Mitigation of Surgical Site Infection Using a Validated Risk Calculator: A Quality Improvement Project

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Abstract

Surgical site infections (SSI) are a significant cause of morbidity and mortality in postoperative patients, occurring in approximately 1-3% of all inpatient surgical procedures and costing an additional $3.3 billion dollars annually in the United States (Alkaaki et al., 2019; Centers for Disease Control and Prevention [CDC], 2020). Many interventions and tools have been developed and validated to reduce SSI burden. This quality improvement (QI) project aims to implement a validated SSI risk calculator from the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) as a screening tool to identify high-risk patients on a colorectal/abdominal inpatient surgical service (American College of Surgeons [ACS], 2023). Surgical inpatients identified by the calculator as "Above Average" risk of developing SSI were alerted to the provider management team upon admission from surgery, giving providers the chance to make management decisions and implement infection prevention interventions as they see fit according to the patient's high-risk status. Patients from the intervention period were chart reviewed at 30 days post-procedure for development of SSI. Following the intervention, there was a 38.74% reduction in SSI rate in the colorectal patient population from the 2022 average SSI rate for this patient population, however this difference was not statistically significant upon analysis. Additionally, the ACS-NSQIP Surgical Risk Calculator accurately predicted the patients who developed SSI to a "fair" degree. The results of this intervention can be expanded upon in future projects, for use in other surgical services and developed as part of a standard admission screening protocol.

Keywords: Surgical site infection, infection, surgery, SSI, American College of Surgeons, ACS-NSQIP, screening tool, colorectal surgery, abdominal wall surgery

Problem Description

Surgical site infections (SSIs) account for 20% of all healthcare-associated infections, totaling 110,800 SSIs from inpatient surgeries in the United States in 2015, according to the 2023 Centers for Disease Control and Prevention Surgical Site Infection Event (CDC, 2023). Defined by the CDC as an infection on the body at the site of skin incision, organ, or space that occur after surgery, SSIs are a significant cause of morbidity and source of prolonged hospitalization, (CDC, 2019). SSIs extend hospital stays by an average of 9.7 days per patient, a total of an additional one million inpatient days annually (CDC, 2020; CDC, 2022). SSIs can greatly affect a patient's postoperative recovery period in the short-term and can cause long-term complications such as multiple subsequent surgeries or life-threatening systemic infection (Azoury et al., 2015). Moreover, SSI is associated with a mortality rate of 3%, with up to 75% of these deaths found to be directly caused by the SSI. (CDC, 2020).

At Oregon Health & Science University (OHSU), the monthly SSI rate for colorectal surgery in 2022 ranged from 0.0% to 16.7%, with a mean of 5.70% (OHSU Department of Infection Prevention and Control, 2022). This average is higher than the national average SSI rate of 1-3% for all surgical procedure types (Alkaaki et al., 2019). However, among various types of surgeries, colorectal procedures are known to have higher rates of SSI, with studies reporting a wide range from 3% up to 30% (Kamboj et al., 2018). When compared to SSI of other procedures, patients developing colorectal surgery SSI often have a more complicated postoperative course and a lengthier hospital stay of up to 24 days longer for deep space infection (Lohsiriwat, 2021). Since colorectal SSI is associated with a greater burden and worse outcomes, reduction in overall SSI rate, and in particular colorectal SSI, is a priority at OHSU.

Available Knowledge

By definition, SSIs occur within 30 days of surgery and can be classified into incisional SSIs that are superficial, or organ-space SSIs that involve deep tissue that was manipulated during the operation (Garner & Anderson, 2016). SSIs may present with signs and symptoms of infection, purulent drainage, incision dehiscence, or an abscess found on examination or imaging (Garner & Anderson, 2016). Risk factors for developing a SSI include both patient-related characteristics and procedure-related factors. Patient-related risk factors are unmodifiable characteristics such as male sex and older age, while modifiable risk factors include uncontrolled diabetes, obesity, and tobacco use (Azoury et al., 2015; Garner & Anderson, 2016). Contributing procedure-related factors, which are those that occur in the perioperative period, include intraoperative tachypnea, hypothermia, high estimated blood loss, intraoperative blood transfusion, and steroid administration (Azoury et al., 2015; Ejaz et al., 2017; Fukada, 2016) (see Appendix A).

Taking into consideration the various patient-related factors that are known to contribute to the development of SSI, various risk assessment tools have been created and validated for the identification of patients at high risk of infection after surgery. A study by Anwar et al. (2018) determined that an SSI risk assessment scale had high accuracy in discriminating between patients who were likely to develop SSI and patients who did not develop SSI. Furthermore, a study using surgical patient data and morbidity outcomes from the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) created an internally derived and validated SSI Risk Score model (van Walraven & Musselman, 2013). The ACS-NSQIP combined patient factors and operative factors in its risk calculation and was found to have good discrimination in identifying patients at risk of developing an SSI within 30 days of surgery (van Walraven & Musselman, 2013).

Utilizing a SSI screening tool provides clinicians the ability to recognize the high-risk patients that may benefit from additional interventions and thus possibly avoid developing a SSI and the sequelae that may stem from a postoperative infection (Anwar et al., 2018). A validated screening tool such as the

ACS-NSQIP Surgical Risk Calculator is a simple way to quantify patient SSI risk with potentially high payoff in preventing SSI burden and decreasing patient morbidity and mortality.

Rationale

At OHSU, the Green Surgery inpatient service is the primary team managing the care of colorectal and abdominal wall surgical patients admitted after their elective procedures. After identifying the problem description on the Green Surgery service at OHSU, it was discovered that the service does not have a protocol in place to identify post-operative inpatients at high risk of developing SSI. The Preoperative Medicine Clinic for this services utilizes the 2014 American College of Cardiology/American Heart Association Perioperative Cardiac Risk Stratification to calculate and document cardiac risk on patients prior to elective surgery, however no information on SSI risk screening is available for their patients. It appears that SSI risk stratification for individual patients is not calculated and not readily available to the providers on this inpatient service. The gap in knowledge of which patients are at increased risk of SSI and needing further interventions may be a contributor to development of SSI in this inpatient population.

Through the literature review, it is evident that standardized, validated SSI screening tools have high accuracy in identifying patients at increased risk of developing SSI. By knowing which patients are high-risk, providers can use this information to implement further SSI risk-reduction interventions for these patients. Because this service does not utilize a SSI screening tool in the inpatient setting, implementing a protocol to incorporate a validated screening tool as a standard procedure is an evidence-based intervention that is expected to decrease the incidence of SSI on the service. In this QI project, the Model for Improvement (MFI) from the Institute for Healthcare Improvement was chosen as the framework to guide change using a systematic format to test measurable changes in a work setting (Institute for Healthcare Improvement [IHI], 2023). Utilizing the MFI, this project identified a specific aim, established measures to quantify observable improvement, and tested a change on the Green Surgery service at OHSU.

Specific Aims

The specific aim of this QI project was to reduce colorectal SSI on the Green Surgery service by 25% by utilizing a validated SSI screening tool to identify postoperative inpatients at high risk of developing SSI. With the immediately available knowledge of which patients on their service are high-risk for SSI, providers have the ability to make management decisions and implement interventions as they see fit, in turn reducing the 30-day SSI rate on their service.

Methods

Context

Oregon Health & Science University (OHSU) is an academic hospital that serves a large metropolitan area across multiple campuses. OHSU has 576 licensed beds and sees 254,966 adult patients through hospital admission and clinic visits yearly (OHSU, 2023). In 2022, OHSU totaled 32,273 surgical cases, 10,889 of which were inpatient cases (OHSU, 2023). This QI project was implemented on the Green Surgery inpatient service, which covers colorectal and abdominal wall general surgery at the OHSU main campus. The service comprises of nine attending surgeons, one nurse practitioner (NP), and rotating resident physicians. Postoperative inpatients on the service are admitted across multiple units at the OHSU main campus, and Green Surgery remains the primary team managing the inpatient care.

OHSU Green Surgery serves adult patients in the metropolitan Portland area as well as throughout the state. Common diagnoses of the surgical patients on this service are colorectal cancer, Crohn's disease, colorectal fistulas, ventral hernias, and bowel obstruction. Many patients in this population have common comorbidities such as hypertension, obesity, diabetes mellitus, and chronic kidney disease. Typical procedures performed by Green Surgery for this patient population include hernia repair, colon resection, ostomy creation/takedown, fistula repair, and abdominal wall reconstruction. From January to September 2022, colorectal surgery SSI rates ranged monthly from 0.0% to 16.7%, with a mean of 5.7% (OHSU Department of Infection Prevention and Control, 2022).

Interventions

The Surgical Risk Calculator from the American College of Surgeons (ACS-NSQIP), as shown in Appendix B, was utilized as the validated SSI screening tool in this QI project to identify the patients at increased risk for SSI. The Surgical Risk Calculator, which is available free of cost online, is a series of 21 demographic and yes/no questions pertaining to a patient's history and case data that automatically generates a percentage of likelihood to develop specific postoperative complications, including SSI (ACS, 2023). As shown for an example patient in Appendix C, percentages of estimated patient risk, compared to average risk, of various surgical complications are generated using the patient data input.

For a period of 30 days, all postoperative inpatients admitted to the Green Surgery service were chart reviewed to enter into the ACS-NSQIP Surgical Risk Calculator. The variables of the ACS-NSQIP Surgical Risk are (see Appendix B): age group, sex, functional status, emergency/elective case, American Society of Anesthesiologist (ASA) class, chronic steroid use, ascites within 30 days prior to surgery, systemic sepsis within 48 hours prior to surgery, ventilator dependency, disseminated cancer, diabetes (oral or insulin dependent), hypertension requiring medication, congestive heart failure within 30 days prior to surgery, dyspnea, smoking status, severe COPD, dialysis dependency, acute renal failure, BMI, and type of procedure.

The patients identified by the calculator as "Above Average" risk for the Surgical Site Infection outcome were selected for notification to the Green Surgery team. Notification was done on a daily basis through Microsoft Teams messaging to the Green Surgery NP, who acted as the point of contact for the service. While specific management guidelines are not within scope of this QI project, the primary management team (Green Surgery) is notified of their patients at increased risk for SSI and thus theoretically have the ability to make specific changes to patient care and infection prevention regimen as they see fit.

Because SSIs are defined as developing within 30 days of surgery, each patient's chart was reviewed at 1 month from their surgery date for diagnosis of SSI. SSI postoperative chart review was completed for all inpatients on the service, regardless of whether they were identified as "Above Average" risk, to determine the number of patients who developed SSI within 30 days of their surgery.

Study of the Interventions

The study of the intervention includes monitoring the number of SSI developed by surgical patients admitted to the unit. Comparison of the SSI rate from prior to implementing the risk calculator to after the implementation facilitated analysis of the impact of the intervention. SSI diagnosis information was obtained through chart review of ICD-10 codes, problem lists, and review of provider notes from ED visits, inpatient admissions, and office visits.

Measures

The primary outcome measure for this QI project is the SSI rate in surgical patients on the Green Surgery service. This information was gathered through chart review of patients from the intervention period, at the 30-day timepoint after their surgery. Since the data is dependent on chart review, a process measure is the percentage of patients with SSI who have an accurate diagnosis and documentation in EPIC. In some cases of SSI development, patients may choose to not seek medical care or may present to an outside medical facility, therefore the data available on EPIC may not be representative of true SSI incidence.

A balancing measure is the possibility of increased provider and nurse workload due to implementing interventions that otherwise may not have been executed without the knowledge of patients' high-risk SSI status. While specific patient management interventions are not within the scope of this QI project, it is reasonable to assume there may be changes or additions to patient management as a result of identifying high-risk patients.

Analysis

EPIC was used to track patients in the intervention period to follow for SSI chart review. The ACS-NSQIP Surgical Risk Calculator was chosen as the validated SSI screening tool for patient SSI risk stratification. De-identified data entry of SSI risk stratification and SSI numbers were tracked on Microsoft Excel. Historical SSI rate data was obtained from the OHSU Department of Infection Prevention and Control. Multiple online statistics calculators were utilized for statistical analysis of the data. One-way analysis of variance (ANOVA) was used to compare the historical mean SSI rates between years. Z-test was utilized to statistically compare the single-sample intervention period SSI rate to the historical 2022 SSI rate for colorectal procedures. The Cohen's kappa coefficient was used to interpret agreement between the ACS-NSQIP high risk predictions and actual SSI outcomes in the intervention period. To generate graphs to visualize data, Microsoft Excel was utilized.

Ethical Considerations

This project was submitted to the OHSU Institutional Review Board (IRB) prior to initiation of the project. This QI project was found to be not human subjects research. Patient information data was de-identified and compliant with HIPAA. The online ACS-NSQIP Risk Calculator was used with no patient identifiers, and information was not stored on the website. All communications of patient information in identifying high-risk postoperative inpatients with the surgical team was made though Microsoft Teams, a HIPAA-compliant platform approved for use by OHSU.

Results

Historical data obtained from the OHSU Department of Infection Prevention and Control shows that SSI rates in colorectal surgeries at OHSU were down trending from 2019 to 2021, from 5.44% to 4.41% to 2.03% in 2021 (See Appendix D). In 2022 (January through September), the average SSI rate for colorectal surgeries was 5.70%, which is an increase from the previous three years and a departure from the down trending SSI rates. However, using one-way ANOVA calculations, the differences among the SSI rates from 2019 to 2022 is not statistically significant, with f-ratio value of 1.709 and p-value of 0.180 ($p < 0.05$) (Appendix E).

The intervention period for the ACS-NSQIP Surgical Risk Calculator screening was set from February 3rd, 2023 to March 2nd, 2023. During this period, 48 inpatient surgical procedures were performed by the Green Surgery service (excluding day surgery cases). Of those, 26 were colorectal procedures and 22 were abdominal wall/other general procedures. All cases were entered into the ACS-NSQIP Surgical Risk Calculator on a daily basis, and 19 out of the total 48 patients were found to be "Above Average" risk. These patient names were notified daily to the Green Service NP, who acted as point of contact for the service.

In the 30 day period following each of the 48 cases, SSIs were discovered in five patients upon chart review. Of these SSI's, one was from a colorectal surgery patient, and four were from abdominal wall/other general patients (see Appendix F). This results in a SSI rate of 10.41% for all Green Surgery inpatient procedures, and an SSI rate of 3.85% for colorectal cases only. This constitutes a decrease of 38.74% in colorectal SSI from 2022 to the intervention period (5.70% to 3.85%). However, when utilizing the z-test for statistical significance, the difference in the intervention rate is not statistically significant with a z-score of -0.320 and p-value of 0.375 ($p < 0.05$) (Social Science Statistics, 2023). Historical SSI data from abdominal wall/other general procedures was not available to statistically compare the total intervention SSI rate of 10.41%.

In total, 19 out of 48 patients (39.6%) during the intervention period were deemed “Above Average” SSI risk and sent to the Green Surgery team for notification of status. Of the five patients who developed SSI in the intervention period, four (80%) had been identified by the ACS-NSQIP Surgical Risk Calculator as “Above Average” risk for SSI, while the remaining patient was “Below Average” for SSI risk (Appendix G). Fifteen of the 19 “Above Average” SSI risk patients did not develop SSI. Using Cohen’s kappa statistical analysis, there was a 64.58% agreement (kappa = 0.292) between the ACS-NSQIP SSI “Above Average” predictions and the actual SSI outcomes in the intervention period, representing a “fair agreement” between the two groups (see Appendix H) (GraphPad, 2023).

Discussion

Summary

This QI project implemented a validated surgical risk calculator from the American College of Surgeons (ACS-NSQIP) to screen and identify postoperative inpatients on a colorectal and abdominal general surgery service who are at high risk of developing SSI. A strength of this project was communicating real-time, immediate knowledge to the provider management team when an “Above Average” SSI risk postoperative patient was admitted to their service. While specific management interventions were not within the scope or aim of this QI project, the objective of the project was for providers to have heightened awareness of patients’ increased SSI risk and thus have the ability to make management decisions accordingly. The 30-day SSI rate after the implementation of the ACS-NSQIP Surgical Risk Calculator intervention was 3.85% for colorectal surgeries, which represents a 38.74% reduction in SSI rate from the 2022 average for the same patient population.

Interpretation

Implementation of the ACS-NSQIP Surgical Risk Calculator to identify patients at high risk of developing SSI, for notification to the provider management team, was associated with a 38.74% reduction in colorectal SSI. The objective of reducing colorectal SSI by 25% was met, however this difference was determined to be not a statistically significant reduction from the previous year average SSI rate. Of note, the SSI rate from all procedure types from the Green Surgery inpatient service (colorectal and abdominal wall/other) was 10.41%, but historical SSI data from this patient population was not available from the OHSU Department of Infection Control and Prevention for comparison.

Of the colorectal and abdominal wall/other patients who developed SSI following the intervention, 80% had been identified by the ACS-NSQIP Surgical Risk Calculator as high risk for SSI. While this QI project was limited to the outcome of SSI, there are multiple studies in the literature evaluating the efficacy of the ACS-NSQIP Surgical Risk Calculator in predicting overall surgical outcomes in the elective colorectal surgical patient population specifically. Two large-scale studies by Cologne et al. (2015) and Keller et al. (2018) both concluded that while the ACS-NSQIP Surgical Risk Calculator had high correlation in predicting postoperative complications in general, it had low accuracy for predicting specific outcomes, such as SSI. In a study of colorectal cancer surgical patients in an older population, Van der Hulst et al. (2022) found the calculator to have fair predictive ability for pneumonia and discharge not to home, but poor predictive ability for all other surgical outcomes such as SSI.

In a single-institution study of 5,028 surgical patients comparing the cohort SSI rate to ACS-NSQIP calculator SSI predictions, there was an overall agreement of 95% (kappa = 0.48), which confers "moderate agreement" in SSI predictive ability of the calculator (Selby et al., 2015). In this current QI project with a much smaller sample size, the agreement between the ACS-NSQIP SSI predictions and the actual SSI outcomes was 64.58% (kappa = 0.292), which represents "fair agreement" in SSI predictive ability in this project. While this QI project was limited in sample size, a larger-scale project may have conferred results closer to the Selby et al. (2015) study with higher agreement between ACS-NSQIP predictions and actual SSI outcomes.

While this project's scope was narrow in patient population and limited to one surgical service, the impact of reducing SSI in any surgical population, including colorectal, is vast for improving patient outcomes. In using a validated calculator to identify postoperative inpatients at increased risk of developing SSI and having the provider management team aware of their high-risk status, more careful consideration of management decisions could positively impact postoperative course to mitigate infections.

Limitations

This QI project was limited in sample size, as only 48 inpatient cases (26 colorectal) were performed during the intervention period. The chart review to determine if SSI was developed postoperatively was limited by documentation in EPIC. All efforts were made to review encounters, provider and nursing notes, problem lists, and ICD-10 codes following 30 days after each intervention patient's procedure. However, if patients presented to an outside facility or did not seek medical care for signs of infection, SSI may be missed upon chart review.

An additional limitation was the type of SSI data available from the OHSU Department of Infection Prevention and Control. While the department keeps records of SSI rates from specific procedure types (including colorectal surgery), it does not have SSI data available for abdominal wall/other general procedures from the Green Surgery service. This limited the ability to compare data for this patient population for statistical significance.

Lastly, this project was likely limited by amount of involvement of the Green Surgery providers. While the team was welcoming of the intervention, Green Surgery is a busy inpatient service and the effect of the high-risk patient notifications on actual management decisions is unknown, as this was out of the scope and objective of the project design.

Conclusions

This quality improvement project demonstrated that a validated surgical risk calculator can be useful in identifying postoperative inpatient at high risk of developing SSI. In future projects, the next steps would be to implement the ACS-NSQIP Surgical Risk Calculator as a standard protocol for Green Surgery postoperative inpatients, such as part of a nursing floor admission set. Future projects can also be generalized to other surgical inpatient services within OHSU. As the ACS-NSQIP Surgical Risk Calculator has been validated and utilized at other facilities, OHSU has the potential to adopt this tool as one factor to help mitigate SSI in all surgical patient populations.

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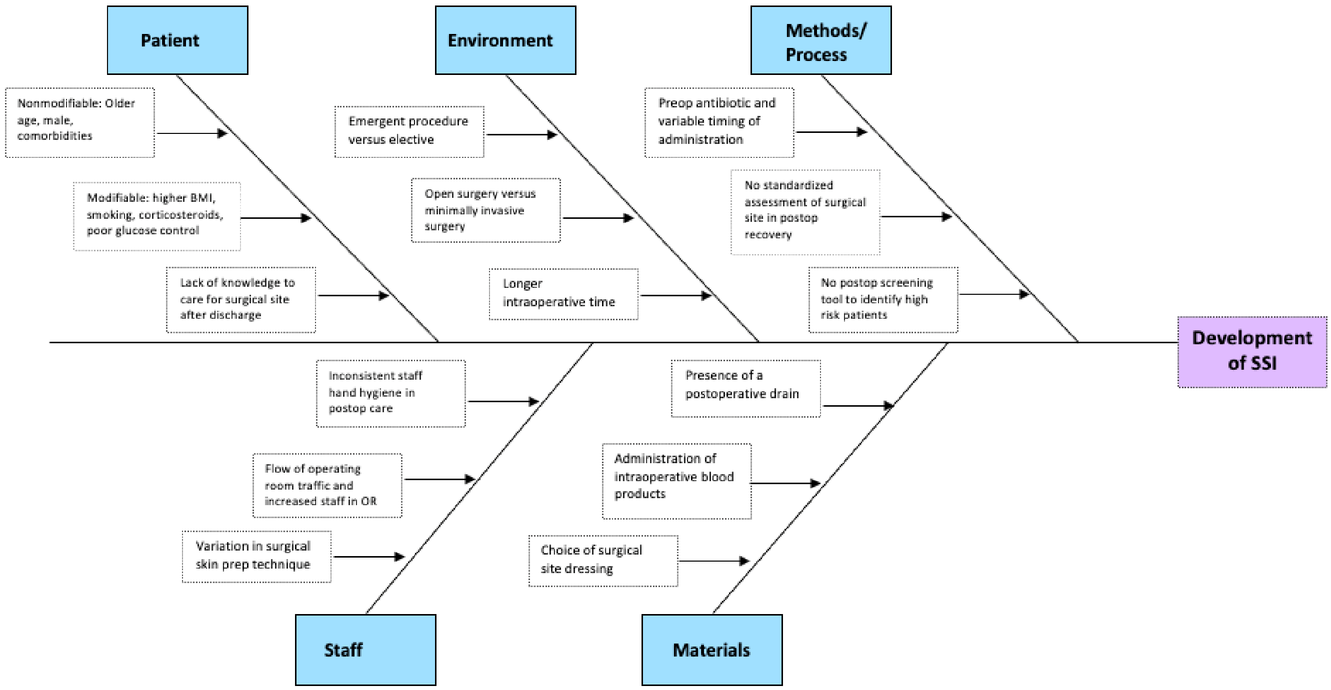
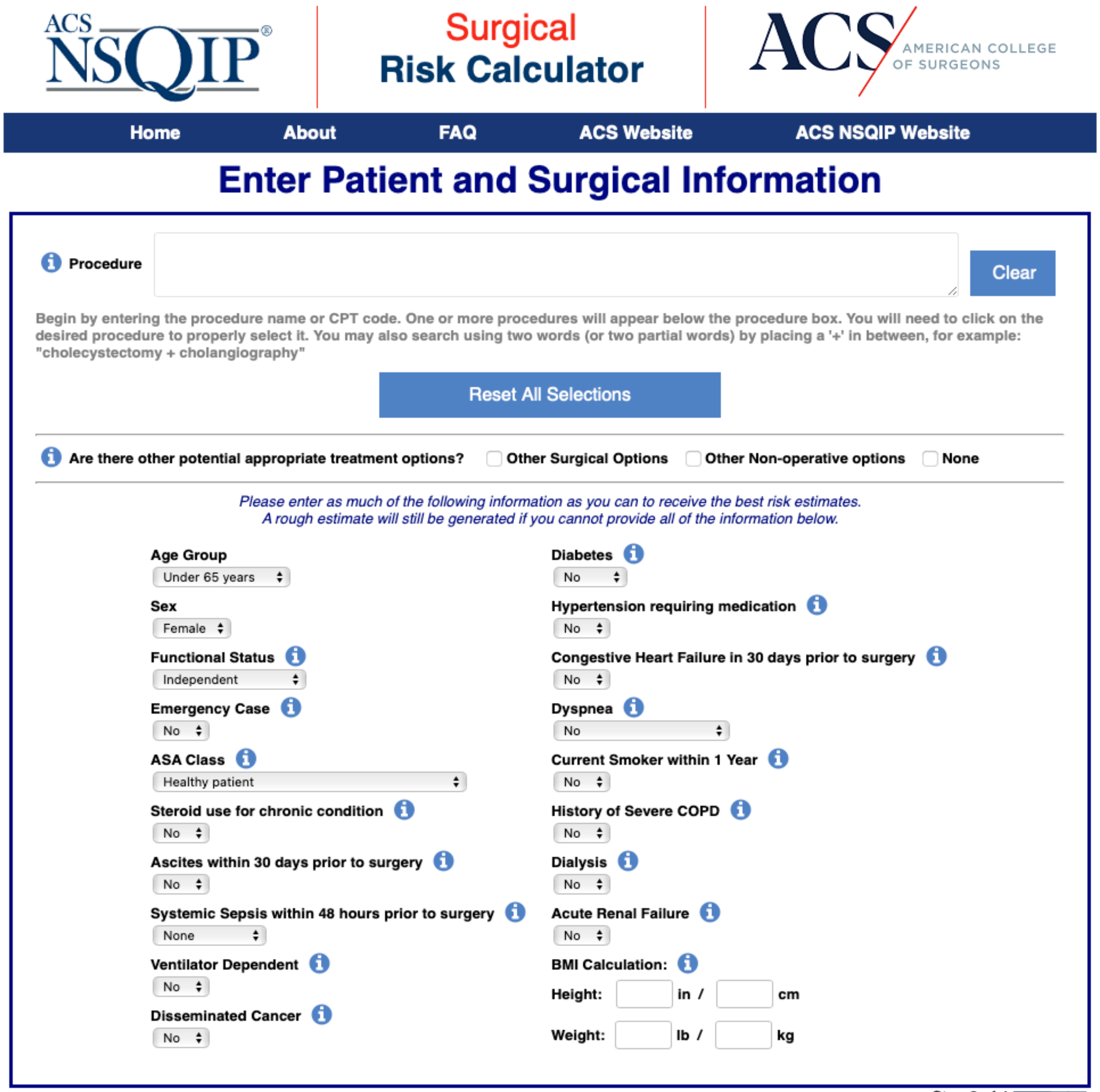
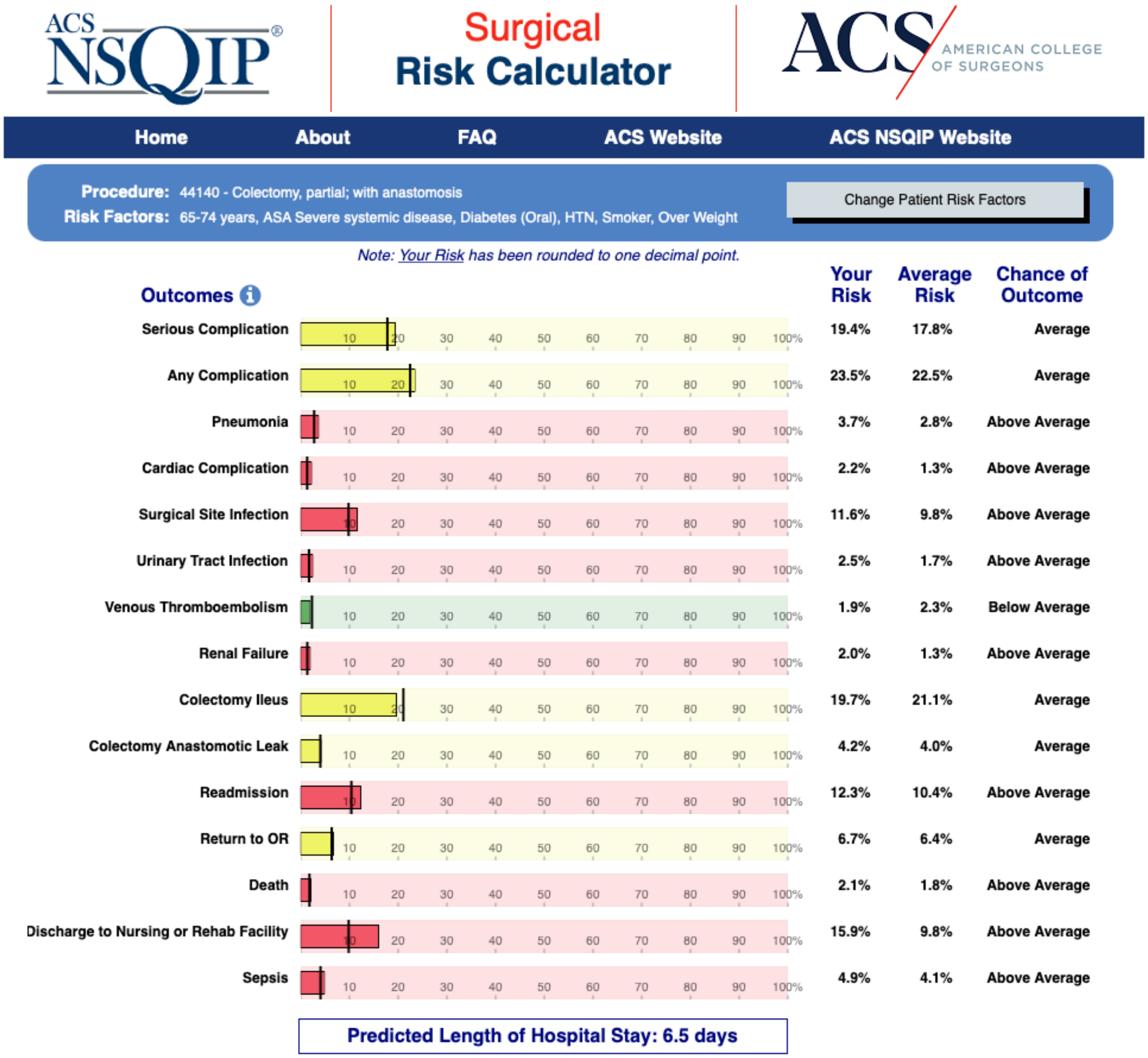
Appendix A: Cause and Effect Diagram for Development of SSI



Appendix B: ACS-NSQIP Surgical Risk Calculator



Appendix C: Risk Calculator Results – Example Patient



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Procedure: 44140 - Colectomy, partial; with anastomosis

Risk Factors: 65-74 years, ASA Severe systemic disease, Diabetes (Oral), HTN, Smoker, Over Weight

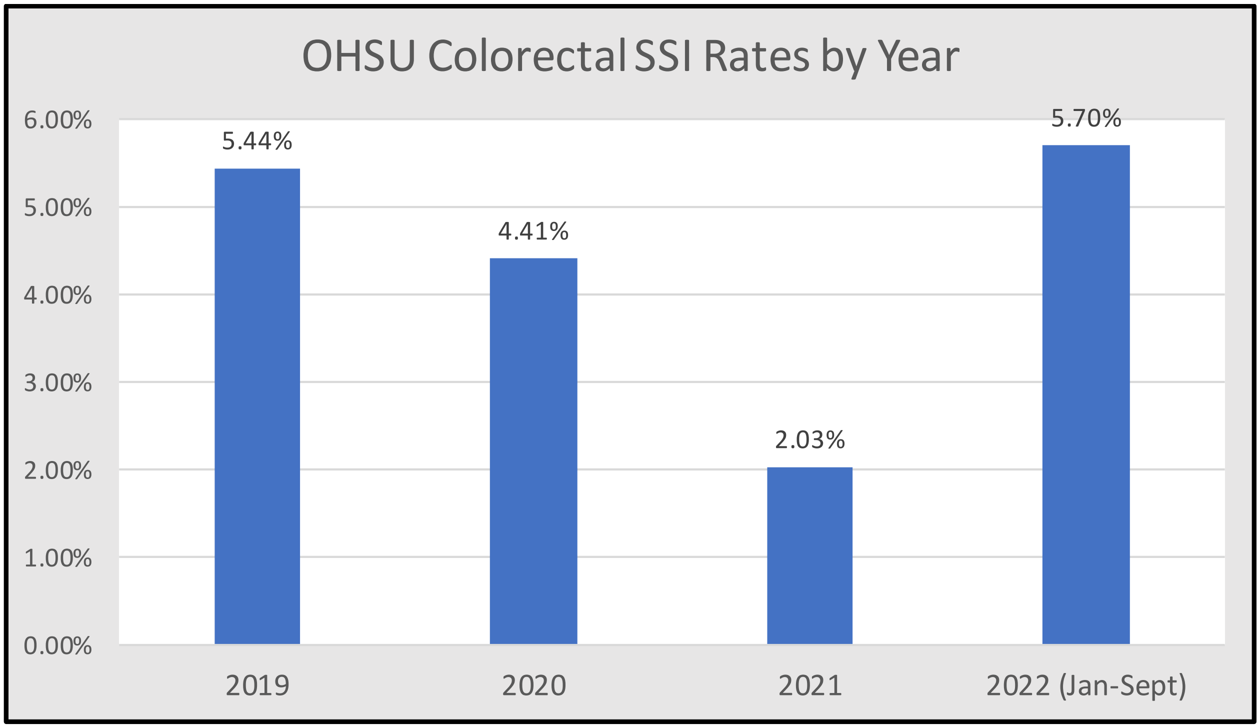
Change Patient Risk Factors

Note: Your Risk has been rounded to one decimal point.

Outcomes	Your Risk	Average Risk	Chance of Outcome
Serious Complication	19.4%	17.8%	Average
Any Complication	23.5%	22.5%	Average
Pneumonia	3.7%	2.8%	Above Average
Cardiac Complication	2.2%	1.3%	Above Average
Surgical Site Infection	11.6%	9.8%	Above Average
Urinary Tract Infection	2.5%	1.7%	Above Average
Venous Thromboembolism	1.9%	2.3%	Below Average
Renal Failure	2.0%	1.3%	Above Average
Colectomy Ileus	19.7%	21.1%	Average
Colectomy Anastomotic Leak	4.2%	4.0%	Average
Readmission	12.3%	10.4%	Above Average
Return to OR	6.7%	6.4%	Average
Death	2.1%	1.8%	Above Average
Discharge to Nursing or Rehab Facility	15.9%	9.8%	Above Average
Sepsis	4.9%	4.1%	Above Average

Predicted Length of Hospital Stay: 6.5 days

Appendix D: diagram SSI



Data obtained from OHSU Department of Infection Prevention and Control.

Appendix E: One-Way ANOVA Analysis of OHSU Colorectal SSI Rates 2019-2022

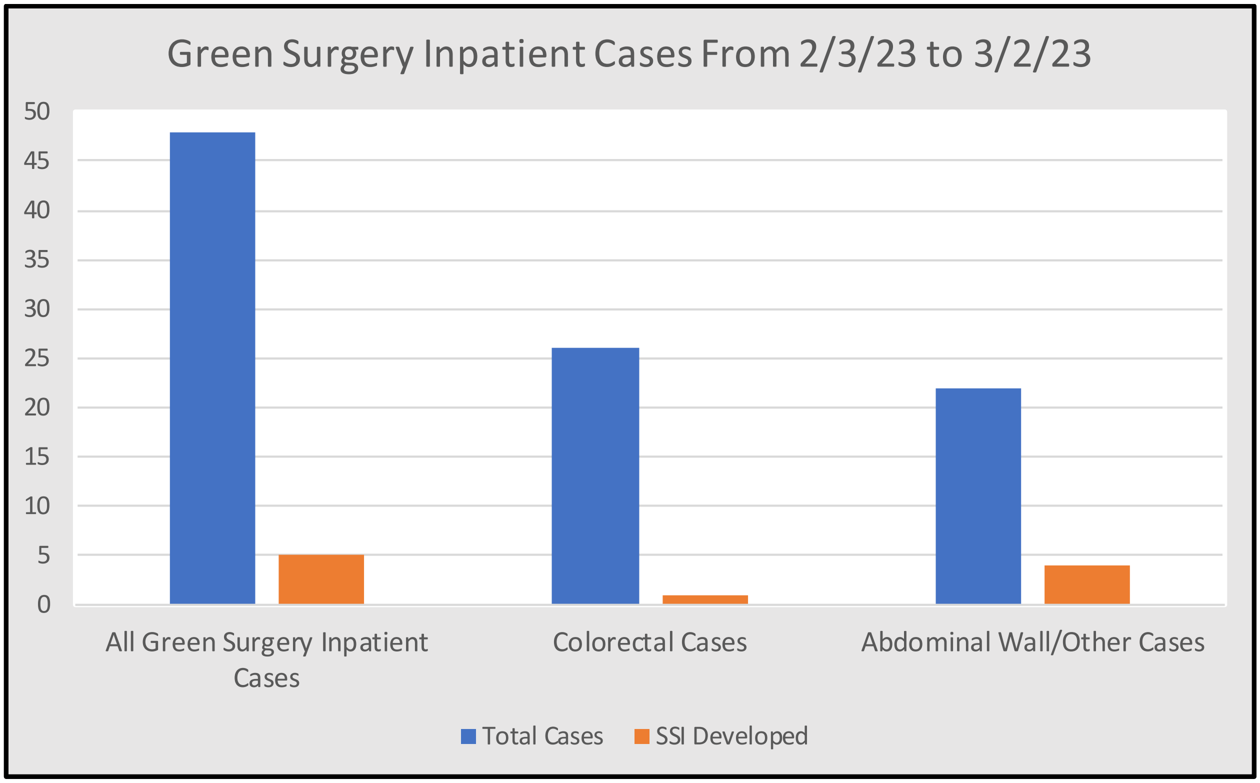
Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5
8.9	0	4.5	0	
5.0	3.0	3.3	0	
0	0	2.8	0	
10.3	0	5.9	16.7	
0	4.9	0	10	
2.9	5.9	4.0	8.6	
6.2	4.4	0	9.1	
13.5	9.4	0	3.8	
3.0	8.1	0	3.1	
11.4	13.8	0		
2.1	3.4	3.8		
2.0	0	0		

Summary of Data						
	Treatments					
	1	2	3	4	5	Total
N	12	12	12	9		45
ΣX	65.3	52.9	24.3	51.3		193.8
Mean	5.4417	4.4083	2.025	5.7		4.307
ΣX^2	586.77	443.15	104.23	559.71		1693.86
Std.Dev.	4.5868	4.3688	2.2365	5.7804		4.419

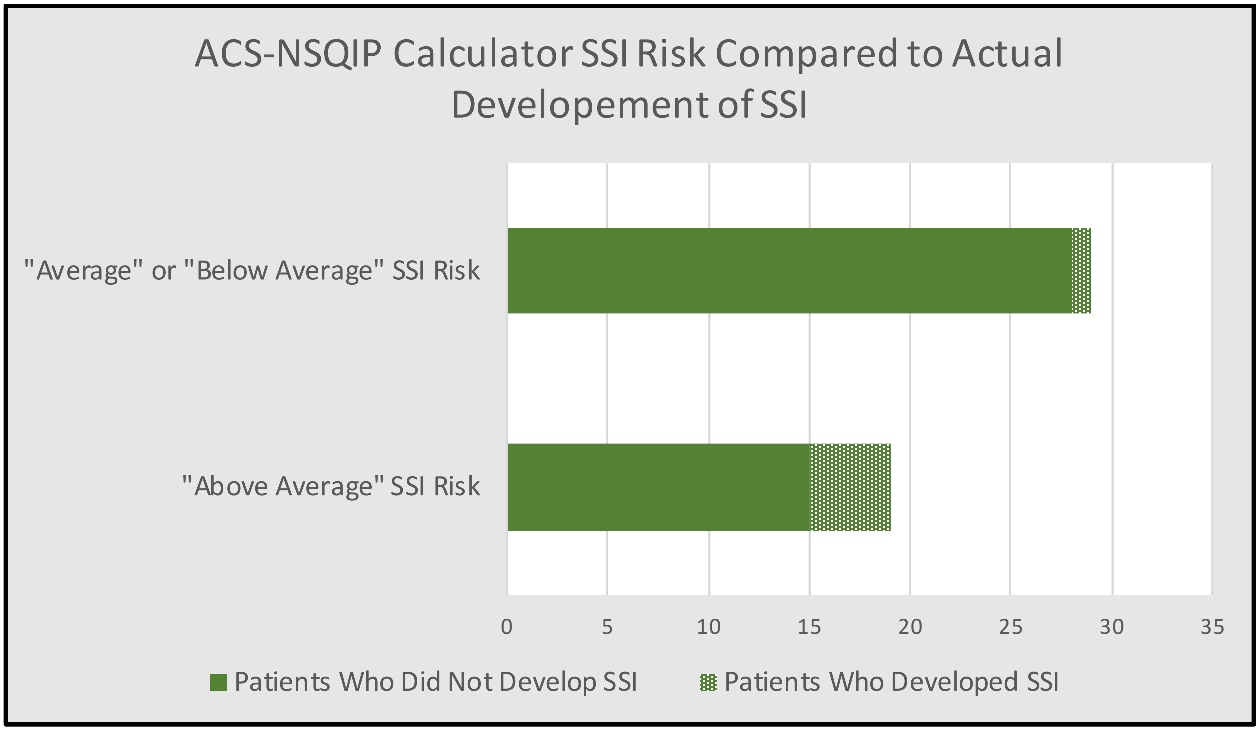
Result Details				
Source	*SS*	*df*	*MS*	
Between-treatments	95.5272	3	31.8424	$F = 1.70949$
Within-treatments	763.7008	41	18.6268	
Total	859.228	44		

The f-ratio value is 1.70949. The p-value is .180036. The result is *not* significant at $p < .05$.

Appendix F: Comparison of Colorectal SSI Rates



Appendix G: ACS-NSQIP Calculator SSI Risk Compared to Actual Development of SSI



Appendix H: Cohen's Kappa Statistics between ACS-NSQIP Predictions and Actual SSI Outcomes from Intervention Period

Quantify agreement with kappa results

	A	B	Total
A	19	29	**48**
B	5	43	**48**
Total	**24**	**72**	**96**

Number of observed agreements: 62 (64.58% of the observations)
Number of agreements expected by chance: 48.0 (50.00% of the observations)

Kappa= 0.292
SE of kappa = 0.085
95% confidence interval: From 0.126 to 0.457

"One way to interpret kappa is with this scale (1):

Kappa < 0: No agreement
Kappa between 0.00 and 0.20: Slight agreement
Kappa between 0.21 and 0.40: Fair agreement
Kappa between 0.41 and 0.60: Moderate agreement
Kappa between 0.61 and 0.80: Substantial agreement
Kappa between 0.81 and 1.00: Almost perfect agreement."

Row A: ACS-NSQIP SSI risk predictions (Column A- "Above Average" SSI risk; Column B- "Average or "Below Average" SSI risk)

Row B: Actual SSI outcomes (Column A- Developed SSI; Column B- No SSI)