Automated Surveillance of Surgical Site Infections in a VA Hospital

Matthew M Churpek

July 28th, 2004

Reader 1 Signature _____

Reader 2 Signature _____

Abstract

Title: Automated Surveillance of Surgical-Site Infections at a Veteran's Affairs Hospital

Background: Surgical site infections (SSIs) account for approximately 17% of hospital-acquired infections. These infections result in an increase in emergency room visits, outpatient visits, radiology services, home health aide services, and readmissions adding an estimated $1 billion-10 billion in indirect and direct medical costs each year. The CDC and the Surgical Infection Society recommend routine surveillance as a method for decreasing the rates of these infections. By monitoring SSI rates, areas of improvement can be identified and interventions can be made to reduce the incidence of SSIs in the hospital. Reductions of up to 35% have been documented with the implementation of SSI surveillance programs. Current methods of surveillance in the VA are only partially automated and are labor intensive. Automated methods of surveillance using electronic medical records have been proposed to decrease the resources involved in SSI monitoring. The VA is well-suited for this with their extensive medical records database and relatively closed system of patients.

Purpose: To construct an automated SSI surveillance system using electronic patient medical record data and validate this system by comparing its performance to the current surveillance method used at the Durham VA hospital.

Methods: In this project, we modified the methods previously described by Richard Platt to create an automated SSI surveillance system at the VA hospital in Durham, North Carolina. We used ICD-9 codes, vital signs, microbiology data, consult orders, and pharmacy records sensitive and specific for SSIs to identify patients with potential infections. Logistic regression was used to create predictive models for SSIs of different severity. This system was validated by comparing its performance to that of the current manual record review performed by the infection control department in the hospital on patients who underwent surgery at the Durham VA hospital from May 1st, 2002 to April 30th, 2004. All surgical-site infections met the criteria set forth by the National Nosocomial Infections Surveillance (NNIS) report. The system was evaluated using the framework set forth by the CDC Working Group for public health surveillance systems

Results: SSIs occurred in 195 of 7340 surgeries conducted in the study period (2.7% attack rate). Of these, 91 were superficial SSIs, 45 were deep SSIs, and 59 were organ/space SSIs. Logistic regression models using data found to be strongly correlated with SSI diagnoses had a sensitivity and specificity of 90.9% and 61.2% for all types of SSIs, 89.2% and 74.2% for severe SSIs (deep and organ/space) and 89.5% and 74.0% for organ/space SSIs, respectively.

Conclusions: This study demonstrates that an automated SSI surveillance system with reasonable sensitivity and specificity can be created by using data from electronic medical records. Such a system can drastically reduce the amount of labor necessary for SSI monitoring and increase the speed these complications are detected. The information technology used at the Durham VA hospital is similar to that used in other VA hospitals, so this system can be exported to other hospitals throughout the country.

Background

Surgical site infections (SSIs) account for approximately 17% of hospital-acquired infections [1]. These infections result in an increase in emergency room visits, outpatient visits, radiology services, home health aide services, and readmissions [2]. The Centers for Disease Control and Prevention (CDC) estimates that approximately 500,000 SSIs occur annually in the United States with an estimated $1 billion-$10 billion in indirect and direct medical costs each year [3, 4]. The CDC and the Surgical Infection Society recommend routine surveillance as a method for decreasing the rates of these infections. By monitoring SSI rates, areas of improvement can be identified and interventions can be targeted. Reductions of up to 35% have been documented with the implementation of SSI surveillance programs [5, 6]. The cost of surveillance has been estimated to be only 20% of the cost of treating preventable infections. Therefore, creating an efficient and accurate method of SSI surveillance should be highly cost-effective [7, 8].

As the number of days surgical patients remain in the hospital decreases and the proportion of surgeries done on an outpatient basis increases, SSIs are more often occurring after discharge from the hospital. Between 47% and 84% of SSIs occur after discharge from the hospital, and most of these are treated on an outpatient basis [2, 9]. Outpatient presentations complicate surveillance of SSIs, as patients may pursue care outside of the hospital's surveillance system. Routine methods

to overcome this obstacle such as patient questionnaires have been shown to have poor sensitivity (15%-30%) and are also labor intensive [2].

Because of the enormous costs and patient morbidity associated with SSIs, the development of an effective surveillance system is essential. The system needs to be sensitive enough to identify SSIs occurring both in and out of the hospital in a timely manner without requiring increased work for hospital infection control teams. The system should also be specific in identifying infections that meet a strict definition of a SSI, such as that proposed by the National Nosocomial Infections Surveillance System (NNIS). A baseline rate of infection would be established, and the system should be able to pick up differences in SSI rates so that proper actions can be undertaken in response to an increase in event rate [10].

Current methods of surveillance, such as patient and surgeon questionnaires, are time-consuming and often lack the sensitivity, specificity, or timeliness necessary to have a significant impact on SSI rates [10]. Other methods include the labor-intensive review of individual full-text patient records. Although risk of SSI for a particular patient can be estimated using the Anesthesia Society of America (ASA) score, [11, 12] a comprehensive SSI surveillance program should monitor all patients regardless of risk score. There is therefore a need for a sensitive method of SSI surveillance that is less labor intensive than conventional methods, and more timely than methods such as patient questionnaires.

Automated methods of surveillance have been proposed to decrease the resources involved in SSI monitoring. For example, Richard Platt and colleagues at Harvard Pilgrim Healthcare monitored pharmacy dispensing data for certain antibiotics, SSI-related ICD-9 codes assigned at discharge, and CPT codes specific for wound infection care to identify patients with SSIs [10,13]. They created an accurate SSI surveillance system to detect SSIs in their institution.

The Veteran's Affairs hospital system has an electronic record system that is conducive to the development and enhancement of automated SSI surveillance. Patient records including inpatient visits, outpatient visits, pharmacy records, vital signs, urgent care visits, and phone calls made to the network are entered and retained electronically. As veterans are mostly or fully covered by this medical plan, they are likely to seek their inpatient, outpatient, and antibiotic care within the network. Also, all veteran's hospitals are linked by a common computer system, therefore, patients that travel to different areas of the state or even country can potentially be monitored by an effective automated surveillance system. This would also allow a system developed at one VA hospital to be used by all VA hospitals in the country. Potentially all veterans that undergo surgery at a Veteran's Affairs hospital could then be monitored for a SSI.

Purpose

In this project, we modified the methods previously described by Platt and others to create an automated SSI surveillance system at the VA hospital in Durham,

North Carolina. We validated this system by comparing its performance to that of the current manual record review performed by the infection control department in the hospital on a sample of surgical patients. Successful implementation of this system will increase the quality of care received by patients and will decrease medical costs by reducing the number of SSI cases in this hospital. This system can be implemented in other VA hospitals throughout the country.

Methods

Study Population

The study population consisted of all patients who underwent a surgical procedure between May 1st, 2002 and April 30th, 2004 at the VA medical center in Durham, North Carolina (DVAMC). CPT codes for surgical procedures were used to identify these patients, as these codes are entered into an electronic database for every surgical procedure done in the hospital (see Appendix 1).

Database management and privacy assurances

The names and social security numbers of the patients were kept confidential, and this data was only used for quality control purposes as a measure of the SSI incidence in the hospital. IRB approval was obtained (ID #00877) for this project.

Case definitions [1]

Criteria for defining a surgical site infection

Superficial Incisional SSI

Infection occurs within 30 days after the operation *and* involves only skin or subcutaneous tissue of the incision *and* at least *one* of the following:

1. Purulent drainage, with or without laboratory confirmation, from the superficial incision.

2. Organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision.

3. At least one of the following signs or symptoms of infection: pain or tenderness, localized swelling, redness, or heat *and* superficial incision is deliberately opened by surgeon, *unless* site is culture-negative.

4. Diagnosis of superficial incisional SSI by the surgeon or attending physician.

Do *not* report the following conditions as SSI:

1. Stitch abscess (minimal inflammation and discharge confined to the points of suture penetration).

2. Infection of an episiotomy or newborn circumcision site. (relevance)

3. Infected burn wound.

4. Incisional SSI that extends into the fascial and muscle layers (see deep incisional SSI).

Note: Specific criteria are used for identifying infected episiotomy and circumcision sites and burn wounds.

Deep Incisional SSI

Infection occurs within 30 days after the operation if no implant† is left in place or within 1 year if implant is in place and the infection appears to be related to the

operation *and* infection involves deep soft tissues (e.g., fascial and muscle layers) of the incision *and* at least *one* of the following:

1. Purulent drainage from the deep incision but not from the organ/space component of the surgical site.

2. A deep incision spontaneously dehisces or is deliberately opened by a surgeon when the patient has at least one of the following signs or symptoms: fever (>38°C), localized pain, or tenderness, unless site is culture-negative.

3. An abscess or other evidence of infection involving the deep incision is found on direct examination, during reoperation, or by histopathologic or radiologic examination.

4. Diagnosis of a deep incisional SSI by a surgeon or attending physician.

Notes:

1. An infection that involves both superficial and deep incision sites is recorded as deep incisional SSI.

2. Report an organ/space SSI that drains through the incision as a deep incisional SSI.

Organ/Space SSI

Infection occurs within 30 days after the operation if no implant† is left in place or within 1 year if implant is in place and the infection appears to be related to the operation *and* infection involves any part of the anatomy (e.g., organs or spaces), other than the incision, which was opened or manipulated during an operation *and* at least *one* of the following:

1. Purulent drainage from a drain that is placed through a stab wound‡ into the organ/space.

2. Organisms isolated from an aseptically obtained culture of fluid or tissue in the organ/space. What about blood?

3. An abscess or other evidence of infection involving the organ/space that is found on direct examination, during reoperation, or by histopathologic or radiologic examination.

4. Diagnosis of an organ/space SSI by a surgeon or attending physician.

† National Nosocomial Infection Surveillance definition: a nonhuman-derived implantable foreign body (e.g., prosthetic heart valve, nonhuman vascular graft, mechanical heart, or hip prosthesis) that is permanently placed in a patient during surgery.

‡ If the area around a stab wound becomes infected, it is not an SSI. It is considered a skin or soft tissue infection, depending on its depth.

Conventional Identification of SSI

SSIs during the study period were prospectively identified using the partially automated surveillance system currently employed at DVAMC by the infection control unit. The surgical cohort is established using ICD-9 codes specific for surgeries of interest to NNIS (see Appendix 2). SSIs are then identified in these patients by electronically searching for patients who received an ICD-9 diagnosis code of 998. Once these patients are identified, their medical records are manually reviewed from the electronic medical record database to verify that the infections meet the NNIS definitions. In addition, a surgical complications

database maintained by another surveillance coordinator for the National Surgical Quality Improvement Program (NSQIP) is reviewed by searching the full-text medical records of the patients they identified. Ward rosters (SICU, MICU, CCU, and Medicine) are also reviewed daily to identify surgical patients in the hospital. A full-text review of their medical records is done to identify possible SSIs. Finally, the infection control team reviews the records of patients identified by informal contacts via phone or email about possible SSIs. All confirmed SSI meet the NNIS criteria.

Automated SSI Surveillance

An electronic filter identified all CPT codes specific to surgical procedures that occurred during the study period (see Appendix 2) and entered these patients into a separate relational database via a daily file transfer protocol (ftp). This surgical procedure file contained the patient's social security number, CPT surgery code, time of surgery, surgical sub-specialty performing the operation, and a text description of the type of surgical procedure performed. Additional filters running concurrently included all doses and times of administration of inpatient antibiotics as well as outpatient prescriptions (Appendix 3), ICD-9 diagnosis code associated with a surgical infection (Appendix 4), vital signs (temperature, blood pressure, oxygen saturation), microbiology orders and results (Appendix 5), abnormal white blood cell counts (>10.0), and consult orders to the hospital wound ostomy-continence consult nurse or to physical therapy for wound care. The data was limited so that only those items that occurred within 30 days from

the time of surgery were used, as this is the criterion used by NNIS for surgical infections occurring after most operative procedures.

Analysis

The automated system of SSI surveillance was validated by comparing the results of the conventional SSI monitoring currently used at DVAMC with that of the fully automated system. All analyses were performed in STATA version 7.0.

All individual variables (e.g., antibiotics, ICD-9 codes, etc.) were examined for their association with a diagnosis of SSI (including individual outcomes of severe SSI and organ/space SSI). Two-sided P values were calculated using the Chi square test or Fisher's exact test for ordinal and dichotomous variables. Continuous variables were compared using 2-sided Wilcoxon rank sum test or the Student's t-test. Variables that occurred in fewer than three SSI patients were discarded. We then developed composite variables within each data source (e.g., inpatient antibiotics, outpatient antibiotics, microbiology orders, microbiology results, wound consults, ICD-9 codes, and abnormal vital signs and white blood cell counts) using the factors most strongly associated with SSIs to maximize the sensitivity. The groups used are found in table 1.

Predictive models were developed including covariates that were associated with the outcome with $P<0.1$ on bivariable analysis. Variables were removed in a stepwise manner and final associations were recorded as risk ratios (RR) with

95% confidence intervals (CI). All covariates were checked for confounding and collinearity. If the addition of a confounding variable affected the ß-coefficient of a covariate by more than 10% it remained in the model. The groups were also analyzed separately in their ability to predict the different types of SSIs. The probability term in the logistic regression models was adjusted to generate more sensitive and more specific models. Receiver operating characteristic (ROC) curves were also generated using Stata.

Evaluation of the system

The automated SSI surveillance system was evaluated according to the recommendations made by the CDC working group for assessing public health surveillance systems for early detection of outbreaks [14]. Important considerations included timeliness, validity, data quality, representativeness, completeness, usefulness, flexibility, acceptability, portability, stability, and cost of the system.

Results

The Cohort

The surgical cohort consisted of 7340 procedures in which the conventional surveillance program identified 195 SSIs. Of these, 59 were organ/space infections, 45 were deep SSIs, and 91 were superficial SSIs. Within the study period only two patients had more than one SSI.

Bivariable analysis

Nine groups of variable combinations were found to be strongly associated with SSIs (table 2). The results of their individual relative risks and 95% confidence intervals for their association with SSIs are shown in Table 3. ICD-9 coded diagnoses related to SSIs and antibiotic prescriptions were the strongest predictors for detecting any type of infection.

Predictive models

An initial predictive model for all SSI was constructed using the composite ICD-9 codes, antibiotic prescriptions, all microbiology data, vital signs, and wound consults (table 2) and had a sensitivity of 91% and specificity of 61%. A more specific model was also created with this data using logistic regression, with resulting sensitivity of 59.9% and specificity of 89.1%. A receiver operating characteristic curve (ROC) was made for this logistic model, with the area under the curve calculated to be 0.856 (Figure 2).

The same nine variables and their components were used to create the best model for detecting severe SSIs (deep SSIs and organ SSIs as defined by the NNIS criteria). The resulting relative risks for the composite variables are shown in Table 4 with 95% confidence intervals. ICD-9 coded diagnoses and antibiotic prescriptions remained the strongest predictors of severe SSIs. The most sensitive model had a sensitivity and specificity of 89.2% and 74.2%, respectively and included the following variables. A more specific model was also created that

had a sensitivity of 58.9% and a specificity of 93.9%. The ROC curve for this model is shown in Figure 3, with a calculated area under the curve of 0.89.

Lastly, these same nine composite variables were used to construct a predictive model for detecting organ/space SSIs. The individual relative risks and 95% confidence intervals are found in Table 5. Fewer organ/space SSIs were available for inclusion, and this reduced the precision of the model. ICD-9 coded diagnoses remained the strongest predictors. The most sensitive model had a sensitivity and specificity of 89.5% and 74.0%, respectively. A more specific logistic model had a sensitivity and specificity of 64.9% and 88.7%, respectively. The ROC curve for this model had an area under the curve of 0.885 and is found in Figure 4.

Discussion

Conventional surveillance of SSIs is a time-consuming process, and commonly used methods such as patient and surgeon surveys have poor sensitivity. Because of the importance of SSIs in patient morbidity and medical costs, an effective way to monitor these infections would be beneficial. The findings in this study demonstrate that such a system can be created with the use of data from an electronic patient medical record system. By using pharmacy data, ICD-9 codes, patient vital signs and lab values, and microbiology orders and results, a surveillance system can be created to detect a substantial number of SSIs with

reasonable specificity. By focusing on more severe or even organ SSIs, one can increase the sensitivity and specificity of the system.

Validity

This automated surveillance system was evaluated using predictive models for different types of SSIs. The results of this study show that this automated surveillance model is better at detecting more severe SSIs. This should be expected as patients with more severe infections will have more contact with the healthcare system and are more likely to have tests ordered, vital signs recorded, and are more likely to receive antibiotics. As many institutions focus on more severe infections, this is a useful characteristic of this surveillance system. However, we did not detect all patients with SSIs, regardless of severity. Many patients who had surgery at DVAMC were treated for their infections at other hospitals within the VA system. The data from all the institutions in North Carolina are not yet being received by the surveillance system. Also, procedures with implanted prosthetic devices that should be monitored for one year for SSI are not currently captured by the current design. As this study monitored patients 30 days after surgery, the surveillance window used for most operations, those patients with SSIs who developed infections after this time period would be missed. Further study is needed to identify the optimum monitoring window for SSIs using this system.

Although the surveillance system created in this study is much more sensitive than common conventional methods such as patient and surgeon surveys, it did not match the performance seen in the study done by Richard Platt and others. With their data, they could detect up to 92% of SSI with a corresponding specificity and positive predictive value of 92% and 21% among a population of 3636 patients that underwent a total of 4086 non-obstetric operations [13]. Using only hospital discharge diagnosis codes and pharmacy dispensing data they determined a sensitivity and specificity of 74% and 98% respectively, with a positive predictive value of 48% [13]. There were some fundamental differences between their study and this one, however. Ninety-two percent of the patients in the Harvard study received care at centers that had automated medical records, and those that did not were excluded from the study [2]. Also, an estimated 10% of patients in the study did not have prepaid coverage for pharmaceuticals and may not have used the Harvard Pilgrim Health Care system for antibiotics [2]. This loss of potential data would be avoided in a system that has fully automated medical records and a pharmacy plan that assures that patients will obtain their antibiotics within reach of the surveillance system. The Platt study also used an additional coding system that is unique to Harvard Pilgrim Healthcare. This coding system may have helped increase the accuracy of their system. The performance of a syndromic surveillance system is dependent on the practices of the healthcare workers at the institution. Accurate coding, diagnoses, drug prescribing, and test ordering all can increase the performance of a syndromic surveillance system. It is possible that their institution has more consistent

practices in how they diagnose, treat, and code for SSIs. Finally, the frequency of the different types of SSIs is not mentioned in their results. There may have been more severe or organ/space SSIs in their study cohort, enhancing the accuracy of their system.

Acceptability

The acceptability for this type of system is growing rapidly as there is an increasing need for earlier disease detection that is less labor intensive than conventional methods. Also, electronic patient data is becoming increasingly available and most outpatient provider systems now capture pharmacy dispensing activity, and claims databases are available to capture information about tests and ICD-9 code diagnoses, making the development of a system similar to this easier. The model used in this study primarily utilized ICD-9 codes, pharmacy data, and microbiology test ordering that should be available at many other institutions. A model could then be created similar to this one, tailored to the institution's specific drug, testing, and coding utilization as well as the types of infections they want to monitor. Such a system requires little maintenance and is much more sensitive than surveys and much less labor intensive than full-text patient chart review.

Timeliness

A particularly powerful advantage that an automated SSI surveillance system has over conventional methods is its timeliness. Surgeon and patient questionnaires

often take months for receipt and their review necessitates additional labor. Even the semi-automated system currently used at DVAMC requires manual patient record review and is heavily reliant on ICD-9 codes that can take weeks to be entered into the medical record. The automated system uses many sources of information, and some data, such as microbiology orders and results, antibiotic prescriptions, vital signs, and wound consult orders are available soon after the patient seeks medical care. The data is extracted from the core institutional database every 24 hours and file transfers can be increased in frequency as required. The system's timeliness allows infection control teams to detect SSIs earlier than conventional methods, expediting interventions to decrease the burden of these complications.

Flexibility and Stability

Another strength of this system is its flexibility. As there is a sensitivity—specificity tradeoff when constructing this type of surveillance system, each individual institution can tailor their system to complement their current infection control program. A surveillance model can be refined to look at specific high-risk individuals or surgeries or it can be designed to detect general trends over time by increasing the sensitivity. An institution can also decide whether to monitor all SSIs or focus on more severe cases such as deep and organ/space SSIs. This system is also a stable one as the definitions for SSIs are strictly set forth by NNIS and so the outcome measure will not change. Also, as new drugs, tests, and ICD-9 codes become available, they can easily be added to the predictive model. This

flexibility and stability allows a syndromic surveillance system to be created for the specific needs of the institution that can change with the advent of new technology and antibiotics.

Cost

This surveillance system is also a cost-effective way to monitor SSIs. The main expense of many conventional SSIs is the labor involved in manually reviewing patient records. This automated method drastically reduces the amount of time needed to monitor these infections. Effort is involved in creating the system by first collecting the data, organizing it into a relational database, and then creating the best predictive model for the types of infections that are to be monitored. The created system then needs to be validated before it is implemented. Once in place, however, the automated surveillance system requires little maintenance and is much less labor intensive than conventional methods.

Improving the System

There are many ways to improve this surveillance system. First, the practice of the workers within the healthcare system can be altered to conform to a set standard for the detection and treatment of SSIs. The accuracy of the system is directly related to the practices of the healthcare team at the individual institution. If drugs, tests, and coding are done haphazardly, the system will be not be able to accurately monitor SSIs. By encouraging accurate and timely coding, appropriate utilization of tests, and proper drug regimens for SSIs, the sensitivity, specificity,

and positive-predictive value of the surveillance system can be improved. These practices will help to increase the efficiency of disease monitoring and of the health system as a whole.

Another way to improve the model would be to look at each surgical specialty separately. Physicians treating a SSI after a urologic procedure may treat the patient with a different antibiotic than would be used for a SSI occurring after a cardiac or gastrointestinal surgery. Identification of the prescribing practices of the different surgical specialties would allow a model to be created that is tailored to each procedure type. Also, different specialties may vary in their ICD-9 coding and test-ordering protocols, and the threshold for obtaining a wound care consult. These differences could allow for a unique model to be generated for each surgical specialty, creating a more accurate surveillance system. Further study needs to be done in this area.

Quality and Representativeness

The *quality* and amount of information available at the time of this study may not be representative of that available at other institutions due to the fully electronic medical records available in the VA system. Both inpatient and outpatient records are contained in this system, and because of their healthcare coverage, the vast majority of Veterans who have their surgery at a VA hospital will also receive their outpatient care in the VA system. This is particularly important in the surveillance of SSIs, as a significant percentage of them occur after hospital

discharge. It is also noteworthy to mention that the patient population at the VA hospital is unique. The current population of Veterans seen at the VA hospital in Durham is predominantly male, and their health needs may not represent those seen in patient populations at other hospitals.

Portability and Completeness

As this study was done in the VA health system it has broad applicability. The computer system used in the Durham VA is the same used across the VISN and in most Veteran's hospitals in the United States. The surveillance system created in this study is therefore portable and can be implemented at other VA hospitals, giving them the ability to detect SSIs with reasonable sensitivity and specificity. Agreements have been reached with infection control chief medical officers and information technology at three other major VA hospitals in North Carolina and their primary care clinics to expand the developed SSI surveillance system to Asheville, Salisbury, and Fayetteville. Approval has also been given by the chief medical officer in VISN 6 to extend the surveillance system to Salem, Richmond, Beckley, and Hampton. At this time, many infection control units in VA hospitals around the country are under-staffed, and the ability to implement an automated system such as this will be a boon. The number of patient records they will need to review would be drastically reduced, freeing up their time to do other necessary infection control duties. This surveillance method requires little maintenance, aside from tailoring it to the specific institution's drug formulary and physician practices. Another advantage of the system's portability is that data can be shared

among the VA hospitals, and patients who have surgery at one VA hospital and are treated for a complication at another can be monitored. This will improve the completeness of the data, increase the sensitivity of this surveillance system and create a cooperative synergistic relationship between area VA hospitals.

Conclusions

In conclusion, this study demonstrates the ability to create a SSI surveillance system using patient data from automated medical records. By using ICD-9 coding, pharmacy records, vital signs, lab data, and microbiology data, a system was created that was more sensitive than conventional methods such as patient and surgeon surveys. This system is useful because it is not labor intensive, requires little maintenance, and is flexible to the needs and practices of an individual institution. It also lends itself to an infection control effort to improve the coding, testing, and drug dispensing practices at the individual institution, as this will increase the sensitivity and specificity of the surveillance system. Finally, as in this study, an efficient SSI surveillance system created at one institution is portable and can then be shared with other institutions using similar electronic databases, creating an integrated SSI monitoring system.

Appendix 1

Surgical CPT codes

Integumentary system	11400-19499
Musculoskeletal system	20000-29999
Respiratory system	30000-32999
Cardiovascular system	33010-37209
Hemic and lymphatic system	38100-38999
Mediastinum and diaphragm	39000-39599
Digestive system	40490-49999
Urinary system	50010-53899
Male genital	54000-55980
Female genital	56405-58999
Maternity Care and Delivery	59000-59899
Endocrine system	60000-60699
Nervous	61000-64999
Eye and ocular adnexa	64091-68899
Auditory	69000-69979

Appendix 2

NNIS Operative Procedure Categories

Code	Operative Procedure	Description	ICD-9-CM codes
AMP	Limb amputation	Total or partial amputation or disarticulation of the upper or lower limbs, including digits	84.00-84.19, 84.91
APPY	Appendectomy	Removal of appendix (not incidental to another operative procedure)	47.01-47.09, 47.2, 47.91-47.99
BILI	Bile duct, liver, or pancreatic surgery	Excision of bile ducts or operative procedures on the gallbladder (except cholecystectomy), liver, or pancreas	50.0, 50.21-50.4, 50.61-50.69, 51.31-51.63, 51.69-51.83, 51.89-51.95, 51.99, 52.09,

			52.22-52.7,
52.95, 52.96, 52.99			
CARD	Cardiac surgery	Open chest procedures on the	35.00-35.95,
35.98, 35..99		valves or septum of heart; does not include coronary artery bypass graft, surgery on vessels, heart transplantation, or pacemaker implantation	
CBGB	Coronary artery bypass graft with both chest and donor site incisions	Chest procedure to perform direct revascularization of the heart; includes obtaining suitable vein from donor site for grafting	36.10-36.14,
36.19			
CBGC	Coronary artery bypass graft with chest incision only	Chest procedure to perform direct vascularization of the heart using, for example, the internal mammary (thoracic) artery	36.15-36.17,
36.2			
CHOL	Cholecystectomy	Removal of gallbladder; includes 51.04, 51.21-51.24 procedures performed using the laparo-scope	51.03,
COLO	Colon surgery	Incision, resection, or	45.00,
45.03, 45.41, 45.49, 45.50,		anastomosis of the large	45.52,
45.71-45.90,		bowel; includes large-to-small and	45.92-45.95,
46.00,		small-to-large bowel anastomosis	46.03,
46.04, 46.10-46.14,			46.43,
46.52, 46.75, 46.76,			46.91,
46.92, 46.94, 48.5-48.69			48.6-48.69
CRAN	Craniotomy	Incision through the skull	01.2-01.59,
02.11-02.14,		to excise, repair, or	02.91,
02.92,		explore the brain; does not include taps or punctures	07.51-07.79, 38.01,
38.11, 38.31,			38.41,
38.51, 38.61, 38.81			

CSEC Cesarean section	Obstetrical delivery by Cesarean section	74.0-74.2, 74.4-74.99
FUSN Spinal fusion	Spinal fusion and refusion	81.00-81.08, 81.30-81.39, 81.62-81.64, 84.51, 84.52
FX Open reduction of fracture	Open reduction of fracture or dislocation of long bones that requires internal or external fixation; does not include placement of joint prosthesis	79.21, 79.22, 79.25, 79.26, 79.31, 79.32, 79.35, 79.36, 79.51, 79.52, 79.55, 79.56
GAST Gastric surgery	Incision or excision of stomach; includes subtotal or total gastrectomy, vagotomy, and pyloroplasty	43.00, 43.3, 44.0-44.03, 44.21, 44.29-44.42, 44.49-44.92
HER Herniorrhaphy	Repair of inguinal, femoral, umbilical, or anterior abdominal wall hernia; does not include repair of diaphragmatic or hiatal hernia or hernias at other body sites	53.00-53.61
HN Head and neck surgery	Major excision or incision of the larynx or trachea and radical neck dissection	30.1-30.4, 40.40-40.42
HPRO Hip prosthesis	Arthroplasty of hip	81.51-81.53
HYST Abdominal hysterectomy	Removal of uterus through an abdominal incision	68.31, 68.39, 68.4, 68.6
KPRO Knee prosthesis	Arthroplasty of knee	81.54, 81.55
LAM Laminectomy	Exploration or decompression of spinal cord through excision or	03.01-03.09, 80.50, 80.51, 80.59

		incision into vertebral structures	
MAST	Mastectomy	Excision of lesion or tissue	85.12,
85.20-85.23,			
		of breast including radical,	85.31-85.48,
85.50,			
		modified, or quadrant resection, lumpectomy, incisional biopsy, or mammoplasty	85.53-85.7
NEPH	Nephrectomy	Removal of all or part of	55.01,
55.02, 55.11, 55.12,			
		the kidney with or without	55.31-55.52,
55.54, 55.91			
		removal of related structures	
PRST	Prostatectomy	Suprapubic, retropubic, radical, or perineal excision of the prostate; does not include transurethral resection of the prostate	60.3-60.69
SB	Small bowel surgery	Incision or resection of	45.01,
45.02,			
		the small intestine; does	45.31-45.34,
45.51,			
		not include small-to-large	45.61-45.63,
45.91,			
		bowel anastomosis	46.01,
46.02,			
			46.20-46.31,
46.39,			
			46.41,
46.51, 46.71-46.74,			
			46.93
SKGR	Skin graft	Full and split-thickness	08.61,
21.83, 27.55-27.57,			
		skin grafts, including	85.82-85.85,
86.60-86.63,			
		flaps, of recipient and	86.65-86.67,
86.69,			
		donor sites	86.70-86.75,
86.91			
SPLE	Splenectomy	Complete or partial excision	41.2,
41.33,41.41-41.5,			
		of spleen	41.93,
41.95, 41.99			

THOR Thoracic surgery	Noncardiac, nonvascular chest surgery; includes pneumonectomy and diaphragmatic or hiatal hernia repair	32.3-32.9, 33.0-33.1, 33.31-33.49, 33.98, 33.99, 34.01-34.03, 34.1, 34.3-34.60, 34.81-34.84, 34.89, 34.93-34.99, 53.80-53.82
TP Organ transplant	Transplantation of human heart, kidney, liver, lung, pancreas, or spleen only; does not include cornea or bone marrow transplants	33.50-33.6, 37.51-37.54, 41.94, 46.97 50.51-50.59, 52.80-52.86, 55.61-55.69
VHYS Vaginal hysterectomy	Removal of the uterus through vagina or perineal incision	68.51-68.59, 68.7
VS Vascular surgery	Operative procedures involving arteries or veins; includes aortic aneurysm repair, vascular grafts, and carotid, iliac, femoral, or popliteal artery operations; does not include coronary artery bypass grafting	38.00, 38.02-38.10, 38.12-38.16, 38.18, 38.30, 38.32-38.40, 38.42-38.49, 38.7, 38.80, 38.82-38.89, 39.0-39.26, 39.28, 39.29 39.50-39.59, 39.7-39.79
VSHN Ventricular shunt	Extracranial ventricular shunts, including revision and removal of shunt	02.2, 02.31-02.39, 02.42, 02.43
XLAP Laparotomy	Nonspecific exploratory procedures of the abdominal cavity	54.11-54.19, 54.3-54.59, 54.71, 54.72, 54.74, 54.75

OBL	Other hemic and lymphatic systems	40.0, 40.21-40.3, 40.50-40.9, 41.98
OCVS	Other cardiovascular system	00.50-00.55, 36.01-36.03, 36.05-36.09, 36.31-36.99, 37.10-37.12, 37.31-37.4, 37.61-37.91, 37.94-37.99, 38.50, 38.52, 38.53, 38.55, 38.57, 38.59, 38.60, 38.62-38.69, 39.30-39.32, 39.41-39.49, 39.8-39.91, 39.93, 39.94
OENT	Other ear, nose, mouth, pharynx	18.02-18.09, 18.21-18.9, 20.21-20.23, 20.41-20.59, 20.92, 20.96-20.99, 21.1, 21.30, 21.32, 21.4, 21.72, 21.82, 21.84-21.87, 21.89, 22.31-22.39, 26.30-26.32, 29.0, 29.2-29.59
OES	Other endocrine system	06.01-06.09, 06.2-06.99, 07.00-07.02, 07.21-07.49, 07.80-07.99
OEYE	Other eye	08.01-08.09, 08.20-08.59, 08.62-08.89, 09.20-09.23, 09.3, 09.6, 09.73, 09.81-09.83

OGIT	Other digestive system	42.01-42.19, 42.31-42.32, 42.39-42.91, 46.40, 46.42, 46.50, 46.60-46.64, 46.79-46.82, 46.99, 47.11-47.19, 48.0-48.1, 48.41-48.49, 48.72-48.76, 53.7, 53.9-54.0, 54.61-54.64, 54.73, 54.92-54.95
OGU	Other genitourinary system	55.53, 55.7-55.89, 56.0-56.2, 56.40-56.89, 57.12, 57.18, 57.19, 57.21, 57.22, 57.51-57.89, 58.39, 58.42-58.5, 58.91-58.99, 59.00-59.19, 59.3-59.71, 59.79, 59.91, 59.92, 60.0, 60.72-60.82, 60.93, 61.0, 61.2-61.49, 61.92-61.99, 62.0, 62.2-62.99, 63.1-63.99, 64.2-64.99, 65.01-65.09, 65.21-65.89, 65.92-65.99, 66.01, 66.02, 66.31-66.79, 66.92-66.94, 66.97-66.99, 67.4, 67.51,

		68.0, 68.2-68.29, 68.8-68.9, 69.19-69.49, 70.4-70.62, 70.72-70.75, 70.8, 71.01-71.09, 71.5-71.9
OMS	Other musculoskeletal system	76.01-76.09, 76.2-76.70, 76.72, 76.74, 76.76, 76.77, 76.79-76.92, 76.94, 76.97, 77.00-77.39, 77.51-77.59, 77.60-77.99, 78.00-78.09, 78.20-78.79, 78.90-78.99, 79.10-79.20, 79.23, 79.24, 79.27-79.30, 79.33, 79.34, 79.37-79.39, 79.50, 79.59, 79.80-79.89, 79.9-79.99, 80.00-80.19, 80.40-80.49, 80.6, 80.7-80.99, 81.1-81.29, 81.40-81.49, 81.93-81.97, 82.01-82.91, 82.99 83.01-83.19, 83.31-83.93, 84.21-84.40, 84.44, 84.48, 84.92-84.99
ONS	Other nervous system	01.6, 02.01-02.07,

			02.94-02.99, 03.1-03.29, 03.4-03.79, 03.97, 03.98, 04.01-04.07, 04.3-04.79, 05.0, 05.21-05.29, 05.81-05.9, 29.92, 31.91
OOB	Other obstetrical procedures	74.3, 75.50, 75.52-75.62,	75.93
OPRO	Other joint prosthesis	Arthroplasty of joints other than hip and knee	81.56-81.61, 81.71-81.85
ORES	Other respiratory system		30.01-30.09, 31.5-31.73, 31.75-31.79, 32.09-32.22, 32.29, 33.92-33.93, 34.71-34.79, 34.85
OSKN	Other integumentary system		85.0, 85.24, 85.25, 85.86-85.89, 85.93-85.99, 86.03-86.09, 86.4, 86.81-86.89, 86.93

Appendix 3: Antibiotics

Outpatient antibiotics
Amoxicillin
Amoxicillin/clavulanic acid
Azithromycin
Ceftriaxone
Cephalexin

Ciprofloxacin
Clarithromycin
Clindamycin
Dicloxacillin
Doxycycline
Erythromycin
Fluconazole
Gentamicin
Levofloxacin
Metronidazole
Linezolid
Rifampin
Vancomycin

Inpatient antibiotics
Amoxicillin
Amoxicillin/clavulanic acid
Ampicillin/sulbactam
Azithromycin
Caspofungin
Cefazolin
Cefotaxime
Cefoxitinsodium
Ceftazidime
Ceftriaxone
Cefuroxime
Cephalexin
Ciprofloxacin
Clarithromycin
Clindamycin
Doxycycline
Erythromycin
Fluconazole
Gentamicin
Imipenem/cilastatin
Levofloxacin
Linezolid
Meropenem
Metronidazole
Minocycline
Nafcillin
Neomycin
Penicillin
Piperacillin/tazobactam
Rifampin
Timentin

Tobramycin
Vancomycin

Appendix 4: Diagnoses assigned in hospitals, emergency departments, or outpatient settings (ICD9 codes)

998.0	Postoperative Shock
998.3	Post-op Wound Disruption
998.5	Postoperative Infection
998.51	Infected Post-op Seroma
998.59	Post-op Infection Nec
998.83	Non-Healing Surg Wnd
780.6	Fever
891.0	Op Wnd Low Leg /S Comp
891.1	Open Wnd Knee/Leg-Comp
682.6	Cellulitis of Leg
682.9	Cellulitis Nos
998.9	Surgical Comp Nos
38.0	Streptococcal Septicemia
38.1	Staph Septicemia
38.10	Staph Septicemia Nos
38.11	Staph Aureus Septicemia
38.19	Staph Septicemia Nec
38.2	Pneumococcal Septicemia
38.3	Anaerobic Septicemia
38.4	Gram-Neg Septicemia Nec
38.40	Gram-Neg Septicemia Nos
38.41	*H. influenzae* Septicemia
38.42	*E. coli* Septicemia
38.43	Pseudomonas Septicemia
38.44	Serratia Septicemia
38.49	Oth Gram-Neg Septicemia
38.8	Septicemia Nec
38.9	Septicemia Nos
790.7	Bacteremia
611.0	Inflam Disease of Breast
682.0	Cellulitis of Face
682.1	Cellulitis of Neck
682.2	Cellulitis of Trunk
682.3	Cellulitis of Arm
682.4	Cellulitis of Hand
682.5	Cellulitis of Buttock
682.6	Cellulitis of Leg
682.7	Cellulitis of Foot
682.8	Cellulitis, Site Nec

682.9	Cellulitis Nos
686.0	Pyoderma
686.1	Pyogenic Granuloma
686.8	Local Skin Infection Nec
686.9	Local Skin Infection Nos
958.3	Posttraum Wnd Infect Nec
711.00	Pyogen Arthritis-Unspec
996.6	Infect/Inflam-Dev/Graft
996.60	Infect Due To Device Nos
996.61	Infect D/T Hrt Device
996.62	Infect D/T Vasc Device
996.63	Infect D/T Nerv Device
996.64	Infect D/T Urethral Cath
996.65	Infect D/T GU Device Nec
996.66	Infect D/T Joint Prosth
996.67	Infect D/T Orth Dev Nec
996.68	Infect D/T PD Cath
996.69	Infect Due To Device Nec
674.3	Oth Comp OB Surg Wound
879.0	Open Wound of Breast
879.1	Open Wound Breast-Comp
879.2	Opn Wnd Anterior Abdomen
879.3	Opn Wnd Ant Abdomen-Comp
879.4	Opn Wnd Lateral Abdomen
879.5	Opn Wnd Lat Abdomen-Comp
879.6	Open Wound of Trunk Nec
879.7	Open Wnd Trunk Nec-Comp
879.8	Open Wound Site Nos
879.9	Opn Wound Site Nos-Comp
875.0	Open Wound-Chest/S Comp
875.1	Open Wound Chest-Comp

Appendix 5: Microbiology Orders and Results

Culture orders
Abdomen
Blood
Bone marrow
Bronchial wash fluid
Cerebrospinal fluid
Feces
Leg
Leg—medial surface

Nail
Pelvis
Peritoneal fluid
Pharynx
Pleural fluid
Scalp
Skin
Sputum
Synovial fluid
Unknown
Urethra
Urine
Vagina
Vaginal secretion
Vein

Culture results
Abscess
Aspirate
Bone
Bronchial washes
Bronchial lavage
Chest fluids
Exudates
Fluid
Fluid unknown
Hip fluid
Hip fluid
Intravenous catheters
Peritoneal
Pleural
Swab
Sensorial
Tissue
Tracheal aspirates
Urine—clean-catch
Urine culture
Wound

References

1. National Nosocomial Infections Surveillance (NNIS) report, data summary from October 1986-April 1996, issued May 1996. A report from the National Nosocomial Infections Surveillance (NNIS) System. Am J Infect Control 1996; 24: 380–8.
2. Sand K, Vineyard G, Platt R. Surgical Site Infections Occurring after Hospital Discharge. J Infect Dis 1996; 173:963—70.
3. Wong ES. Surgical site infections. In: Mayhall CG, editor. Hospital epidemiology and infection control. 2nd ed. Philadelphia: Lippincott; 1999. p. 189–210.
4. Holtz TH, Wenzel RP. Postdischarge surveillance for nosocomial wound infection: a brief review and commentary. Am J Infect Control 1992;20:206–13.
5. Haley RW, Culver DH, White JW, et al. The efficacy of infection surveillance and control programs in preventing nosocomial infections in US hospitals. Am J Med 1985; 78:3—7.
6. Haley RW. Incidence and nature of endemic and epidemic nosocomial infections. In: Bennett JV, Brachman PS, eds. Hospital infections. Boston: Little Brown, 1986:359—74.
7. Condon RE, Haley RW, Lee JT, et al. Does infection control control infection? Arch Surg 1988; 123:250—6.
8. Olson M, Lee JT. Continuous, 10-year wound infection surveillance: results, advantages, and unanswered questions. Arch Surg 1990; 125:794—803.
9. Brown RB, Bradley S, Opitz E, Cipriani D, Pieczarka R, Sands M. Surgical wound infections documented after hospital discharge. Am J Infect Control 1987; 15: 54–8.
10. Platt R, Yokoe DS, Sands KE, et al. Automated Methods for Surveillance of Surgical Site Infections. Emerg Infect Dis 2001; 7:2.
11. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WL, Guideline for the prevention of surgical site infection, 1999. Infect Control Hosp Epidemiol 1999; 20: 247-78.
12. Haynes SR, Lawler PG. An assessment of the consistency of ASA physical status classification allocation [see comments]. Anaesthesia 1995;50:195-9.
13. Sands K, Vineyard G, Livingston J, Christiansen C, Platt R. Efficient identification of postdischarge surgical site infections using automated medical records. J Infect Dis 1999; 179: 434-41.
14. Buehler JW, Hopkins RS, Overage JM, Sosin DM, Tong V. Framework for evaluating public health surveillance systems for early detection of outbreaks. MMWR recommendations and reports. CDC. 2004; 53: 1-11.

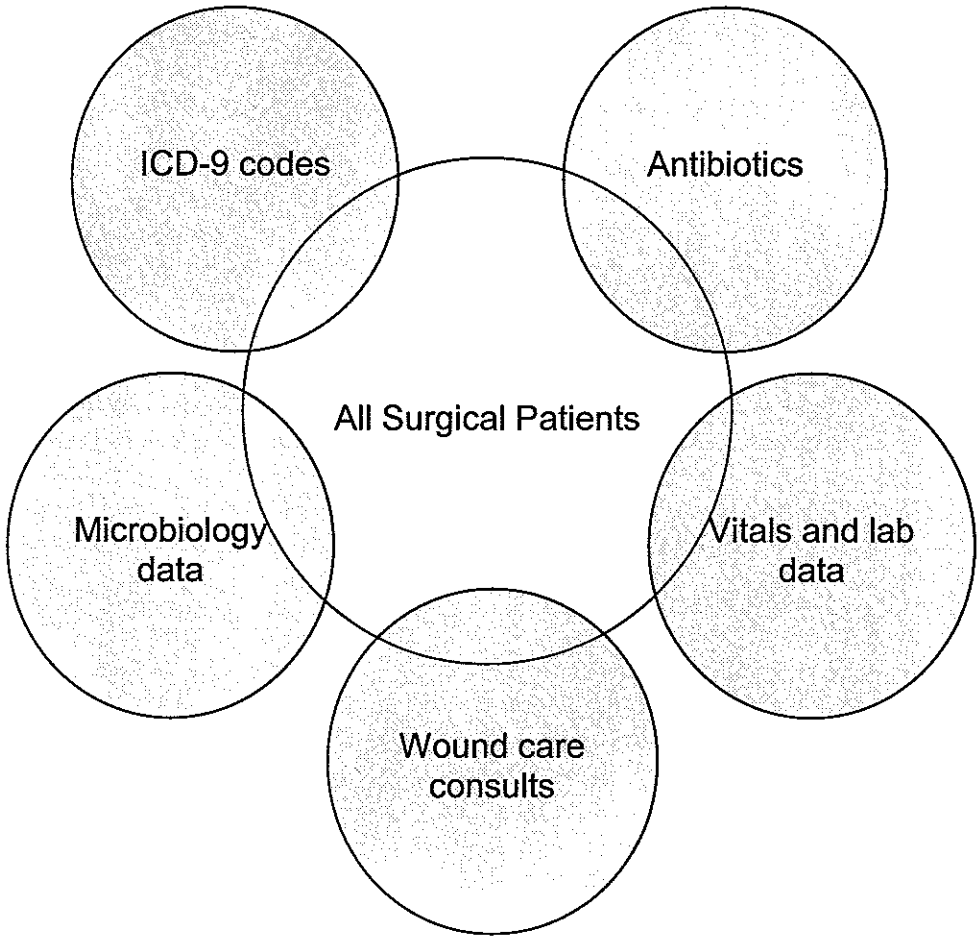

Figure 1: Graphical simplification of the identification of potential SSIs. Patients found where circles overlap are identified as potentially having a SSI.

Table 1: Data groups used in multivariable analysis.

Variable	Data Type
1. SSI-associated diagnoses	ICD-9 codes
2. Outpatient antibiotics	Automated pharmacy data
3. Inpatient antibiotics	Automated pharmacy data
4. All antibiotics	Automated pharmacy data
5. Wound consults	Automated consult orders data
6. Microbiology orders	Automated microbiology orders data
7. Microbiology results	Automated microbiology results data
8. All microbiology data	Automated microbiology data
9. Patient vital signs and labs	Automated patient medical records data

Table 2: Variables strongly associated with SSIs used in multivariable analysis.

Variable	Description	Data Type
1. SSI-associated diagnoses	682.7, 682.9, 891.0, 891.1, 958.3, 998.59, 998.83, 998.31, 998.32	ICD-9 codes[1]
2. Outpatient antibiotics	Amoxicillin/clavulanic acid, cephalexin, clindamycin, levofloxacin, fluconazole, metronidazole, vancomycin	Automated pharmacy data
3. Inpatient antibiotics	Amoxicillin/clavulanic acid, ampicillin/sulbactam, cefazolin, cefoxitin, cephalexin, clindamycin, metronidazole, piperacillin/tazobactam, timentin, vancomycin	Automated pharmacy data
4. All antibiotics	Inpatient + outpatient antibiotics	Automated pharmacy data
5. Wound consults	Consult to wound-ostomy nurse or physical therapy for wound care	Automated consult orders data
6. Microbiology orders	Orders for blood, leg, leg-medial side, peritoneal fluid, unknown, and vein sample cultures	Automated microbiology orders data
7. Microbiology results	Microbiology results from tissue and wound samples	Automated microbiology results data
8. All microbiology data	Microbiology orders + results	Automated microbiology data
9. Patient vital signs and labs	Systolic BP<90, pO2<90, T>38°C, WBC>11.0	Automated patient medical records data
	[1] See Appendix 4 for ICD-9 code definitions	

Table 3: Independent Predictors of all SSI types

Variable	Risk Ratio	95% Confidence interval	Sensitivity(%)	Specificity(%)
1. SSI-associated diagnoses	13.40	10.23-17.57	44.4	95.4
2. Outpatient antibiotics	4.72	3.56-6.26	53.4	81.3
3. Inpatient antibiotics	10.65	7.11-15.97	85.6	65.6
4. All antibiotics	12.79	8.06-20.29	89.3	61.8
5. Wound consults	6.52	4.90-8.70	35.8	92.9
6. Microbiology orders	4.47	3.37-5.94	41.2	87.2
7. Microbiology results	7.47	5.47-10.21	24.6	96.4
8. All Microbiology data	6.03	4.56-7.97	51.3	86.1
9. Patient vital signs and labs	5.34	3.92-7.26	69.5	71.1

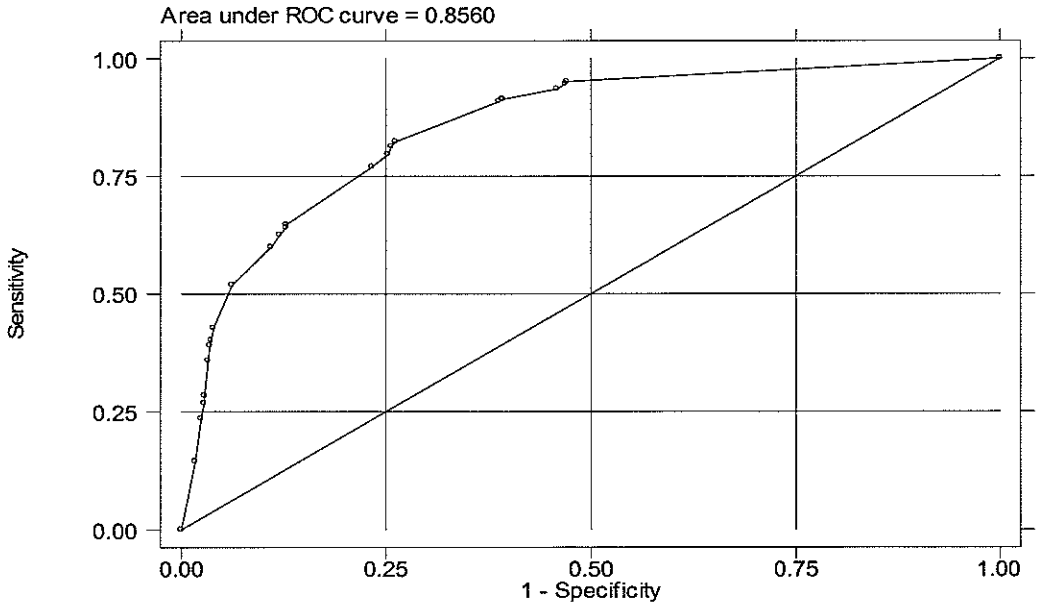

Figure 2: Receiver operating characteristic (ROC) curve for regression model predicting all types of SSIs.

Table 4: Independent predictors of severe SSIs.

Variable	Risk Ratio	95% Confidence interval	Sensitivity(%)	Specificity(%)
1. SSI-associated diagnoses	14.47	9.92-21.05	49.0	94.4
2. Outpatient antibiotics	4.62	3.15-6.79	52.9	80.9
3. Inpatient antibiotics	16.54	8.63-31.71	90.2	65.0
4. All antibiotics	20.79	9.66-44.73	93.1	61.3
5. Wound consults	7.54	5.11-11.12	39.2	92.6
6. Microbiology orders	5.91	4.03-8.66	48.0	87.0
7. Microbiology results	12.50	8.46-18.45	35.3	96.3
8. All Microbiology data	10.04	6.74-14.95	63.7	85.8
9. Patient vital signs and labs	10.22	6.22-16.78	81.4	70.8

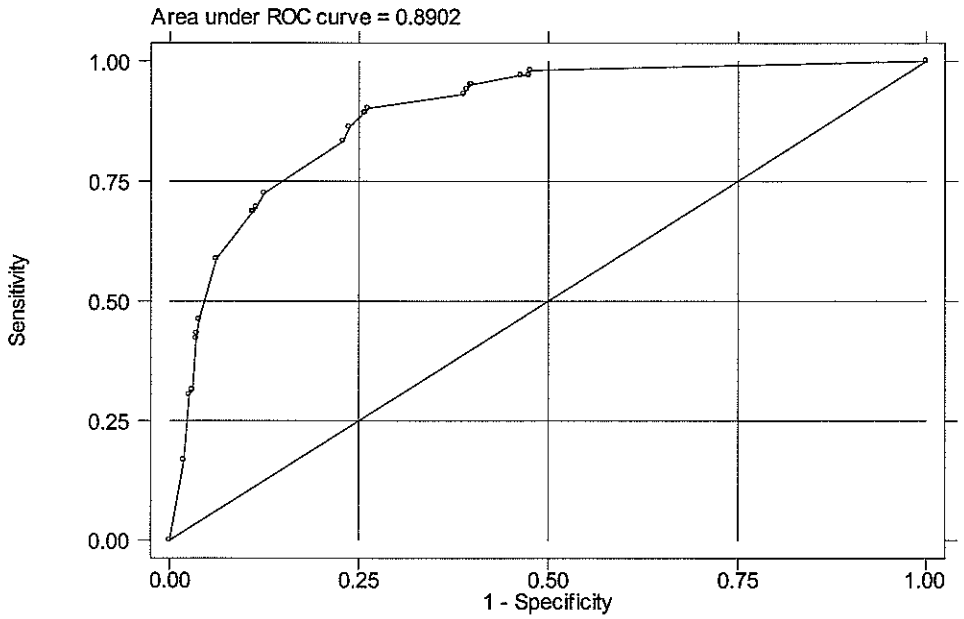

Figure 3: Receiver operating characteristic (ROC) curve for regression model predicting severe types of SSIs.

Table 5: Independent predictors of organ/space SSIs.

Variable	Risk Ratio	95% Confidence interval	Sensitivity(%)	Specificity(%)
1. SSI-associated diagnoses	10.17	6.04-17.10	40.4	94.0
2. Outpatient antibiotics	3.97	2.37-6.65	49.1	80.7
3. Inpatient antibiotics	18.70	7.47-46.75	91.2	64.7
4. All antibiotics	27.58	8.63-88.11	94.7	60.9
5. Wound consults	8.50	5.06-14.28	42.1	92.4
6. Microbiology orders	7.10	4.24-11.89	52.6	86.5
7. Microbiology results	10.57	6.12-18.26	31.6	96.0
8. All Microbiology data	12.38	7.11-21.56	68.4	85.5
9. Patient vital signs and labs	9.78	5.08-18.85	80.7	70.5

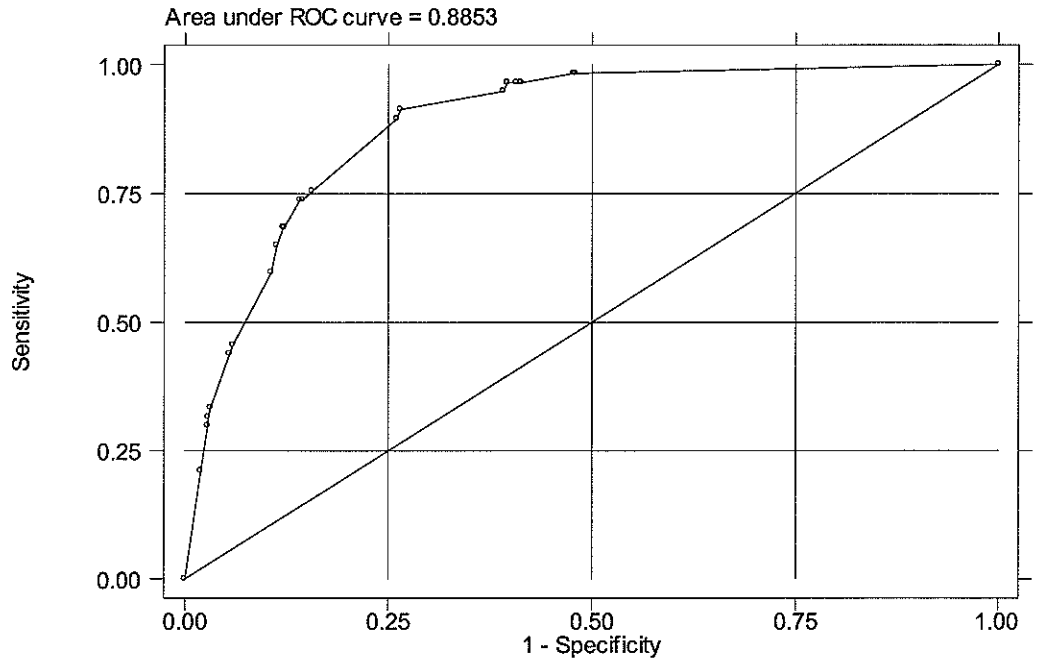

Figure 4: Receiver operating characteristic (ROC) curve for regression model predicting organ/space types of SSIs.