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ORIGINAL SCIENTIFIC REPORT

Development and Validation of a Scoring System to Predict Surgical Site Infection After Ventral Hernia Repair: A Michigan Surgical Quality Collaborative Study

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Abstract

Introduction Surgical site infections (SSIs) are a rare but significant complication following an elective ventral hernia repair. This study aims to develop a risk assessment tool in order to predict the risk of developing SSIs postoperatively.

Methods All patients undergoing an elective ventral hernia repair were identified using the Michigan Surgical Quality Collaborative (MSQC) database. Patients' demographics, comorbidities and technical aspects of the operations were extracted. Logistic regressions were used to create a predictive scoring system for SSIs.

Results A total of 4983 were included. SSIs occurred in 3.4% of the patient population. A stepwise forward logistic regression identified the need to use drains, BMI, wound classification at the end of the surgery, presence of severe adhesions, a history of CAD, the need for intensive care after surgery, the use of pressors, EtOH abuse and history of PVD as being independently associated with the development of postoperative surgical site infections.

Conclusion In patients undergoing an elective hernia repair, the incidence of SSI is low. Several preoperative and perioperative factors can contribute to the development of SSIs.

Introduction

Over 400,000 ventral or incisional hernia repairs are performed each year in the USA, many performed on an elective basis. These range from small hernias, which are repaired primarily or with mesh in an outpatient setting to complex abdominal wall reconstructions, which sometimes require a prolonged hospital stay [1].

Patients who develop ventral or incisional hernias exhibit a wide range of comorbidities that pose a complex challenge to their postoperative care [2]. A rare but devastating complication is the development of a surgical site infection (SSI). The overall incidence of SSIs is estimated to be 4.9% in this patient population. The development of a SSI can increase length of hospital stay by 9.7 days and add an additional $20,800 in hospital costs.

Hospital-acquired infections continue to be a common cause of mortality in hospitals. In fact, a study done in 2002 shows there to be more than 1.7 million occurrences of hospital-acquired infections in a 1-year span. These incidences led to more than 99,000 deaths [3]. Surgical site infections contributed to about 20% of the hospital-acquired infections and are the second most contributors to hospital-acquired infections after urinary tract infections. A more recent analysis showed a rate of 9.5 cases of SSIs per 1000 surgical hospitalizations [4]. This study also showed that patients with a procedure in the category of skin, subcutaneous tissue and breast are almost three times more likely to

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get a SSI during their hospitalization. Surgical admissions complicated by a SSI showed an increased stay of about 9.7 days and an increased cost of about $20,842. Previous literature on open ventral or incisional reducible hernia repairs had about a 5.5% incidence of a wound complication [5]. Of these complications, development of SSI was found to have an incidence of about 4.9%. Procedures done laparoscopically had about a 1.1% incidence of a SSI.

The present study aimed to investigate potential preoperative risk factors as well as perioperative decision making, such as initiation and duration of perioperative antibiotics that would provide a risk assessment tool in order to predict the risk of developing superficial surgical site infections postoperatively.

Methods

This is a retrospective study utilizing the Michigan Surgical Quality Collaborative (MSQC) database. After IRB approval, all patients undergoing an elective ventral or incisional hernia repair were identified using CPT codes (49560: repair initial incisional or ventral hernia; reducible and 49565: repair recurrent incisional or ventral hernia; reducible). Only patients undergoing an elective operation were included in the analysis. The Michigan Surgical Quality Collaborative is a combined effort from Michigan hospitals to improve the quality of surgical care in all aspects of patient's care, spanning from better patient care to lower overall cost. The collaborative includes more than 50 hospitals across the state, thus representing the largest regional database in the USA.

For the purposes of the study, the population was divided into two groups based on the development of postoperative surgical site infection. The definition of surgical site infection included superficial surgical site infection, deep surgical site infection and deep space/organ infection as defined by the Centers for Disease Control and Prevention.

Multiple variables were extracted from the database, including age, gender, body mass index, alcohol use, tobacco abuse, functional status preoperatively, presence of comorbidities (diabetes, chronic obstructive pulmonary disease, sleep apnea, congestive heart failure, arrhythmias, coronary artery disease, hypertension, peripheral vascular disease, deep vein thrombosis) and American Society of Anesthesiologists (ASA) classification. The technical aspects of the surgery were also extracted, including the type of surgical procedure, the use of mesh, the presence of intraperitoneal adhesions, use of drains postoperatively, use of insulin intraoperatively, intraoperative temperature, use of vasopressors, use of preoperative antibiotic prophylaxis and wound classification at the end of the surgery.

Statistical analysis

The cohorts with and without surgical site infections were compared for differences in demographics, clinical characteristics and intraoperative findings using a bivariate analysis. Chi-square or Fisher's exact test were used to compare proportions. Continuous variables were examined for normality of distribution using the Shapiro–Wilk test. Student's t test was used for analysis of normally distributed variables while nonparametric tests were compared using Mann–Whitney U test.

In order to identify the independent predictors of postoperative surgical site infection, the study population was randomly divided in thirds. Two-thirds of the study population was used for the derivation of the scoring system, while one-third was used to validate it. In order to derive the scoring system, a forward stepwise logistic regression was performed adjusting for variables that were different in the univariate analysis at a $p < 0.2$. Adjusted odds ratios and 95% confidence intervals were derived from the regression. The summation of the beta coefficients from the regressions was used to describe a composite score to predict the development of SSIs. Based on the scoring system, every patient was assigned a score. The validation group was then divided in groups based on the scoring system, and logistic regressions were performed. Adjusted odds ratios with 95% CI were identified for each group and those were compared to the derivation groups. The area under the curve (AUC) with 95% CI was calculated for both groups.

Results

A total of 4983 patients underwent an elective ventral hernia repair from 2013 to 2015 and met the criteria for inclusion in the study. Of these, 167 (3.4%) patients developed postoperative surgical site infections, and 4816 (96.6%) did not develop an infection.

The demographics and clinical characteristics are depicted in Table 1. Patients that developed surgical site infections were more likely to have a higher BMI (35 vs. 32) and have a history of chronic obstructive pulmonary disease, coronary artery disease, congestive heart failure and peripheral vascular disease (16 vs. 10%, 22 vs. 14%, 2 vs. 0.3% and 7 vs. 3%, respectively). Patients that developed surgical site infections were significantly more likely to be assigned an ASA fitness grade of III or IV compared to their counterparts (55 vs. 43% for grade III and 5 vs. 3% for IV, respectively, $p < 0.05$).

Table 2 depicts the procedural details of the hernia repair. Repair of recurrent hernia and more extensive reconstruction via component separation were associated

Table 1 Demographics and clinical characteristics

	No SSI ($n = 4816$)	SSI ($n = 167$)	p value
Male gender	2570 (53.4)	97 (58.1)	0.229
Age			
BMI	31.8 ± 7.6	35.2 ± 8.0	<0.001
Comorbidities			
Diabetes	929 (19.3)	48 (28.7)	0.014
Use of tobacco	1185 (24.6)	44 (26.3)	0.608
Use of EtOH	138 (2.9)	0 (0.0)	0.015
Dyspnea	451 (9.4)	22 (13.2)	0.078
COPD	484 (10.0)	26 (15.6)	0.021
CHF	14 (0.3)	3 (1.8)	0.018
Arrhythmias	356 (7.4)	19 (11.4)	0.055
CAD	654 (13.6)	36 (21.6)	0.003
HTN on medication	2524 (52.4)	108 (64.7)	0.002
PVD	141 (2.9)	12 (7.2)	0.002
History of DVT	323 (6.7)	22 (13.2)	0.001
History of bleeding disorder	155 (3.2)	11 (6.6)	0.017
Functional status			
I	4718 (98.0)	162 (97.0)	
II	71 (1.5)	3 (1.8)	
III	10 (0.2)	2 (1.2)	
IV	17 (0.4)	0 (0.0)	0.063
ASA classification			
I	275 (5.7)	3 (1.8)	
II	2327 (48.3)	64 (38.3)	
III	2068 (42.9)	92 (55.1)	
IV	146 (3.0)	8 (4.8)	0.002

BMI body mass index, *COPD* chronic obstructive pulmonary disease, *CHF* congestive heart failure, *CAD* coronary artery disease, *HTN* hypertension, *PVD* peripheral vascular disease, *DVT* deep vein thrombosis, *ASA* American Society of Anesthesiology

Table 2 Procedural details

	No SSI ($n = 4816$)	SSI ($n = 167$)	p value
Surgical procedure			
Repair of initial ventral hernia	3643 (75.6)	108 (64.7)	<0.001
Repair of recurrent hernia	997 (20.7)	58 (34.7)	<0.001
Repair of umbilical hernia	176 (3.7)	1 (0.6)	<0.001
Component separation	190 (3.9)	16 (9.6)	<0.001
Procedural details			
Placement of mesh	2769 (57.5)	104 (62.3)	0.219
Presence of adhesions			
Mild	3843 (79.8)	97 (58.1)	
Moderate	510 (10.6)	32 (19.2)	
Severe	463 (9.6)	38 (22.8)	<0.001
Presence of drains	1474 (30.6)	104 (62.3)	<0.001
No intraoperative use of insulin	4776 (99.2)	164 (98.2)	0.002
Intraoperative warming	3789 (78.7)	149 (89.2)	0.001
Intraoperative use of vasopressors	1347 (28.0)	71 (42.5)	<0.001
Antibiotic prophylaxis	4451 (94.2)	160 (98.2)	0.031
Patient transferred to SICU after OR	43 (0.1)	9 (5.4)	<0.001
Wound classification at the end of the surgery			
Clean	4284 (89.0)	122 (73.1)	
Clean/contaminated	398 (8.3)	26 (15.6)	
Contaminated	59 (1.2)	12 (7.2)	
Infected	75 (1.6)	7 (4.2)	<0.001

SICU surgical intensive care unit, *OR* operating room

Table 3 Independent predictors of SSIs

Step	Variable entered	AOR (95% CI)	adj-p
1	Presence of drains	1.65 (1.38, 1.99)	<0.001
2	BMI	1.04 (1.02, 1.06)	<0.001
3	Wound classification	1.49 (1.19, 1.85)	<0.001
4	Presence of adhesions	1.31 (1.06, 1.62)	0.013
5	History of CAD	1.65 (1.12, 2.43)	0.021
6	Patient to SICU from OR	2.50 (1.07, 5.88)	0.035
7	Intraoperative use of vasopressors	1.42 (1.02, 1.98)	0.039
8	History of EtOH abuse	1.21 (1.01, 1.85)	0.04
9	History of PVD	1.98 (1.03, 3.80)	0.04

AUROC (95% CI) 0.72 (0.68, 0.76), adj-$p < 0.001$

BMI body mass index, *CAD* coronary artery disease, *SICU* surgical intensive care unit, *OR* operating room, *PVD* peripheral vascular disease

with a higher probability of surgical site infection (35 vs. 21% and 10 vs. 4%, respectively, $p < 0.05$). Interestingly the use of mesh was not associated with a higher incidence of surgical site infection (Table 2). The need to use drains resulted in a twofold increase in the incidence of surgical site infections (62 vs. 31%, $p < 0.05$). As expected, hypothermia and use of vasopressors were associated with higher incidence of SSIs in the study population (Table 2).

A stepwise forward logistic regression identified the need to use drains, BMI, wound classification at the end of the surgery, presence of severe adhesions, a history of CAD, the need for intensive care after surgery, the use of pressors, EtOH abuse and history of PVD as being independently associated with the development of postoperative surgical site infections [Table 3, AUROC (95% CI): 0.72 (0.68, 0.76), adj-$p < 0.001$]. The composite score derived from the regression is shown in Table 4. The score was validated with a validation group (Table 5). Figure 1 shows the probability of developing surgical site infection stratified by the score.

Table 4 Scoring system

Variable	Point
Presence of drains	5
BMI	
10	1
20	2
30	3
>40	4
Wound classification	
Contaminated	2
Infected	4
Presence of adhesions	3
History of CAD	4
Patient to SICU from OR	2
Intraoperative use of vasopressors	4
History of EtOH abuse	1
History of PVD	1

BMI body mass index, *CAD* coronary artery disease, *SICU* surgical intensive care unit, *OR* operating room, *PVD* peripheral vascular disease

Table 5 Validation of the scoring system

Groups	Mean probability (%)	Score	Derivation group AOR (95% CI)	Validation group
1	1.6 ± 0.1	1–6	1.52 (0.32, 2.31)	1.41 (0.89, 1.87)
2	3.5 ± 0.2	7–11	1.89 (1.21, 3.54)	1.97 (1.54, 2.41)
3	7.4 ± 0.4	12–15	2.67 (1.94, 3.57)	2.54 (2.01, 3.98)
4	12.4 ± 0.6	16–19	2.82 (1.54, 4.57)	3.01 (1.24, 5.23)
5	24.1 ± 0.7	≥20	4.56 (3.17, 7.23)	5.62 (3.89, 8.34)

AOR (95% CI) adjusted odds ratios (95% confidence intervals)

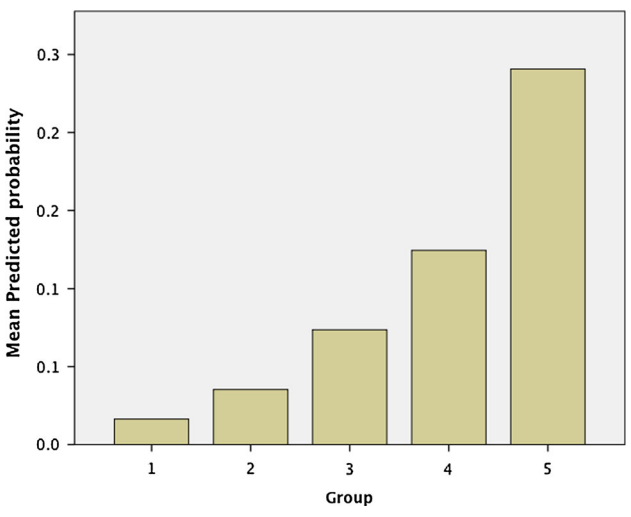

Fig. 1 Predicted probability per group

Discussion

The present study provides a novel risk assessment scoring system for SSI that can serve as a tool to counsel and risk stratify patients undergoing an elective ventral hernia repair. Development of surgical site infection is a rare complication in patients undergoing an elective ventral hernia repair. The suggested grading system can allow us to counsel our patients and predict risk factors for developing a superficial surgical site infection.

There have been previous studies examining the risk factors of SSI after a hernia repair. One such study is that of the Ventral Hernia Working Group. This study proposed a grading system to assess the perioperative risk of a wound complication [6]. The grading system was based on various factors including obesity, smoking, COPD, immunocompromise and previous infection, among others. This grading system, however, was based only on the literature review, and not on actual patient data. The study also focuses on recommending the use of synthetic versus biological mesh based on the grading system. It also looks at all wound complications rather than SSI alone. A more focused scoring system was proposed by Berger [7]. The proposed scoring system was based on concomitant hernia repair, presence of skin flaps, ASA, BMI and wound classification. Each factor is assigned a different value of points, and patients are placed into different groups depending on their final score, similar to our proposed system. Group I had the lowest risk with a score of 0, and Group V had the highest with a score of 11–16. It is important to point out that this study included acute cases of ventral hernia repair in their formulation of the score, while our study was entirely made of elective cases. As such, our scoring system is more applicable in the elective setting. A modern application that assesses the perioperative risk of SSI in ventral hernia repair is the CeDAR mobile software. Based on a 1-year prospective study, the authors formulated a mathematical equation to derive a patient's probability of an SSI and the associated hospital costs [8]. The risk factors included in this equation are smoking, active infection, previous repair, uncontrolled diabetes, presence of stoma and BMI > 26. The derived mathematical formula requires the mobile application, which may restrict its use among clinicians. Our novel scoring system takes into account several risk factors that were not in the previous studies. One such factor is the presence of drains. The presence of drains has shown to be an independent risk factor in the incidence of SSI after a ventral hernia repair [9]. Our analysis also shows a history of CAD and PVD to be significant risk factors as well. These were not considered in previous studies, but contribute to the overall score in our system. It is possible that

microvascular disease impairs the chemotaxis of white cells, potentially resulting in impaired wound healing and ability to fight infections.

There might be several implications to the present study. The use of scoring systems that predict the probability of SSI can act as a guide to the clinician when making the decision to administer perioperative antibiotics. Though there is a limited number of studies focusing on perioperative antibiotics in open ventral hernia repairs, there has been much done regarding open inguinal hernia repairs. A cochrane analysis done in 2012 did not show a clear benefit to universally administering antibiotics perioperatively [10]. Rather than a universal approach, it is possible that the use of the scoring system would allow clinicians to have a more targeted approach. Based on our findings, we believe that a subpopulation of patients undergoing an open ventral or incisional hernia repair will potentially benefit from perioperative antibiotics while other groups would not. We propose a risk stratification score that clinicians can use to help guide them to properly identify that subpopulation which is at increased risk of developing an SSI based on objective measurements. We can further apply our findings in the intraoperative and postoperative phases of care as well. As our results indicate, inserting drains significantly increase the chance of having an SSI. Therefore, minimizing the insertion of drains intraoperatively, removing them sooner than later in the postoperative care of the patient may be of benefit.

Our study is not without limitations. It is a retrospective study composed of a patient population from the Michigan Surgical Quality database. This presents the possibility of various biases that could have affected the results. To overcome these limitations, it is clear that we need large prospective randomized trials to further assess the validity of our scoring system. In addition, the use of antibiotics and their impact on development of surgical site infections was not assessed. The duration of perioperative antibiotics was not recorded in the database and as such, no associations can be made. Furthermore, the majority of the patients received preoperative antibiotics and no statistical conclusions could be drawn. Finally, the duration of drains was not addressed in the database and subsequently we were not able to identify a correlation between the duration of drains and the probability of developing a SSI.

In conclusion, in patients undergoing an elective hernia repair, the incidence of SSI is low. Several preoperative and perioperative factors can contribute to the development of SSIs. A novel scoring system may be beneficial in identifying group of patients who are at high risk. Further research is warranted.

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