4] based on logistic regression modeling.

Whereas risk adjustment for SSI rates based on multiple modeling is undoubtedly a better approach, development of an adequate model is still needed for this newer method. For example, risk models developed by NHSN have included surgical approach and duration of surgery,[5] but these factors were also partially determined by patient characteristics and proxies of the perioperative process or the competence of surgical team.[6,7] Multiple modeling for SSI risk adjustment aims to filter out only the noise in SSI rates caused by variation in intrinsic patient characteristics. If that fails, then it is possible that the interpretation of the resulting SIR would be distorted. Therefore, the present study aimed to calculate the SIR based on a model that included all collected variables in the current surveillance system in Japan and on a model that included only patient-related variables. In addition, we aimed to compare the interpretations of the SIRs between the 2 models.

METHODS

Study population

There are 2 SSI surveillance systems in Japan: the Japanese Healthcare Associated Infections Surveillance (JHAIS) system, established in 1999 and coordinated by the Japanese Society of Environmental Infections; and the Japan Nosocomial Infection Surveillance (JANIS) system, established in 2002 and coordinated by the Ministry of Health, Labor, and Welfare. The systems are run independently because of different coordinators and entry criteria, although both JHAIS and JANIS use Centers for Disease Control and Prevention definitions of SSI[8] and perform surveillance following NHSN protocols. JANIS receives voluntary SSI surveillance data from hospitals with more than 200 beds.

We collected data from 8 participating JANIS hospitals regarding patients who underwent colon surgery through December 2010. The beginning of data collection varied by hospital and ranged from September 2007 to September 2010. Except for one hospital where SSI surveillance was not performed for emergency operations, SSI surveillance was conducted for all colon surgeries. The hospitals had an average of 578 acute care beds (range, 312-592 beds), with 5 classified as tertiary care and the other 3 as secondary care. Ethics approval to collect patient data from the hospitals was obtained from the Institute for Health Economics and Policy.

Data collection

Infection control professionals collected the following data for each patient under surveillance: type of SSI, wound class, ASA score, general anesthesia, emergency procedure, trauma association, implant, colostomy, sex, age, laparoscopic use, and duration of surgery. The following dichotomous variables were established from components of the basic risk index[2]: wound class (clean or clean-contaminated vs contaminated or dirty) and ASA score (1 or 2 vs 3, 4, or 5). Age and surgery duration were continuous variables.

Statistical analysis

We developed 2 multiple logistic regression models for SIR calculation and compared the probabilities of hospital-level expected SSI between these models. The 2 models were (1) a model that included all variables currently collected in the JANIS system and (2) a model that included only patient characteristics and not variables related to the perioperative process or surgical technique. These models can be presented by the following equations:

$$\begin{aligned}\text{Logit P}(SSI) &= \alpha + \beta_1\ \ Wound\ class + \beta_2 ASA\ Score\\ &\quad + \beta_3 Emergency + \beta_4 Colostomy\\ &\quad + \beta_5 Sex + \beta_6 Age + B_7 Surgical\ approach\\ &\quad + \beta_8 Duration\ of\ surgery\end{aligned}$$

$$\begin{aligned}\text{Logit P}(SSI) &= \alpha + \beta_1\ \ Wound\ class + \beta_2 ASA\ Score\\ &\quad + \beta_3 Emergency + \beta_4 Colostomy + \beta_5 Sex + \beta_6 Age\end{aligned}$$

Predictive performance of each model was evaluated by calculating the c-index. The difference between the 2 c-indices generated from the above models was tested using the algorithm suggested by DeLong et al.[9] These models were then used to predict the probability of occurrence of an SSI (expected SSI). SIRs were calculated for each model as the ratio of an observed SSI rate in a population divided by the expected SSI rate in that population.[4] To facilitate the interpretation of SIRs between analysis strategies, we calculated the difference in expected SSI rates. A P value of less than .05 was considered as statistically significant. All analyses were performed with STATA software, version 10.1 (STATA Corp, College Station, TX).

RESULTS

Observed SSI rates, patient characteristics, and clinical characteristics are summarized by hospital in Table 1. Hospitals were sorted in increasing order of observed SSI rate. Surveillance data were collected for 1,530 colon surgery patients. Colon surgery patients had a total of 185 SSIs (12.1% infection rate), of which 111 were superficial, 27 were deep, and 47 were space/organ infections. Among the hospitals, hospital 4 had the lowest percentage of patients with open surgery at 33.2%, as well as the longest duration of surgery (272 minutes). Conversely, hospital 2 had the highest percentage of open surgery (95.8%) and the shortest duration of surgery (166 minutes).

Table 2 displays the odds ratios (ORs) for adjusted risk models based on the model that included patient and clinical variables versus the model that included patient-related variables only. Given that almost all surgeries in the study were performed under general anesthesia and did not have trauma or implants, these factors were excluded from the logistic regression covariates. For the full variables model (model 1), wound class (OR, 2.72; 95% confidence interval [CI]: 1.70-4.35), surgical approach (OR, 3.69; [95% CI: 2.21-6.16]), and duration of surgery in 10-minute intervals (OR, 1.05; [95% CI: 1.03-1.07]) were statistically associated with increased risk of SSI. For the other model, which excluded perioperative variables (model 2), wound class (OR, 2.79; [95% CI: 1.75-4.44]) was statistically associated with increased risk of SSI. No statistical associations were observed between the ASA scores and SSI rates in either model. The c-indices for models 1 and 2 were calculated as 0.701 and 0.621, respectively. The 2 models differed statistically in their predictive ability ($P < .001$).

The expected SSI rates predicted by the 2 models and SIR are shown in Table 3. In model 1, the expected SSI rates for hospital 4 and hospital 5 were predicted as 11.1% and 13.4% and ranked fifth and third in terms of SIR, respectively. However, when perioperative variables were excluded (model 2), expected SSI rates for hospital 4 and hospital 5 were predicted as 12.9% and 11.8% and ranked third and fifth in terms of SIR, respectively. Compared with the expected SSI rate in model 1, the expected SSI rates for model 2 at hospital 4 and hospital 5 were increased to 15.6% and decreased