The American Journal of Surgery 217 (2019) 1089–1093

Contents lists available at ScienceDirect

The American Journal of Surgery

journal homepage: www.americanjournalofsurgery.com

Reduction of surgical site infections in colorectal surgery: A 10-year experience from an independent academic medical center

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ARTICLE INFO

Article history:
Received 9 March 2018
Received in revised form
31 October 2018
Accepted 8 November 2018

Keywords:
Surgical site infection
Colorectal surgery
Quality improvement
Evidence-based practice

ABSTRACT

Background: Surgical site infections (SSI) are a source of patient morbidity and increased cost. In 2007, our organization discovered an SSI rate of 18% after colorectal surgery (CRS), corresponding to an ACS NSQIP benchmarked high outlier.
Methods: From 2007 to 2016, surgeons championed a stepwise, multidisciplinary improvement pathway for SSI reduction. NSQIP was used to track SSI rates and estimate cost savings.
Results: From 2007 to 2016, 1508 patients underwent CRS at our facility. In 2007, our SSI rate was 18%. In 2016, the SSI rate was 7%, corresponding to a NSQIP benchmarked exemplary performance. 54 patients avoided the morbidity of a SSI. The expense of SSI reduction implementation was $180,000. Cost savings was estimated at $1.3 million.
Conclusions: Our approach reduced SSI rates by 58% over ten years. We observed a significant morbidity reduction and cost savings. Our strategy could be adopted within other medical centers focused on CRS SSI improvement.

Introduction

Surgical site infections (SSI) are a well-recognized contributor to post-operative morbidity and cost.[1,2] Patients who develop deep SSI report significant suffering and negative impact on quality of life.[3] In addition, SSIs have been shown to prolong hospital stay,[2] and delay initiation of adjuvant therapies in cases of malignancy.[4] Moreover, SSIs are associated with a substantial increase in healthcare expenditures, with an average cost of $27,631.00 per SSI.[5] SSIs following colorectal surgery (CRS), in particular, can be a challenging and frustrating complication for the patient and care team.

In 2007, our institution began participating in the American College of Surgeons National Surgical Quality Improvement Program (NSQIP). This data led to the discovery that our SSI rate after CRS was 18%, which corresponded to the bottom decile when benchmarked against similar institutions. We recognized an opportunity for process improvement. The use of NSQIP data to track and improve surgical outcomes has been well-documented.[6] To address the SSI issue in CRS patients at our institution, we gathered a multidisciplinary team consisting of surgeons, infectious disease physicians, nurses, pharmacists, and nutritionists. We utilized a gradual and stepwise approach, with small changes based on best available data emerging from each specialty. The objective of this study was to share the multidisciplinary steps towards SSI reduction over a 10-year period in patients undergoing CRS.

Materials and methods

Our institution is a 325-bed independent academic medical center that serves as the main campus of an integrated multispecialty health system serving 19 counties in a three-state region. All colorectal surgeries during this 10 year period were performed at a single institution by general surgeons. General surgery residents were involved in pre, intra, and postoperative care of patients. CRS procedures were defined by CPT codes (44140, 44141, 44143, 44144, 44145, 44146, 44147, 44150, 44155, 44157, 44158, 44160, 44204, 44205, 44206, 44207, 44208, 44210, 44211, 44212,

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https://doi.org/10.1016/j.amjsurg.2018.11.010
0002-9610/

45110, 45111, 45113, 45119, 45123, 45130, 45135, 45395, 45402, 45550). This study was reviewed and deemed exempt by our Institutional Review Board. Definitions for superficial, deep and organ space SSIs followed those outlined by NSQIP.[7]

From 2007 to 2016, our surgeons championed a stepwise improvement pathway aimed at reduction of SSIs in CRS, using plan, do, study, and act (PDSA) principles. This was a multidisciplinary collaboration involving stakeholders from departments of surgery, anesthesia teams, infectious disease specialists, pharmacists, nurses, dieticians, and our patients. Small changes were made over time using emerging data from each part of the team (Fig. 1).

The timeline for specific interventions over the 10-year period is illustrated in Fig. 2. An emphasis was placed on use of minimally invasive surgery (MIS) when appropriate. Starting in 2010, patients identified as high-risk for SSI based on initial surgical consultation were sent to an optimization clinic overseen by internal medicine physicians. This specifically involves optimization of medical comorbidities that may impact post-operative outcomes, such as diabetes mellitus, pulmonary disease, malnutrition, chronic kidney disease and tobacco abuse. Surgeon education was provided regarding SSI risks related to wound class. Surgeons were strongly encouraged to leave wounds open for all class 3 and 4 wounds, as well as class 2 wounds in high-risk patients. In these cases, open wounds were managed according to surgeon preference and included wet-to-dry dressings, wound vac placement, and in more recent years, vessel loops have been used to keep the skin open. In 2011, the use of wound protectors became standard for CRS cases. Our institution adopted a restricted blood product transfusion protocol during this time, and our surgeons adhered to these recommendations.[8] In 2013, separate closing trays were introduced for all CRS procedures. Also in 2013, our department implemented a standardized enhanced recovery after surgery (ERAS) protocol. Our institution-specific ERAS program has been previously described.[9] This included both chemical (PO neomycin and metronidazole) and mechanical (GOLYTELY) bowel prep, as well as intravenous ceftriaxone and metronidazole as preferred preoperative antibiotics. Antibiotics were dosed using a weight-based protocol. Intravenous antibiotics were also made available to anesthesia teams in operative room medicine dispensers, for re-dosing in long cases or cases of high blood loss. In 2014, 2% chlorhexidine gluconate (CHG) and 70% isopropyl alcohol was chosen as the standardized skin prep agent in the operating room for CRS cases. Additionally, during the preoperative visit, patients are provided with CHG wipes to be used the night prior to surgery and in the preoperative area on the day of surgery. Our institution also started pre and postoperative patient wound care education. Patients are provided with interactive educational videos that can be watched from hospital televisions on an internal network, and patients are encouraged by nursing staff to watch these and ask questions. In 2015, an institutional "SSI bundle" was implemented for all general surgery cases. This included forced-air patient warming (Bair Hugger®, 3M, Maplewood, MN) in the preoperative area, maintenance of intraoperative normothermia with forced-air warming devices, and maintenance of intraoperative glycemic control. In addition, timers were placed by scrub sinks to guide proper duration of surgical personnel hand wash. In 2016, we introduced preoperative nutrition supplementation. This utilizes a nutritional supplement drink (Impact Advanced Recovery®, Nestle Health Science, Bridgewater, NJ) TID for 5 days prior to surgery and a carbohydrate loading beverage, such as apple juice or Gatorade® (PepsiCo, Purchase, NY), starting the night before surgery. Fig. 1 shows our specific interventions categorized by the pre, intra, and postoperative period. A majority of the interventions were incorporated into a standardized order set for CRS in the electronic medical record for convenience and enhanced compliance.

We retrospectively analyzed data from the 10 year time period and identified the rates of overall, superficial, deep, and organ space SSI. Patient demographics, co-morbidities and operative characteristics were compared for patients at the beginning versus the end of the ten year period. Statistical analysis included the Chi-Square, Wilcoxon rank sum and Cochran-Armitage trend tests. A P value < 0.05 was considered statistically significant. We estimated the expense of infection prevention based on costs of all new perioperative interventions aimed at SSI reduction. We estimated cost-savings using NSQIP SSI cost estimates in 2007 dollars.[5]

Results

From 2007 to 2016, 1508 patients underwent CRS at our institution. In 2007, the NSQIP SSI rate was 18% and averaged 16% from the timeframe between 2007 and 2010. From 2011 to 2013, the NSQIP SSI rate averaged 16%. From 2014 to 2016, the NSQIP SSI rate

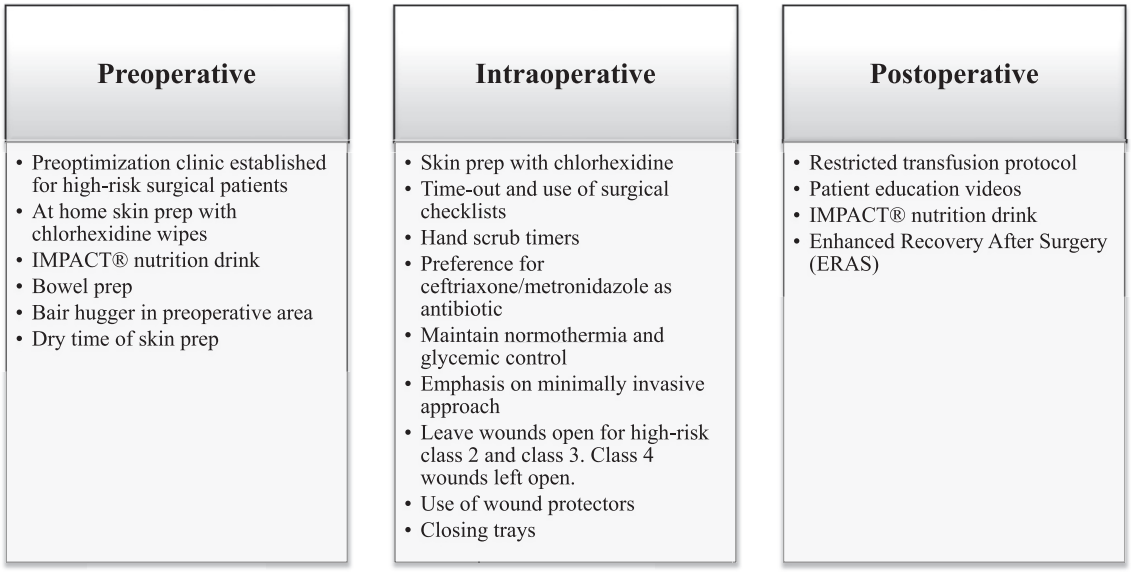


Fig. 1. Changes implemented to reduce surgical site infections and improve care by phase.

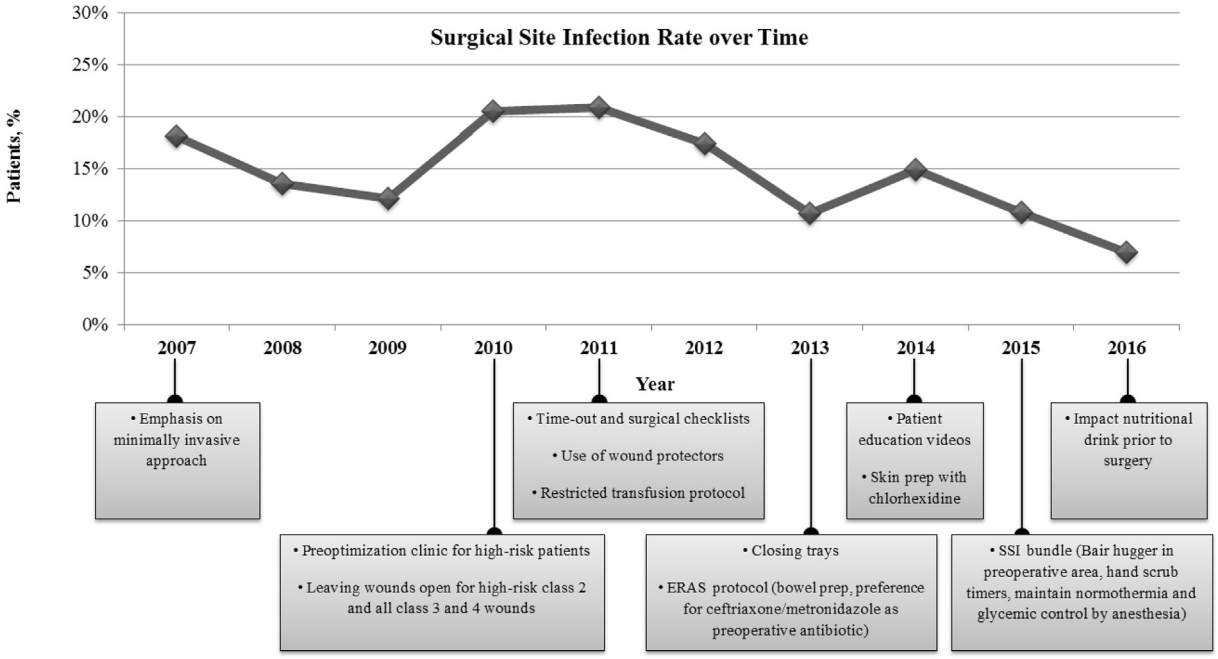
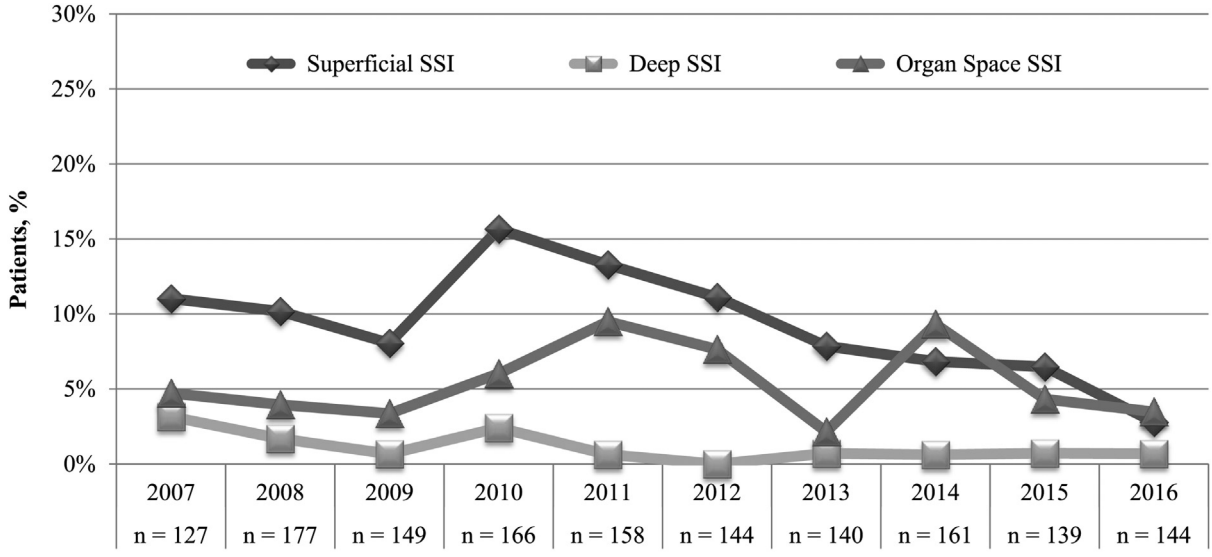


Fig. 2. Surgical site infection rates after colorectal surgery and infection prevention implementation strategies over time.

averaged 11% with a final SSI rate of 7% in 2016. Fig. 2 illustrates the overall SSI rate over the 10-year period and the interventions implemented. A significant negative trend in superficial and deep SSIs were observed over the study period (Fig. 3).

Our interventions were associated with a 58% relative decrease in SSI rates over the ten year period, from 18% in 2007 down to 7% in 2016. This corresponded to NSQIP exemplary performance in the top ten percentile benchmarked performance for 2016. If we



SSI = Surgical site infection.

$P = 0.003$ for comparison of superficial SSI across all years.

$P = 0.03$ for comparison of deep SSI across all years.

$P = 0.73$ for comparison of organ space infections across all years.

Fig. 3. Type of surgical site infections that occurred over the study period.

assume a constant 18% SSI rate across the time period without intervention, we estimate 54 patients avoided the morbidity of postoperative SSIs with these interventions. During this time period, the estimated expense of SSI reduction implementation was $180,000 for all products and supplies. Using the estimated 54 SSIs that were avoided, at an estimated cost of $27,631 per SSI,[5] the cost-savings was estimated at $1.3 million from prevention of SSIs after accounting for cost of implementation.

Patient groups remained similar over the ten-year period, with the exception of an increase in BMI and higher number of wound class 3 and 4 cases, and slightly fewer emergent/urgent cases toward the end of the 10-year period (Table 1). A significant decrease in length of stay, transfusion rate, and 30-day mortality was noted at the end of the study period (Table 2). Operative approach was available for 2012–2016 cases and included 51% laparoscopic, 46% open, and 2% robotic. This includes all cases, regardless of whether it was emergent or elective. Anastomotic leak data were limited to cases performed from 2012 through 2016 (n = 736); the anastomotic leak rate was 3% overall, and 1% in 2016. Discharge disposition was only available for 2010–2016 cases (n = 985), however, the majority of patients, overall, were discharge to home (85%).

Discussion

Over the past decade, much has been written about methods for reduction of SSIs in CRS patients. Today, there are many "SSI bundles" and guidelines available to assist with SSI prevention and treatment.[10,11] However, when we began our journey to SSI reduction over 10 years ago, there was not such a robust availability of guidelines to help educate our practices. Though there were some existing guidelines,[12,13] new data was constantly emerging, and a standard approach to SSI reduction did not necessarily exist.

Once we had identified our SSI rate in CRS patients, the general surgery department at our medical center championed a process improvement pathway using a multidisciplinary team. This involved a culture change that developed a more standardized approach to perioperative care of CRS patients, incorporating changes based on emerging evidence-based literature, with less reliance on individual surgeon preference. The majority of changes were based on quality evidence and have been validated in the literature. The use of MIS has demonstrated reduction in the odds of an SSI occurring.[14] There is some evidence that delayed primary closure may lead to reduction in SSI rate.[15] We utilized wound protectors in CRS cases, though evidence regarding their efficacy is mixed.[16,17] We used restrictive transfusion protocols based on evidence that transfusion has been associated with increased risk of SSI.[18] Chlorhexidine surgical skin prep is utilized given the lower association with SSI rates.[19] Maintenance of normothermia and adequate perioperative glycemic control may help to lower SSI rates.[20,21]

We demonstrated a significant reduction in CRS SSI rates over this 10-year study period. As noted in Table 1, though patient characteristics remained similar over time, there was a notable increase in BMI and wound class 3 and 4 cases toward the end of the study period. We believe this underscores the significance of our interventions, as one might expect the SSI rates to increase with higher BMI and more contaminated wounds. Additionally, we observed a significant decrease in mean length of stay, transfusion rate, and 30-day mortality at the end of the study period. Though the focus of this study was SSI reduction, these additional findings indicate other positive effects of continued dedication to improving patient care.

This study demonstrates the feasibility of SSI reduction in CRS at an independent academic medical center using a multidisciplinary approach. In addition, it illustrates the importance of continuous evaluation of outcomes and process improvement, using evidence-based practices to guide changes to perioperative care. We show that a focused and sustained effort using evidence-based interventions is beneficial from a morbidity and cost perspective.

Our stepwise approach to SSI reduction was not without challenges during this decade of process improvement. At the administrative level there was resistance to the initial costs associated with new items included in the improvement process, such as wound protectors, chlorhexidine, and preoperative nutritional drinks. This was overcome by explaining our philosophy of continuous improvement and that this expense for increased prevention efforts would ultimately reduce morbidity and the total cost of care.

Many surgeons had attributed postoperative SSIs to technical factors in the operating room, with less emphasis on the pre and postoperative characteristics. Throughout our study period, data began to emerge demonstrating the previously underemphasized contribution of perioperative factors to SSIs. Through continuous surgeon education, we were able to achieve a uniform recognition of the importance of optimizing pre and postoperative factors for SSI reduction. Surgeons identified that surgical technique was only a small part of the picture related to SSI.

There are also some potential limitations of our data. These include the retrospective observational nature and single institution experience. There was a higher proportion of dirty/infected wound classifications in recent years, which may be due to improvement in accurately classifying wounds, and as a result, more wounds may have been left open. Also, the compliance rates

Table 1
Patient and procedural characteristics over time.

Variable	Overall	2007	2016	*P* value
Mean Age, years	64.4 ± 15.5	67.5 ± 16.8	62.9 ± 15.4	0.007
Mean BMI, kg/m^2	28.8 ± 6.6	28.1 ± 5.6	30.1 ± 7.5	0.05
Sex, n (%)				0.42
Female	745 (50)	68 (54)	70 (49)	
Male	760 (50)	59 (46)	74 (51)	
Tobacco use, n (%)	289 (19)	18 (14)	26 (18)	0.41
Diabetes, n (%)	184 (12)	19 (15)	20 (14)	0.98
Emergent/urgent case, n (%)	224 (15)	30 (24)	21 (14)	0.05
Procedure type, n (%)				0.32
Colon	1370 (91)	113 (89)	133 (92)	
Rectal	135 (9)	14 (11)	11 (8)	
Wound class, n (%)				0.03
Clean/Clean - Contaminated	963 (64)	90 (71)	83 (58)	
Contaminated/Dirty	542 (36)	37 (29)	61 (42)	

Table 2
Hospital length of stay and postoperative complication rates over time.

Variable	Overall	2007	2016	*P* value
Mean LOS, days	6.8 ± 7.9	8.6 ± 9.2	6.7 ± 6.4	0.003
Postoperative complications, n (%)				
Any surgical site infection[a]	221 (15)	23 (18)	10 (7)	0.008
Superficial	142 (9)	14 (11)	4 (3)	0.007
Deep	17 (1)	4 (3)	1 (0.7)	0.19
Organ space	83 (6)	6 (5)	5 (3)	0.76
Urinary tract infection	42 (3)	5 (4)	2 (1)	0.26
Venous thromboembolism	26 (2)	2 (2)	2 (1)	0.99
Pneumonia	34 (2)	6 (5)	4 (3)	0.38
Acute renal failure	21 (1)	2 (2)	2 (1)	0.99
Transfusion	91 (6)	13 (10)	6 (4)	0.05
Clostridium difficile infection	3 (0.2)	0	3 (2)	0.25
30-day mortality	58 (4)	11 (9)	4 (3)	0.03

LOS = length of stay.
[a] Patients with more than 1 concurrent SSI are counted only once for this outcome.

and costs for many of our interventions are unknown. We have previously reported our outcomes of ERAS implementation that demonstrated a 75% compliance rate.[9] Starting in 2010, all patients undergoing elective CRS identified as high-risk were seen in the preoptimization clinic, however, emergent/urgent cases were unable to be optimized. In addition, we did not specifically track trends in variables such as tobacco cessation, improved blood glucose control, or nutrition status. We were unable to assess the number and cost of open wounds and their management due to variation in surgeon preference. Although the number of class 3 and 4 wounds and open wounds increased, the length of stay did not appear to be impacted. Emergent cases that met the CPT codes included in this series had a length of stay that was approximately one day longer than elective cases. We recognize that our institutional length of stay for CRS is slightly higher than national averages; however, open wound management did not delay discharge if the patient had met standard discharge criteria.

Our experience with continuous process improvement has led us to consideri future interventions for SSI reduction. Throughout the 10-year period that was examined here, there have been multiple research projects at our medical center investigating different interventions for SSI prevention. These included a study of preoperative hair clipping conducted from October 2009 to February 2015, as well as a study of topical mupirocin applied to the surgical site that began in November 2015 and has recently concluded. Of note, both studies showed no difference in SSI rates for the interventions compared.[22,23]

Conclusion

Our surgeon-led, multidisciplinary approach to SSI reduction in CRS used a series of PDSA cycles and continuous process improvement that resulted in a 58% overall reduction of SSI rates as measured by NSQIP over a ten year period. Using these interventions, our institution observed a significant morbidity reduction and cost savings. The specific components of our implementation strategy could be adopted within other medical centers focused on CRS SSI improvement.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest

There are no conflicts of interest to disclose.

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