Title:

A Rational Approach for Multicentered Surgical Site Infection (SSI) Surveillance using Partitioning Analysis

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Running title: Survey and intervention to reduce SSI

Summary:

[Background] Surgical site infection (SSI) is an ongoing major public health problem throughout the world that increases healthcare costs. Utilizing a methodology that can help clinicians to continuously collect data about SSIs, analyze it and implement the feedback back into routine hospital practice has been identified as a top national priority in Japan. [Aim] The purpose of this study was to conduct an intervention study through Operations Research using partitioning at multiple facilities, and to reduce the incidence and consequences of SSI. [Methods] The Setouchi SSI Surveillance Group, which consists of 7 institutes, started SSI surveillance in 2006. Until May of 2008, there were four surveillance periods (A to D). Three thousand eighty nine patients underwent gastrointestinal surgery and were followed up for 30 days after their operations. Twenty six factors that have been reported to be related to SSI were evaluated for all patients. The top 3 factors from each surveillance period were determined and then actual practice improvements were planned for each subsequent period. [Findings] The total SSI occurrence was 6.9% for Period A, 6.3% for Period B, 6.4% for Period C and 3.9% for Period D. Comparing Periods A and D, there was a statistical significance in the decrease of SSI occurrence (p=0.012). [Conclusion] Using the results and partitioning analysis of active SSI surveillance to contribute to action plans for improving clinical practice was effective in significantly reducing SSIs.

Keywords: Partitioning analysis, Surgical site infection, Active surveillance

Introduction

Surgical site infection (SSI), a type of healthcare-associated infection, is a major public health problem throughout the world. Nationwide surveillance in Japan revealed that 6-8% of patients undergoing a surgical procedure develop an SSI every year. For certain operations, especially gastrointestinal surgery, the incidence rate is over 10%. In addition to the negative effects on quality of life for patients, patients with an SSI remain in the hospital for an additional week longer on average and are also more likely to be admitted to the Intensive Care Unit (ICU), which is a large factor in increasing healthcare costs[1-3].

Many facilities around the world have conducted SSI surveillance in order to reduce hospital-acquired infections. However, surveillance data reminds us that the causes of SSI are complex and there is no single solution capable of eliminating all SSIs. Although there is a study stating that active surveillance can reduce SSIs[4], each hospital needs to make an effort to utilize a methodology that allows continuous data collection, analysis and feedback, and can be readily incorporated into routine hospital activities to reduce SSI rates.

Until now, SSI surveillance has generally used a conventional linear multivariate model to investigate the causes of SSIs[5]. This approach requires a certain minimum number of samples to identify factors associated with SSIs from among many data items so that the analysis is usually conducted for the total data set, not for each individual hospital. Therefore, the analysis results are often complex and difficult to comprehend and apply to each hospital's situation and thus it has appeared that the feedback from infection control professionals has not been so effective in actually reducing SSIs. To reduce SSIs, it is necessary to establish suitable systems and methods of feedback that allow SSI-related factors to be dealt with more effectively for each medical institution.

We conducted our surveillance using the principles of Operations Research (OR), which is a theoretical framework to support and explain decision making to others using mathematical and statistical models. The software we used is JMP "Partitioning" which creates a decision tree called a classification and regression tree (CART). Using this statistical method, we could find points for improvement from among many observed items even with a limited number of samples, and the output of "Partitioning" allowed us to visualize SSI-related factors to plan our SSI surveillance measurements for each hospital. Making a hospital specific active plan is important to reduce the SSIs of each individual hospital.

The purpose of this study was to conduct an intervention study at multiple facilities through OR using partitioning, and to examine the possibilities for lowering SSI occurrence.

Methods

The Setouchi SSI Surveillance Group (SSSG), which is composed of Okayama University Hospital and six other facilities (A: Okayama Saiseikai General Hospital, Okayama, Japan; B: Hiroshima City Hospital, Hiroshima, Japan; C: Matsuyama Shimin Hospital, Matsuyama, Japan; D: Tsuyama Central Hospital, Tsuyama, Japan; E: Shobara Red Cross Hospital, Shobara, Japan; and F: Chugoku Central Hospital, Fukuyama, Japan), conducted this study. The computerized surveillance was divided into four periods; Period A (October to December, 2006), Period B (March to May, 2007), Period C (October to December, 2007) and Period D (March to May, 2008). SSI surveillance and the subsequent intervention after each period was conducted on the surgical operations at the SSSG facilities during the periods listed above. The surveillance was for 3 months for each of the four periods. The total length of the study was 20 months, including 2 months for analysis after each of the four surveillance periods, so the actual surveillance was for a total of 12 months. Also, one facility (Okayama Saiseikai General Hospital) was added from Period B. The other facilities were all in the study from the beginning.

SSIs were identified through active concurrent surveillance according to the criteria of the Centers for Disease Control and Prevention (CDC)[6,7]. A total of 3,089 subjects had gastrointestinal surgical operations at the SSSG facilities. There were 575 cases in Period A, 743 cases in Period B, 920 cases in Period C and 827 cases in Period D. Various factors were analyzed for their relation to SSI.

Analysis factors were as follows: age[8], gender, illness[8], whether preoperative chemotherapy or radiotherapy was performed[9], Altemeier wound classification[9], American Society of Anesthesiologists (ASA) preoperative assessment score, anesthesia procedure, operation duration[10], intraoperative blood loss[11], protection on the wound or not, hair removal[12], external injury or not, elective or emergency operation[11], with colostomy or not[13], diabetes mellitus[9], smoking[9, 14], obesity[15], steroid use[14], with implants or not, whether multiple procedures were performed during the operation, the occurrence of surgical complications or not, whether silk thread was used during the operation or not[16-19], whether silk thread was used for the abdominal wall, the number of days antibacterial protection was used, drain usage[20] and type of drain (suction drain or closed passive drain)[20]. These factors have all been reported to be related to SSIs and perioperative management. All patients were followed up on for 30 days after their operations.

Before the initial surveillance period began, educational lectures were given twice to the doctors and nurses who were in charge of infection control teams (ICT) and then they, as the ICT leaders in each hospital, educated other staff at group meetings at their hospital about the definition of SSI, how to detect an SSI and infection control. This was done to avoid uneven methods of detection or having different definitions of SSI at each facility. After that, a one month practice surveillance was carried out for the staff to get used to the system and to ensure that the data acquired from all of the facilities were organized in a similar manner. In the practice surveillance, only the SSI occurrence rate, but not a statistical analysis of SSI-related factors, was examined.

After the first surveillance period, the data was analyzed to identify the factors that were closely related to SSIs in each hospital. These factors were examined at a post-SSI surveillance meeting for the purpose of educational feedback and the attendees, as the ICT leaders in each facility, shared the feedback from the meeting with the staff of their hospital in order to improve their handling of SSI-related factors before starting the next surveillance period. This procedure was repeated after each surveillance period (A to D).

Statistical analyses

The data acquired was analyzed to find the factors most relevant to SSI for each hospital.

All data were analyzed using JMP 8.0.2 statistical software (SAS Institute, Cary, NC, USA)[21,22]. "Partitioning" is, according to JMP's technical notes[23], a version of classification and regression tree (CART) analysis and does not assume an underlying statistical model so that a set of factors, including those having a high linear relationship among the factors, can be investigated at the same time. Furthermore, it can also be applied to a limited number of samples. If a factor is categorical, the variable to be split at a given level is determined and if a factor is continuous, the cutoff value for the split is determined by maximizing a quantity called the LogWorth statistic, which is related to the likelihood ratio chi-square statistic[23]. After the calculation of the LogWorth statistic for each factor, the most effective factor is selected for the first split. The following splits are each determined the same way. One reason we adopted CART analysis for this project is that the visualized results and evaluation criteria are intuitively easy to understand.

In this paper, a chi-square test was first used to examine the increase or decrease of SSIs by hospital. A $p<0.05$ was considered to be statistically significant. In the CART analysis, a recursive partitioning search was made to find the factors that could effectively help reduce SSIs.

An example of our partitioning analysis is shown in Figure 1. In this figure, the most relevant factor to the occurrence of SSIs is located at the top split, followed by the second factor below the top node. The splits stops when the analyzing factors are thought to no longer affect an improvement in the SSI rate, or when the number of samples in the node reaches less than 10. This means that in Figure 1 the factor with the most relevance to SSI occurrence at this particular hospital was the duration of operations. The second most relevant factor was the age of the patients, and the third was the benignancy or malignancy of the disease.

In our process of choosing factors to target for improvement, we selected the one which was located nearest to the top of the tree, unless it was impossible to improve, such as age or gender. In order to avoid the situation where we could not choose any factors to be improved, we made second to third splits to find at least one factor to be a candidate for improvement.

Results

The subjects were 1,815 males and 1,234 females. The average age was 60.4 – 67.2 years old. The mean duration of operations was 135.6 – 225.4 minutes (Tables I, II).

SSI occurrence analysis after the first surveillance period

During Period A, SSI surveillance was conducted at 6 hospitals. The seventh hospital, hospital A, joined the program from Period B. As Table III indicates, the initial SSI occurrence rates among the facilities were somewhat varied from 4.6 to 11.3% (Table III).

Results of the CART Analysis

Data collected from the above facilities were analyzed and the factors related to SSI at each hospital are shown in Table IV according to their level of significance. Highly related factors were the duration of operation (three hospitals), the type of prophylactic antibiotic therapy (two hospitals), and age (two hospitals). Wound classification was a moderately related factor in two of the hospitals. The amounts of blood loss and drain type (either an open or closed drainage system) were identified as strong factors for hospitals B and C, respectively. Colostomy, emergency or not, ASA score and the number of days preventive antibiotics were used were identified as weak or moderate factors in two facilities.

After period D, the following improvements were made among the seven hospitals: 1) Open drains were no longer used, 2) No more implants of exogenous materials, such as mesh, during operations, and 3) The number of days preventive antibiotics were used was reduced.

Improvements after introducing Operations Research

The total SSI occurrence was 7.00% for Period A, 6.34% for Period B, 6.57% for Period C and 3.86% for Period D (Figures 2, 3). Although a statistical examination did not reveal any significance from Period B to D, the overall incidence of SSI was significantly decreased from Period A to D ($p=0.012$) after combining several improvements for perioperative factors that were determined by the CART analysis.

SSIs decreased at 3 facilities among the 7, and increased at 3 facilities (Figure 2). However, there was no facility that showed a statistically significant increase in SSIs.

The effect of cost saving in healthcare

Data acquired on healthcare costs was only from the Okayama University Hospital. We calculated the cost of medical supplies at the surgical unit of the Okayama University Hospital to determine whether SSI surveillance might contribute to cost savings in healthcare. As shown in Figure 5, the calculated costs for medical supplies per operation gradually decreased from periods B to D.

Discussion

Recent significant progress in surgical medicine includes sterilization during operations, aseptic techniques and the development of antimicrobial drugs. Still, there are complications in operations that are difficult to overcome even now. Although surgical care in Japan has a high standard amongst developed countries, the current situation in terms of infection control is not sufficient. Many kinds of SSI prevention programs have been started without specific clinical evidence and different facilities have their own traditional methods which have been passed down to the current practitioners.

In general, surveillance is conducted with a goal of decreasing SSIs. However, most current "surveillance" merely means collecting data. Specific methods of data feedback have not been investigated enough to date. To prevent SSIs, giving data feedback to all of the doctors and medical care providers is necessary. However, many of them do not have the training to comprehend the raw statistical results calculated from the data, and the surveillance alone cannot always produce an improvement in medical practice. In other words, feedback only about the "p-value" acquired from the data is not understandable for all doctors and medical providers and brings no improvement. But on the other hand, there is a report that the introduction of active SSI surveillance (surveillance plus feedback) can reduce the SSI occurrence rate[4]. There is also a report that SSIs can be reduced simply by introducing SSI surveillance[24,25]. In our study, the overall SSI incident rate was reduced from 7.00% down to 3.86% through the surveillance and feedback done by the SSSG.

CART analysis can identify factors related to SSI with a feasible statistical condition. The reports and graphs displayed by JMP's Partition Platform are intuitive and easy to understand. We would like to recommend CART analysis, in particular the JMP Partition Method, for the data analysis of active surveillance.

The purpose of this active surveillance, which was decreasing SSIs, was achieved. Not all of the SSI related factors examined in the study showed a statistical significance. Even though some factors did not have statistical significance, many of them are considered necessary for SSI prevention in terms of clinical care. It is important to investigate those factors and create useful measures from them. It is not necessary to wait and take measures only after the factors show statistical significance. Figure 1 shows the results of one hospital by CART analysis and it displays the advantage of visualization with CART analysis. This is very helpful when showing the data analysis to people who are not statistical specialists. Presenting the results in a simple visual manner is very meaningful in the medical field, and not just for SSI prevention. We also recognized the importance of how to build up problem solving procedures with a very limited number of samples.

In this surveillance data, there was one factor that had a very high SSI rate compared to the National Nosocomial Infection Surveillance (NNIS) rate. This does not mean that the prevention measures taken in this study were inferior to the ones from NNIS facilities. The difference is due to the fact that the inpatient period in Japan is typically longer than in the United States. Infections that would be post-discharge and therefore unrecorded in the U.S. happen while the patient is still in the hospital in Japan and thus recorded.

Conventional linear models are valuable methods and meaningful, but they require large amounts of sample data, especially for the multitude of factors that we examined. CART can analyze a comparatively smaller data set so that we can give feedback on the results faster. This makes it possible to keep motivation high to continue SSI surveillance among the participating medical providers.

In this study we demonstrated the availability of partitioning for SSI surveillance and how it can help decrease the occurrence of SSIs. The results and findings of this study might not apply to all hospitals because of variances of medical and/or social circumstances. However, this type of partitioning method can give feedback on the best practices to try to decrease SSIs for each participating hospital. However, CART analysis still has the limitation that, without pruning the tree, we may find some irrelevant factors from distant branches, which will not lead to an improvement of our medical procedures, or necessitate another sample to be collected. In addition, we should keep in mind that extremely small samples also have a risk of instability which may lead to irrelevant factors being targeted for improvement.

The prevention of SSIs is an inevitable issue for current surgical treatment. Prevention using surveillance and the partitioning method can be very useful to reduce SSIs at a wide range of facilities from a small unit in a medical clinic on up to the national level, especially for nations whose SSI surveillance is not currently nationally coordinated, such as in Japan.

Conclusion

In this study, we analyzed data from an active SSI surveillance with a partitioning analysis, visualized the SSI related factors from limited data samples collected in a short period through Operations Research, and after giving feedback we were able to lower the SSI rate.

Partitioning analysis is able to extract useful information from a limited amount of data and time, and it can also display valuable information on the relevant factors plainly and intuitively even from a small medical facility. Therefore, statistical analysis by CART is considered to be useful for facilities that are planning to introduce SSI surveillance.

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Legends:

Table I: The number of patients per period and hospital. A total of 3089 patients were included in this study.

Table II: Clinical characteristics of patients registered in each participating hospital.

Patients and operation profiles were reviewed specifically for age, gender, operation time, wound classification, ASA classification and the type of operation (emergency or elective).

Table III: The SSI incidence rate per period and hospital.

Table IV: Possible SSI-related factors extracted by CART analysis in each participating hospital.

Indicated factors related to SSI according to the level of significance. +++; related to SSI with a high level of significance, ++; moderately related to SSI, +; related to SSI with lower significance, chemotherapy; preoperative chemotherapy, wound classification; wound classification according to the Altemeier classification, ASA; American Society of Anesthesiologists preoperative assessment score, blood loss; intraoperative blood loss, emergency; emergency operation, silk thread and wall; silk thread was used for the abdominal wall, days of antibiotic; number of days antibacterial protection was used, type of antibiotic; type of prophylactic antibiotic therapy, open drain; open type of drain, not a closed drainage system.

Figure 1: An example of CART analysis.

In the partitioning analysis (decision trees), a recursive partitioning search was made for each factor to determine how to best make a split. The most relevant factor to the occurrence of SSIs is located at the top split, followed by the second factor below the top node..

Figure 2: Graphical changes of the SSI incidence rates in each hospital.

SSIs decreased at 3 facilities among the 7, and increased at 3 though there was no facility that showed a statistically significant increase in SSIs.

Figure 3: The improvement of the total SSI incidence rate after surveillance.

The total SSI occurrence was 7.00% for Period A, 6.34% for Period B, 6.57% for Period C and 3.86% for Period D.

Figure 4: Periodical changes of the SSI incidence in each organ.

SSIs are said to be very common following the surgical treatment of esophageal lesions and the same data was found in this study.

Figure 5: The cost for hospital supplies per operation at the Okayama University Hospital.

The total cost of medical supplies in the surgical unit of the Okayama University Hospital was divided by the number of operations during periods B to D. Japanese Yen (¥) were converted into US dollars ($); ¥1=$0.0125.