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Impact of a preventive bundle to reduce surgical site infections in gynecologic oncology

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HIGHLIGHTS

- A SSI prevention bundle included pre, intra and postoperative strategies.
- The bundle reduced overall SSI and superficial SSI by 55% and 54%.
- This reduction in SSI was sustained over >6 quarters.

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ABSTRACT

Objective. To assess the impact of a surgical site infection (SSI) prevention bundle for Gynecologic Oncology patients at a large academic tertiary centre in Toronto, Canada.

Methods. A SSI prevention bundle was implemented in February 2017 including: preoperative chlorhexidine shower, prophylactic antibiotics, glycemic control, normothermia, and separate closing tray. Data were collected prospectively using the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) institutional data, and chart review of surgeries between January 2016 and September 2017 was performed. The primary outcome was rate of SSIs, secondary outcomes were: superficial, deep and organ space SSIs, sepsis, wound disruption, length of stay, 30-day readmission and reoperation. Logistic regression analysis was conducted to identify predictors of SSIs.

Results. 339 baseline and 224 post-intervention patients were included. 53 incurred one or more SSIs: 43 superficial, 6 deep, and 14 organ-space. The bundle decreased overall SSIs by 55% (12.1% to 5.4%, $p = 0.008$) and superficial SSIs by 54% (9.7% to 4.5%, $p = 0.023$). Improvement was sustained for 6 quarters.
No significant difference was found in other secondary outcomes. On multivariable analysis, surgery in the pre-bundle period, BMI ≥30, laparotomies and longer operative duration were independent risk factors for overall SSIs (OR 2.23, 95% CI 1.06–5.06, –OR 3.01, 95% CI 1.57 – 5.87, OR 3.70, 95% CI 1.56 – 10.18 and – OR 2.16, 95% 1.11 – 4.19, respectively).

Conclusions. This prevention bundle successfully decreased SSIs in patients undergoing gynecologic cancer surgery. We recommend improving quality of care by wide implementation of SSI prevention bundles in Gynecologic Oncology patients.

1. Introduction

Surgical site infections (SSI) are a preventable cause of patient morbidity and mortality. They occur following approximately 10 to 35% of Gynecologic Oncology surgeries [1–5]. SSIs are associated with delay to initiation of adjuvant therapy and worse overall survival [1], and result in a substantial economic burden [6–8]. In a recent meta-analysis encompassing 26 studies, Zimlichman et al. estimated a cost of 20,785

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US$ and a length of stay of 11.2 days attributable to each SSI [6]. The field of Gynecologic Oncology poses a uniquely elevated risk of SSIs due to high-complexity surgeries, patient comorbidities, and potential for contamination from ascending endogenous vaginal, cervical and gastrointestinal microorganisms to the operative site [9]. As such, SSIs represent one of the most frequent causes of readmission in this patient population, accounting for up to 30% of readmissions following hysterectomies [10,11]. Care bundles were first introduced in 2001 by the Institute for Healthcare Improvement [12]. Preventive bundles consisting of simultaneously implemented interventions have been developed in several surgical subspecialties to tackle the multifactorial etiology of SSIs across the phases of perioperative care [13,14]. Preventing SSIs is a complex task, as numerable modifiable and non-modifiable risk factors can contribute to a patient's potential for infection. The individual elements of a SSI preventive bundle can target the multifactorial etiology of SSIs. Bundles can enhance consistency and adherence to integrated measures through a systematic and multidisciplinary approach. Several studies have demonstrated the role of SSI bundles in colorectal surgery [14,15], orthopedic surgery and cardiac surgery [13,16]. There is limited literature on the effectiveness of SSI bundles in Gynecologic Oncology surgery [2–5,17].

Patient safety monitoring networks such as the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) have been instrumental in measuring and presenting rates and benchmarks for medical and surgical complications including SSIs, providing a prospectively maintained database with validated 30-day postsurgical outcome data. The Gynecologic Oncology division at Sunnybrook Health Sciences Centre (SHSC) in Toronto, Ontario, Canada, joined the NSQIP program in January 2016. The impetus for the development of this care bundle arose from previous results on semi-annual NSQIP reports, in which our department was identified as a negative outlier (tenth decile) with high rates of SSIs in risk-adjusted comparison to institutions of similar size, teaching affiliation and patient population. To address the rate of SSIs, a multidisciplinary working group for prevention of SSIs in Gynecologic Oncology was established in September 2016 and implemented an evidence-based bundle of practices in February 2017.

The goal of this study was to evaluate the effect of a preventive bundle on SSI rates in Gynecologic Oncology surgery. The primary outcome was the rate of overall SSIs, and secondary outcomes were: rates of superficial, deep and organ-space SSIs, wound disruption, sepsis, length of stay and 30-day readmission and reoperation. In addition, we aimed to investigate patient and surgical risk factors associated with SSIs, and to record balancing measures and adverse outcomes resulting from the implemented bundle.

2. Methods

2.1. Study design and population

All Gynecologic Oncology elective cases included in the NSQIP database between January 1, 2016 and September 30, 2017 at Sunnybrook Health Sciences Centre (SHSC) in Toronto, Ontario, Canada were eligible. Data were abstracted from the institutional NSQIP database, thus ensuring high-quality standardized and validated data collection, and allowing direct comparison to benchmark rates used amongst NSQIP hospitals internationally. NSQIP data is prospectively collected from a systematically sampled set of surgical cases by trained clinical reviewers. The procedures included laparotomies and laparoscopies for major cancer surgery; including hysterectomies and cytoreductive procedures, with and without bowel resection. Emergent cases were excluded.

An SSI prevention bundle initiative was introduced for all Gynecologic Oncology surgeries on February 1, 2017. The preimplementation period spanned from January 1, 2016 to January 31, 2017. The intervention period was from February 1, 2017 to September 30, 2017.

Patient demographics, preoperative comorbidities, oncologic details, intraoperative factors, and 30-day outcomes and complications were collected using the NSQIP institutional data and by reviewing patient charts. Chart review was conducted on these cases to supplement NSQIP data to obtain further details on patient demographics and operative factors. Operative notes were reviewed to identify intraoperative complications and length of surgery. To evaluate whether the bundle caused unintended outcomes, balancing measures (such allergic reaction to antibiotics or cases of *clostridium difficile*) were tracked during the study period.

This study was approved by the SHSC Research Ethics Board.

2.2. Definitions

SSIs (superficial, deep and organ-space) were defined according to Centers for Disease Control and Prevention criteria [18,19], and were identified through the institutional NSQIP database. The number of overall SSIs was defined as the number of episodes during which patients incurred one or more types of SSI within 30 days of surgery. For example, if a patient concurrently had an organ-space SSI and a superficial SSI, this was categorized as one overall SSI episode.

2.3. Bundle

To address the SSI rate, a multidisciplinary working group for prevention of SSIs in Gynecologic Oncology was established in September 2016. The bundle was initiated in February 2017, and consists of individual elements selected and adapted from existing guidelines and published bundles, including several recommendations supported by the World Health Organization [20] and Centers for Disease Control and Prevention [19]. This systematic approach targeting pre, intra and postoperative phases of a Gynecologic Oncology patient's journey is a multidisciplinary effort, with participation of surgeons, anesthesiologists, nurses, and representation from the endocrinology as well as infection control teams. The working group meets on a bimonthly basis to review adherence to bundle components, challenges with implementation and to review rates of SSIs. Semi-annual decile rankings of the NSQIP reports are tracked.

Practices previously in place prior to implementation of the bundle included preparation of the incisional area with 2% chlorhexidine gluconate and 70% isopropyl alcohol, and timely administration of prophylactic antibiotics within 30 min of incision.

The bundle added preoperative, intraoperative, postoperative and post-discharge individual measures (Box 1). Preoperatively, patients undergoing laparoscopies or laparotomies were instructed to shower with 4% chlorhexidine gluconate soap the night prior as well as the morning of surgery. Warming devices were used in the preoperative waiting area, as well as in the operating room prior to and during surgery with the goal of maintaining a core body temperature above 36 degrees. Euglycemia was achieved with standardized intraoperative and postoperative order sets for diabetic patients. The target blood glucose level was ≤140 mg/dL for patients with type 2 diabetes. Standardized IV insulin infusion dosing algorithms were initiated for blood glucose levels >140 mg/dL. For type 1 diabetic patients, standardized insulin dosing was used for blood glucose levels >72 mg/dL. A policy of restricted operating room traffic was initiated. This policy aimed to decrease traffic to contain and uphold sterility of the surgical environment, and included a limit of 9 staff members in the operating room at all times. Preoperatively, prophylactic antibiotics were standardized to ensure appropriate use and dosage. Intraoperatively, redosing occurred at 3–4 h. Compliance to antibiotic redosing was captured by the SSI working group. All patients without an allergy received cefazolin and metronidazole for procedures including hysterectomy and/or bowel resection, while clindamycin and metronidazole were used for patients with allergies. Following surgery, patients were

Box 1
Elements of the surgical site infection prevention bundle.

- Preoperative period
  - 4% chlorhexidine gluconate shower
  - Normothermia in preoperative area
  - Standardized prophylactic antibiotics
  - For diabetic patients: Order set and glycemic control
- Intraoperative period
  - Restricted operating room traffic policy
  - Avoidance of shaving. Clipping only when absolutely necessary.
  - Preparation of the surgical field with 2% chlorhexidine gluconate and 70% isopropyl alcohol
  - Prophylactic antibiotic redosing at 3–4 h
  - Normothermia
  - For laparotomies: Separate sterile tray for closure of fascia and skin
  - For laparotomies: Staff glove change for closure of fascia and skin
  - For diabetic patients: Order set and glycemic control
- Postoperative period
  - Patient education
  - For laparotomies: Dressing removal at 48 h
  - For diabetic patients: Order set and glycemic control

educated on symptoms and signs of SSIs. This antibiotic selection was based on recent studies and guidelines [21–24].

In addition, for cases performed through laparotomy, a separate sterile tray for closure of fascia and skin was used with new instruments, suction tip and electrocautery device, and surgeons and nurses changed their gloves. Postoperatively, dressing removal was at 48 h.

2.4. Statistical analysis

The primary outcome was rate of overall SSIs. Secondary outcomes were rates of superficial, deep and organ-space SSIs, wound disruption, sepsis, length of stay, 30-day readmission and reoperation.

We collected data on patients who underwent surgery before (January 1, 2016 to January 31, 2017) and after (February 1, 2017 to September 30, 2017) implementation of the bundle: a power analysis was conducted to confirm that this sample was adequately powered to detect a 50% reduction in our baseline rate of SSI. Using two-sided Fisher's exact test with a significance level of 0.05, our sample size provided 80.2% power to detect a difference in overall SSI rate between both cohorts.

To describe population characteristics, proportions and measures of central tendency were calculated for categorical and continuous variables. BMI categories were defined based on WHO criteria. Operative duration categories were defined based on distribution of data. To compare demographic, oncologic and surgical characteristics between both periods, Pearson χ^2 test or Fisher exact test for categorical variables and *t*-test for continuous variables were used. Wilcoxon rank-sum and Mann-Whitney tests were used for nonparametric distributions. Two-sided *p*-value < 0.05 was considered statistically significant.

Univariate and multivariable exact logistic regression were conducted to identify independent predictors of SSIs. *p*-Value, exact odds ratios (OR) and corresponding 95% confidence intervals (CI) were estimated for each predictive factor. To identify the most significant predictive factors of SSIs, variables detected to be statistically significant on univariate analysis ($p \leq 0.05$) and identified as clinically important were included in a multivariable logistic regression model. Variables assessed for inclusion included patient factors (smoking, diabetes, body mass index (BMI) stratified as ˂25, 25–30, >30 kg/m^2, ASA class, primary malignancy, tumor stage) and operative factors (surgical approach, intraoperative complication such as bowel, bladder or ureteric injury, operative duration, bowel surgery or appendectomy, and surgery in the pre versus postintervention period).

Analyses were performed using Statistical Analysis Software (SAS) version 9.4 for Windows, Cary, NC.

3. Results

A total of 563 patients were included in this study: 339 patients underwent surgery prior to implementation of the bundle, and 224 patients following implementation.

Baseline characteristics for pre and postintervention groups are presented in Table 1. There was no significant difference in demographics including: age, BMI, ASA (American Society of Anesthesiologists) class, diabetes, hypertension, distribution of primary malignancy or neoadjuvant chemotherapy status. In the post-intervention cohort, there was a lower proportion of smokers (4.5% vs 9.4%, $p = 0.03$).

Operative details are listed in Table 2. There was no difference between the pre-intervention and post-intervention groups in terms of surgical approach, proportion of patients undergoing bowel resection or appendectomy, median estimated blood loss, or incidence of intraoperative complications. Median operative time was shorter in the post-intervention cohort (147 versus 127 min, $p = 0.002$).

Implementation of the bundle resulted in a relative risk reduction of 55% in overall SSIs compared to the preintervention rate (12.1% to 5.4%, $p = 0.008$), and the rate of superficial SSIs decreased by 54% from 9.7% to 4.5% ($p = 0.023$). The odds of developing a SSI in the preintervention period relative to the postintervention period was 2.43 (95% CI 1.22–5.20, $p = 0.009$).

Our department's NSQIP biannual decile ranking result for SSIs improved and was no longer a negative outlier. This trend was sustained: our department has maintained NSQIP benchmark target of a SSI rate of <8% over the last 6 quarters (Fig. 1).

While a statistically significant decrease in overall and superficial SSIs was observed, other types of SSIs also decreased albeit did not reach statistical significance: deep and organ-space SSIs decreased from 1.5% to 0.5% ($p = 0.41$) and 3.2% to 1.3% ($p = 0.18$), respectively (Table 3). No significant difference was found in other secondary outcomes: sepsis (1.8% to 0.9%, $p = 0.49$), wound disruption (3.5% to 0.9%, $p = 0.06$), readmission (7.4% to 4.9%, $p = 0.29$), reoperation

Table 1
Characteristics of Gynecologic Oncology patients undergoing surgery pre and postimplementation of the SSI bundle.

	Preintervention [n = 339 (%)]	Postintervention [n = 224 (%)]	*p*-Value
Age (years)_ ± SD	62.1 ± 12.3	62 ± 11.9	0.86
BMI (kg/m^2)			0.75
>30	128 (37.8)	76 (33.9)	
25–30	101 (29.8)	74 (33)	
<25	105 (31)	69 (30.8)	
Diabetes	36 (10.6)	33 (14.7)	0.33
Hypertension	140 (41.3)	86 (38.4)	0.54
Smoking	32 (9.4)	10 (4.5)	**0.03**
History of steroid use	5 (1.5)	5 (2.2)	0.53
Weight loss of >10% in last 6 months before surgery	6 (1.8)	5 (2.2)	0.76
Neoadjuvant chemotherapy	30 (8.9)	18 (8)	0.76
ASA class 3–5	262 (77.3)	179 (79.9)	0.53
Primary malignancy			0.14
Ovarian	128 (37.8)	86 (38.4)	
Uterine	168 (49.6)	123 (54.9)	
Cervical	26 (7.7)	10 (4.5)	
Other	17 (5)	5 (2.2)	

Data are mean or n (%) unless otherwise specified.
BMI: body mass index.
ASA: American Society of Anesthesiologists.
SD: standard deviation.
bold means statistically significant, with p below 0.05

Table 2
Operative characteristics.

	Preintervention [n = 339 (%)]	Postintervention [n = 224(%)]	*p*-Value
Surgical approach			0.14
Laparoscopy	126 (37.2)	98 (43.7)	
Laparotomy	213 (62.8)	126 (56.3)	
Bowel resection or appendectomy	52 (15.3)	30 (13.4)	0.55
Median estimated blood loss (mL)	200	200	0.07
Median operative time (min)	147	127	**0.002**
>180	108 (31.9)	50 (22.3)	
120–180	123 (36.2)	79 (35.3)	
<120	108 (31.9)	95 (42.4)	
Intraoperative complication	21 (6.2)	10 (4.5)	0.45
Bowel injury	9 (2.7)	4 (1.8)	
Bladder injury	5 (1.4)	3 (1.3)	
Ureteric injury	6 (1.8)	2 (0.9)	
Other	1 (0.3)	1 (0.5)	

Data are mean or n (%) unless otherwise specified.
bold means statistically significant, with p below 0.05

Table 3
Rate of surgical site infection pre and postimplementation of the preventive bundle.

	Preintervention [n = 339 (%)]	Postintervention [n = 224(%)]	*p*-Value
Overall SSI	41 (12.1)	12 (5.4)	**0.008**
Superficial	33 (9.7)	10 (4.5)	**0.02**
Deep	5 (1.5)	1 (0.5)	0.41
Organ-space	11 (3.2)	3 (1.3)	0.18
Sepsis	6 (1.8)	2 (0.9)	0.49
Wound disruption	12 (3.5)	2 (0.9)	0.06
Readmission	25 (7.4)	11 (4.9)	0.29
Reoperation	11 (3.2)	3 (1.3)	0.18
Length of stay			
Mean ± SD	3.2 ± 6.0	3.1 ± 4.0	0.11
Median	3	3	
Range	0, 101	0, 23	

SD: standard deviation.
bold means statistically significant, with p below 0.05

(3.2% to 1.3%, $p = 0.18$), and length of stay (median 3 days in pre and postintervention periods, $p = 0.11$).

When further assessing by surgical approach and procedure rates, SSIs significantly decreased for laparotomies (16.9% to 7.9%, $p = 0.02$), however no statistical difference was seen for laparoscopies (4.0% to 2.0%, $p = 0.48$) and in procedures that included bowel resection or appendectomy (17.3% to 10.0%, $p = 0.52$). The decrease in SSI was consistent across disease sites: ovarian cancer (13.3% to 4.7%) and endometrial cancer (13.1% to 5.7%).

A univariate analysis was performed to assess the correlation between risk factors and the overall risk of developing a SSI (Table 4). The following factors were found to significantly correlate with an increased risk: surgery in the pre-bundle period (OR 2,43, 95% CI 1,22–5.20, p =0.009) smoking (OR 2.63, 95% CI 1.03–6.15, $p = 0.04$), BMI categories (OR 2.19, 95% CI 1.07–4.74, $p = 0.03$ for BMI > 30 kg/m^2 compared to BMI between 25 kg/m^2 to 30 kg/m^2, and OR 4.41, 95% CI 1.84–12.22, $p = 0.0003$ for BMI > 30 kg/m^2 compared to BMI ˂ 25 kg/m^2), laparotomy as compared to laparoscopy (OR 4.68, 95% CI 2.04–12.55, $p < 0.0001$), longer operative duration (OR 3.36, 95% CI 1.53–7.85, $p = 0.002$ for cases longer than 180 min compared to cases shorter than 120 min) and intraoperative complication (OR 4.23, 95% CI 1.60–10.35, $p = 0.004$). Bowel resection or appendectomy, tumor stage, primary malignancy, diabetes and ASA class were not found to significantly correlate with an increased risk of SSI.

On multivariable analysis (Table 5), surgery prior to implementation of the bundle, BMI over 30 kg/m^2, operative duration >180min and laparotomies were found to be independent predictive factors associated with an increased risk for overall SSIs (OR 2.23, 95% CI 1.06–5.06, $p =$

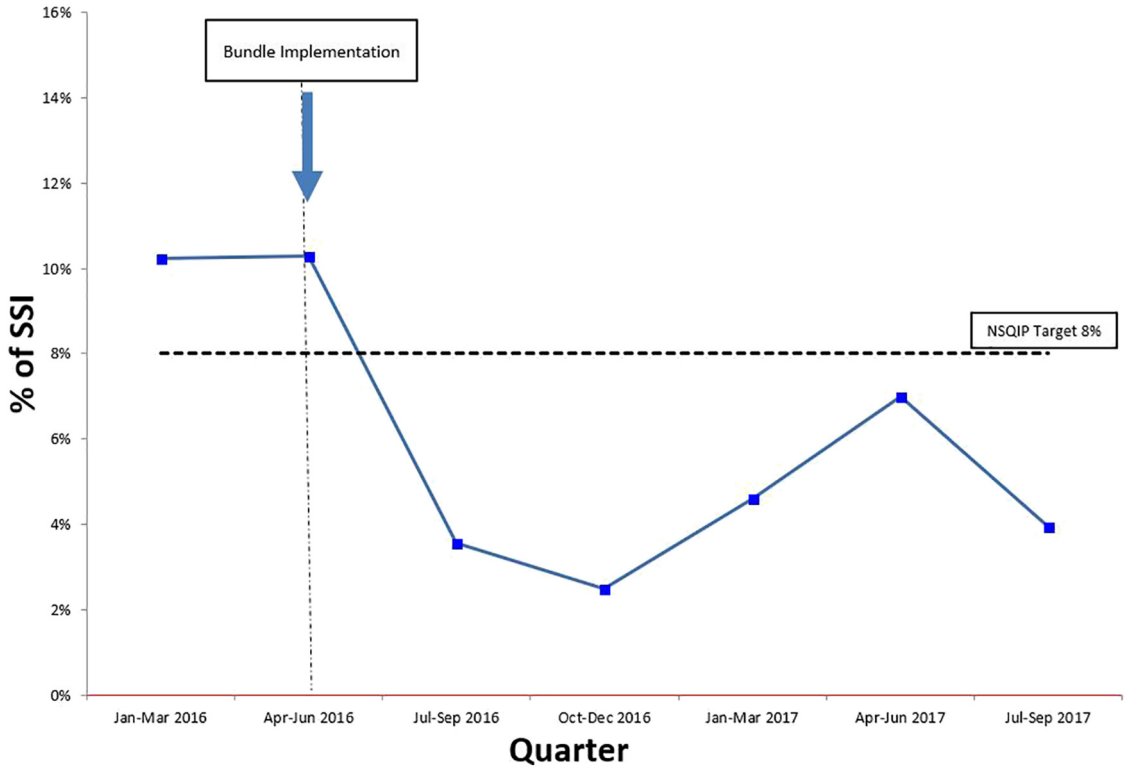

Fig. 1. Title: Rate of SSI per quarter before and after implementation of the bundle. SSI: Surgical Site Infection, NSQIP: National Surgical Quality Improvement Program.

Table 4
Univariate analysis for risk factors of overall SSIs.

Predictive factors	OR, 95% CI	*p*-Value
Surgery in preintervention period (vs postintervention)	**2.43** (1.22–5.20)	**0.009**
Smoking	**2.63** (1.03–6.15)	**0.04**
BMI categories		**0.001**
>30 vs <25 kg/m²	**4.41** (1.84–12.22)	**0.0003**
>30 vs 25–30 kg/m²	**2.19** (1.07–4.74)	**0.03**
Surgical approach (Laparotomy vs Laparoscopy)	**4.68** (2.04–12.55)	**<0.0001**
Intraoperative complication	**4.23** (1.60–10.35)	**0.004**
Operative duration		**0.003**
>180 vs <120 min	**3.36** (1.53–7.85)	**0.002**
>180 vs 121–180 min	**2.15** (1.06–4.49)	**0.03**
Bowel resection and/or appendectomy	1.80 (0.81–3.72)	0.15
Tumor stage (III/IV vs I/II)	1.89 (0.99–3.69)	0.06
ASA class (3–5 vs 1–2)	1.98 (0.85–5.36)	0.13
Primary malignancy (endometrial vs ovarian)	1.04 (0.55–1.99)	0.91
Diabetes mellitus	0.79 (0.26–1.95)	0.78

OR: odds ratio, CI: confidence intervals.
bold means statistically significant, with p below 0.05

0.033, OR 3.01, 95% CI 1.57–5.87, $p = 0.0005$, OR 2.16, 95% CI 1.11–4.19, $p = 0.022$, and OR 3.70, 95% CI 1.56–10.18, $p = 0.001$, respectively).

There were no documented cases of *clostridium difficile* or anaphylactic reactions to antibiotics or chlorhexidine preparation.

4. Discussion

The rate of SSI is a marker of the quality and safety of care provided by a healthcare institution. Implementation of our preventative bundle was successful in decreasing the rate of overall SSIs and superficial SSIs by 55% and 54% respectively in complex oncological surgeries.

Most previously published bundles in Gynecologic Oncology have been successful in decreasing rates of SSIs in different patient populations [2–4,17]. Johnson et al. reported a significant reduction in the risk of SSI following implementation of a bundle for Gynecologic Oncology laparotomies (6% to 1.1%, relative risk reduction of 82.4%, $p = 0.01$), including sterile closing tray and staff glove change for fascial and skin closure, dressing removal at 24 to 48 h postoperatively, discharge with chlorhexidine soap and follow-up nursing phone call [3]. Taylor et al. [2] and Lippitt et al. [17] implemented similar bundles and achieved reductions in SSIs of 12.5% to 7.4% (odds ratio 0.56, $p = 0.01$) and 20% to 3% (odds ratio 0.13, $p \leq 0.001$), respectively. In the present study we elected to include not only laparotomies but also laparoscopies for gynecologic cancer. Although we did not find a statistically significant decrease in SSIs in laparoscopic surgeries, the rate was lowered and further research may be warranted.

For Gynecologic Oncology patients undergoing colon resection or colostomy, Schiavone et al. developed a bundle with preoperative oral antibiotics and optional mechanical bowel preparation, resulting in a drop in the rate of SSIs from 37% to 12% ($p \leq 0.001$) in a cohort of 115 patients preintervention and 118 postintervention [4]. Our bundle decreased rates of SSIs from 17.3% to 10% for procedures involving bowel resection or appendectomy ($p = 0.52$). The non-significant difference in our results could be due to a smaller sample size (52 patients preintervention and 30 patients postintervention), a difference in classification (we included all patients who underwent a procedure involving the gastrointestinal tract, including appendectomy only), or their bundle may have achieved a greater improvement due the difference in the composition of the bundle (e.g. with the addition of preoperative oral antibiotics). This further emphasizes the need for tailoring the bundle to specific patient populations and additional research to define those populations.

Table 5
Multivariate analysis for risk factors of overall SSIs.

Predictive factors	OR, 95% CI	*p*-Value
Surgery in preintervention period (vs postintervention)	**2.23** (1.06–5.06)	**0.033**
Surgical approach (Laparotomy vs Laparoscopy)	**3.70** (1.56–10.18)	**0.001**
BMI (>30 vs ≤30 kg/m²)	**3.01** (1.57–5.87)	**0.0005**
Smoking	2.53 (0.93–6.34)	0.07
Operative duration (>180 vs≤180 min)	**2.16** (1.11–4.19)	**0.022**

OR: odds ratio.
bold means statistically significant, with p below 0.05

Bruce et al. [5] investigated whether the single intervention of a closure tray could decrease rates of SSI for patients undergoing exploratory laparotomy by a Gynecologic Oncologist. The closure tray alone did not decrease overall SSI rates in their cohort of 875 patients with both benign and malignant indications (10.2% SSI rate preimplementation to 7.9% postimplementation, $p = 0.148$). However, a subgroup analysis revealed that patients with malignant pathology, advanced stage or ascites significantly benefited from a reduction in SSIs, a subgroup similar to patients included in our study. The reason for the lack of benefit in their entire cohort could further reflect on the complexity and multifactorial causes of SSIs and hence underscore the advantage of surgical bundles. A study by Waits et al. [25]. demonstrated that with each additional component in an SSI prevention initiative, the rate of SSI decreased, supporting a greater improvement with bundling. The success of our bundle and of others illustrates that a multifaceted intervention is necessary to tackle the complex etiology of SSIs and could result in a significant reduction in morbidity and cost savings. Taylor et al.'s bundle was estimated to cost approximately 19.26 US$ per case with total savings of 65,625 US$ per month [2].

Strengths of our study include that it is the first in the Gynecologic Oncology literature to focus on NSQIP patients exclusively, ensuring highly standardized prospectively collected data thus limiting the chance of selection bias. Moreover, the NSQIP data collection procedure ensures that all postoperative complications are captured, including those that occur at other hospitals, a previously identified limitation in other studies [5]. We used validated outcome definitions and included a wide range of complex Gynecologic Oncology procedures increasing the generalizability of the study results while looking at subgroups to further define the appropriate population that could benefit from the bundle. This also allows direct and reliable comparison to risk-adjusted benchmark rates of SSIs recognized internationally. Our bundle contains interventions that have a high-level of supporting evidence, and are advocated by the World Health Organization Global Guidelines for prevention of SSIs [20] and Center for Disease Control and Prevention [19]. The Gynecologic Oncology SSI prevention team at our institution was multidisciplinary, taking advantage of a diverse set of expertise and assembled on a regular basis for over a year to not only implement the bundle but also adjust and problem solve to further define the most appropriate components. Further, we performed a multivariable analysis to assess the risk factors contributing to the development of SSIs in order to identify modifiable elements that could be targeted.

Limitations of this study include the lack of randomization and the bundled nature of this initiative, while effective at addressing the multifactorial etiology of SSIs, did not enable us to identify which strategies were most successful. In addition, compliance to certain bundle components (such as normothermia or euglycemia) could not be tracked as the charting was not standardized. Ongoing efforts should also concentrate on cost-effectiveness analysis and optimizing modifiable patient risk factors, such as smoking. In our cohort, smokers had a risk of SSI of >20% despite the bundle.

5. Conclusion

Adoption of this multifaceted preventive bundle resulted in a substantial and sustainable reduction in SSIs across complex surgical procedures and different surgical modalities in Gynecologic Oncology patients while fostering a culture of safety and quality. Our department

has remained below NSQIP benchmark target for a sustained amount of time, 6 quarters at the time of publication. We recommend implementation of preventive bundles to reduce SSIs in Gynecologic Oncology patients and further research to better define the most appropriate contents of the bundle for each patient population.

Conflicts of interests

There are no conflicts of interests to disclose.

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Design of SSI prevention bundle: JMVN, MS, ABN, DV

Implementation of SSI prevention bundle: all authors contributed to implementation

Acquisition of data: JMVN, MS, DV

Analysis and interpretation of data: JMVN, MS, DV

Drafting of manuscript: JMVN, DV

Tables and figures: JMVN, MS

Critical revision: all authors contributed to critical revision

Study supervision: DV

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