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Practice Management

Minimizing variance in pediatric surgical care through implementation of a perioperative colon bundle: A multi-institution retrospective cohort study☆

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ABSTRACT

Background: Employing an institutional initiative to minimize variance in pediatric surgical care, we implemented a set of perioperative bundled interventions for all colorectal procedures to reduce surgical site infections (SSIs).
Methods: Implementation of a standard colon bundle at two children's hospitals began in December 2014. Subjects who underwent a colorectal procedure during the study period were analyzed. Demographics, outcomes, and complications were compared with Wilcoxon Rank-Sum, Chi-square and Fisher exact tests, as appropriate. Multivariable logistic regression was performed to assess the influence of time period (independent of protocol implementation) on the rate of subsequent infection.
Results: One hundred and forty-five patients were identified (preprotocol = 68, postprotocol = 77). Gender, diagnosis, procedure performed and wound classification were similar between groups. Superficial SSIs (21% vs. 8%, $p = 0.031$) and readmission (16% vs. 4%, $p = 0.021$) were significantly decreased following implementation of a colon bundle. Median hospital days, cost, reoperation, intraabdominal abscess, and anastomotic leak were unchanged before and after protocol implementation (all $p > 0.05$). Multivariable logistic regression found time period to be independent of SSIs (OR: 0.810, 95% CI: 0.576–1.140).
Conclusion: Implementation of a standard pediatric perioperative colon bundle can reduce superficial SSIs. Larger prospective studies are needed to evaluate the impact of colon bundles in reducing complications, hospital stay and cost.
Level of evidence: III — Retrospective cohort study

Surgical site infections (SSIs) are a common source of increased costs, morbidity and mortality following colorectal procedures resulting in prolonged hospital stay, reoperation, readmission and excessive resource utilization [1–3]. Significant efforts have been made to decrease the frequency of these occurrences [4,5], notably in the field of colorectal surgery, where standardized care pathways have been effective at reducing the rate of SSIs [5,6]. While uniform care pathways have been employed in many adult surgical subspecialties [7,8], the standardization of care in pediatric surgery has only recently been undertaken [9,10].

Standardized care in pediatric surgery has been effective in improving length of stay [11,12], hospital costs [13,14] and outcomes [15,16] but, there has been little progress in their application to address SSI. Recently, the first report of a "GI (gastrointestinal) bundle" in pediatric surgery [14] applied a standard perioperative protocol to all gastrointestinal surgeries resulting in a 63% reduction in SSI following stoma closure. However, this study was broadly applied to all gastrointestinal surgery, including hepatobiliary and foregut procedures. Given that colorectal procedures carry the highest reported risk of SSI at approximately 30% [3,17], the next crucial step is to look specifically at these procedures to evaluate the efficacy of such bundles.

Abbreviations: SSI, Surgical Site Infection; CDC NHSN, Centers for Disease Control and Prevention, National Health Safety Network; IQR, Interquartile Range.

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As part of an ongoing quality improvement project to minimize variance in pediatric surgical care and reduce SSI, a standard perioperative colon bundle was established in December 2014 for all pediatric colorectal procedures at two children's hospitals. We performed a retrospective cohort study investigating the effect of this quality intervention on SSI rates and hospital resource utilization. We hypothesize that introduction of a standard perioperative colon bundle will reduce infectious complications and thereby reduce postoperative length of stay, hospital cost and rates of readmission.

1. Material and methods

1.1. Data source & patient selection

After institutional review, children who underwent a colorectal procedure during the study period (June 2013–November 2016) were retrospectively identified. Surgeries were performed by 10 pediatric surgeons at 2 urban children's hospitals. Colorectal procedures were identified based on *Common Procedural Terminology* codes (44188, 44204–44208, 44210–44213, 44277, 44140, 44141, 44143–44147, 44150, 44151, 44155–44158, 44160, 44620), which correspond to open or laparoscopic total or partial colectomy and open or laparoscopic colostomy creation or closure. Subjects whose procedure occurred during the analysis period, excluding a 6-month period immediately following the implementation of the colon bundle in December 2014 (December 2014–May 2015), were included in the study. Those who underwent isolated anal procedures or those who did not undergo primary abdominal wound closure during the index procedure were excluded from analysis. Electronic medical records were retrospectively reviewed for demographic information, preoperative diagnosis, procedure performed, wound classification, operative time, length of stay, hospital cost, protocol compliance, postoperative antibiotic usage, operative complications, surgical site infections, anastomotic leak, readmission, reoperation, and death.

1.2. Colon bundle development

The pediatric colon bundle was initially adopted from a larger adult initiative to reduce SSI after colorectal procedures, sourced from contemporary literature and best practice recommendations, and modified to reflect unique concerns present in the care of children. The established protocol was championed by pediatric surgery fellows and presented to all faculty stakeholders who had an opportunity to propose revisions prior to deployment.

The perioperative colon bundle (Fig. 1) consists of practice recommendations for all phases of care including preoperative, intraoperative and postoperative management of children undergoing colorectal procedures. Patients undergoing elective procedures underwent an optional preoperative bowel prep or enema as appropriate. Pre- and intraoperative skin preparation was standardized along with antibiotics. Intraoperative normothermia was maintained and was considered present if cold temperatures less than 36 °C were limited to less than 45 min of the procedure. Euglycemia was measured and maintained in patients with preoperative risk for blood glucose abnormalities,

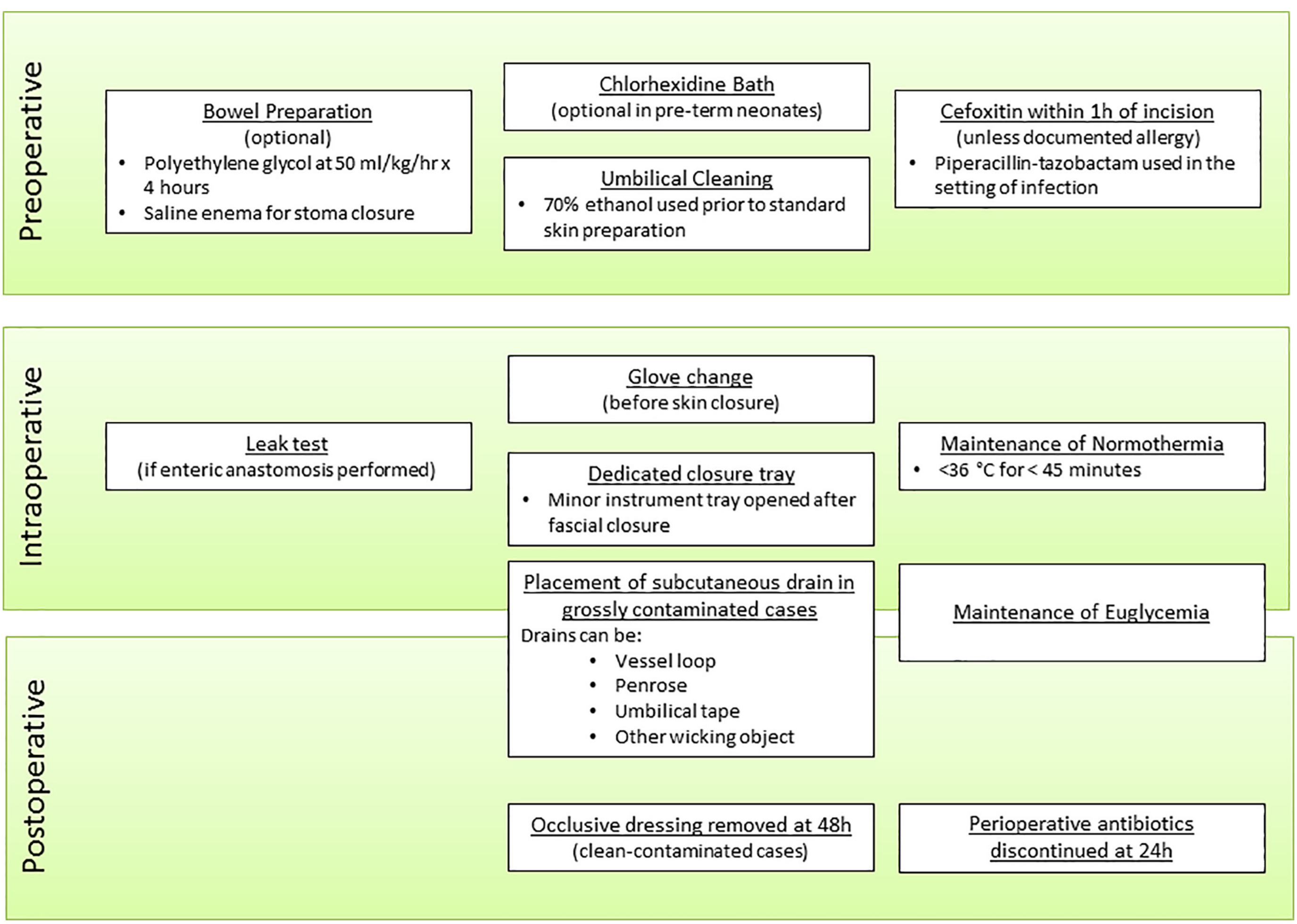

Fig. 1. Standardized perioperative colon bundle. An institutional colon bundle developed from contemporary literature and best practice recommendations, and modified to reflect unique concerns present in the care of children. Implemented in all children undergoing colorectal procedures

including diabetes mellitus. If an enteric anastomosis was created, a leak test was performed. Prior to closure, gloves and surgical instruments were exchanged. In cases where the wound was grossly contaminated, a drain or superficial wicks were left in the subcutaneous tissue until the first dressing change.

1.3. Definitions & outcomes

The standardized institutional colon bundle was implemented in December 2014 for all patients undergoing colorectal procedures at 2 children's hospitals. Protocol compliance, procedure classification, and all surgical complications including SSI were defined, for the purposes of the study, retrospectively during data analysis. Protocol compliance was defined as documentation of >50% of the 8 components of the colon bundle including implementation of one of the intraoperative surgical components and is only reported for postprotocol patients. Age was categorized into the clinically significant cohorts of infants (<1 year), toddlers (1–4 years), school-age children (5–11 years), and adolescents (>11 years). Inflammatory bowel disease was inclusive of ulcerative colitis, indeterminate colitis and Crohn's disease. Benign colon disease was an inclusive diagnostic category used to refer to functional indications for colorectal procedures including: prior diversion and patient request for enteric continuity, or neurogenic bowel. Alternatively, children classified as having 'benign colon disease' had surgical indications that were not represented in the other, more traditional diagnostic categories. Threatened bowel was defined as colon threatened by ischemia, necrotizing enterocolitis or perforation. The procedure categories, open and laparoscopic colectomies were inclusive of proctectomy. Joint colostomy closure and anorectoplasty were categorized as colostomy closure. Other colorectal procedures were inclusive of pull-through procedures and cecostomy tube placements. Emergent procedures were thus classified if they were performed for threatened bowel, trauma, in-hospital failure of medical management of inflammatory bowel disease, or acute presentations of bowel obstruction. Surgical site infections were determined retrospectively based on the Centers for Disease Control and Prevention, National Health Safety Network (CDC) definitions [18]. Briefly, superficial SSI was documented if at least one of the following was true: 1) purulent drainage from a superficial wound, 2) organisms are identified in an aseptic culture taken from the incision or subcutaneous tissue, 3) the wound is deliberately opened in the presence of erythema, pain, tenderness, swelling or heat and a culture of the incision or subcutaneous tissue is not obtained, or 4) diagnosis of superficial SSI is given by a surgeon or attending physician. All patient records were reviewed at the time of data collection which began in July 2017, and chart review included all events within the 30 day postoperative period to capture all SSIs. Intraabdominal abscess and organ/space SSI were used interchangeably. Enteric anastomotic leak was defined as evidence of anastomotic failure on reoperation or imaging findings consistent with intraabdominal transit of fluid from the intraluminal to the extraluminal space. Other complications not related to wound infection, including postoperative small bowel obstruction, *C. difficile* colitis, or anastomotic stricture were reported based on a documented diagnosis in the electronic medical record. Extended duration postoperative antibiotic prophylaxis was defined as the continuation of perioperative antibiotics beyond the first postoperative day. Cases were analyzed, regardless of compliance status, in pre- and postprotocol groups.

The primary outcome was the incidence of SSI after implementation of a standardized pediatric colon bundle. Secondary outcomes were operative time, length of stay, anastomotic leak rate, reoperation rate, and hospital cost.

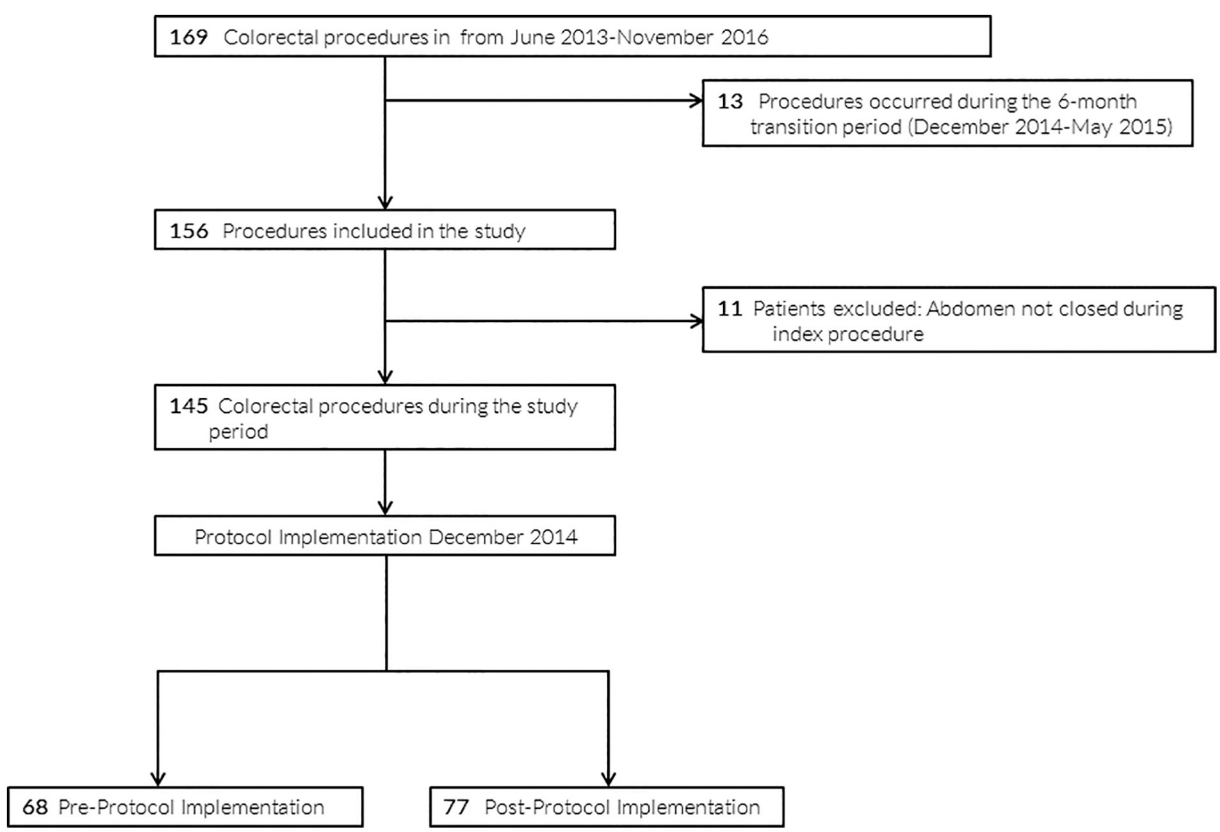

Fig. 2. Flowchart of patient selection for review following implementation of a perioperative colon bundle. Children who underwent colorectal procedures and were at risk for a surgical site infection during the study period were identified from an initial cohort of 169 procedures in 134 children. Children who were operated on during the transition period and those who did not undergo primary abdominal closure during the index procedure were excluded from analysis. Ultimately 145 procedures were analyzed in the study

Table 1
Patient characteristics.

	Total (%)	Protocol Implementation Pre- (%)	Post- (%)	p
	N = 145	N = 68	N = 77	
Age, median (IQR), years	6.2 (1.4–13.3)	6.3 (3.2–15.3)	6.2 (0.8–12.1)	0.024
Age (category)				0.068
<1 year	31 (21.4)	8 (11.8)	23 (29.9)	
1–4 years	26 (17.9)	14 (20.6)	12 (15.6)	
5–11 years	45 (31.0)	23 (33.8)	22 (28.6)	
>11 years	43 (29.7)	23 (33.8)	20 (26.0)	
Female	74 (51.4)	34 (50.0)	40 (51.9)	0.886
Diagnosis				0.861
Inflammatory bowel disease	25 (17.2)	14 (20.6)	11 (14.3)	
Benign colon disease	45 (31.0)	20 (29.4)	25 (32.5)	
Malignancy	7 (4.8)	4 (5.9)	3 (3.9)	
Threatened bowel	31 (21.4)	15 (22.1)	16 (20.8)	
Hirschsprung's disease	14 (9.7)	6 (8.8)	8 (10.4)	
Anorectal Malformation	23 (15.9)	9 (13.2)	14 (18.2)	
Procedure				0.689
Colostomy creation	17 (11.7)	9 (13.2)	8 (10.4)	
Colostomy closure	28 (19.3)	14 (20.6)	14 (18.2)	
Open colectomy	40 (27.6)	19 (27.9)	21 (27.3)	
Laparoscopic colectomy	29 (20.0)	15 (22.1)	14 (18.2)	
Other	31 (21.4)	11 (16.2)	20 (26.0)	
Emergent Procedures	47 (32.4)	25 (36.8)	22 (28.6)	0.374
Wound classification				0.360
Clean or clean–contaminated	71 (58.7)	37 (60.7)	34 (56.7)	
Contaminated	35 (28.9)	19 (31.1)	16 (26.7)	
Dirty or infected	15 (12.4)	5 (8.2)	10 (16.7)	

Data are stratified based on when the colorectal procedure occurred with those occurring prior to the implementation of a standardized colon bundle compared to those occurring in the presence of an established colon bundle. Significance is defined as $p < 0.05$. IQR: interquartile range

1.4. Statistical analysis

Descriptive statistics were tabulated. Nonparametric data are reported as medians with interquartile ranges (IQRs). Continuous variables were not normally distributed, and therefore differences between protocol groups were compared using a Wilcoxon rank-sum test. Categorical variables were analyzed with a Chi-Square test for independence or Fisher's exact test for small samples. Analysis of antibiotic usage was performed separately. Patients receiving antibiotics greater 7 days were considered to have antimicrobial therapy outside the domain of the operative indication and were excluded from subanalysis. Duration of postoperative antibiotic usage was then dichotomized into those receiving surgical prophylaxis antibiotics (completed within 24 h of the procedure) and those who received extended duration prophylaxis. A Fisher's exact test was used to compare antibiotic duration before and after bundle implementation. Compliance was not considered in analysis of the primary outcome i.e. pre- and postprotocol cohorts were compared for the incidence of SSI in an intention-to-treat fashion, regardless of per case compliance. Significance was defined at $p < 0.05$. Analyses were performed using IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, N.Y., USA).

1.5. Multivariable analysis

To ascertain the influence of time period, independent of protocol implementation, on the rate of SSI, a bivariate lead-in analysis was used to identify risk factors for SSI in our cohort. Preoperative factors with $p < 0.20$ were included in a multivariable logistic regression. Time period was categorized into 6-month intervals (biannual epoch) and included in the model as a continuous variable. Odds ratios with 95% confidence intervals (95% CIs) are reported.

2. Results

2.1. Demographic data

Our review identified 169 colorectal procedures performed on 134 patients during the study period. Thirteen procedures performed during the transition period and 11 patients whose abdomens were not primarily closed during the index procedure were excluded from analysis. Ultimately, 145 procedures, performed on 110 patients, underwent analysis; 68 of these occurred prior to protocol implementation and 77 after the colon bundle was established (Fig. 2).

Demographic and preoperative data are stratified by experimental group as reported in Table 1. Median age of subjects was 6.2 years and the majority of colorectal procedures were performed on females (51%). There were 14 newborns (age < 3 months) in our study, 3 (4%) in the preprotocol group ($n = 68$), and 11 (14%) in the postprotocol group ($n = 77$). Infants were significantly more common in the postprotocol group ($p = 0.009$). The predominant preoperative diagnoses were benign colon disease (31%), threatened bowel (21%), and inflammatory bowel disease (17%). Median age was statistically, although not clinically, different in pre- and postprotocol groups ($p = 0.024$). Sex, preoperative diagnosis, procedure performed, number of emergent procedures and wound classification were not statistically different in the pre- and postprotocol implementation periods (all $p > 0.05$). Most of the colorectal

Table 2
Outcomes.

	Total (%)	Protocol Implementation Pre- (%)	Post- (%)	p
	N = 145	N = 68	N = 77	
Operative time, median (IQR), h	2.5 (1.8–4.0)	2.6 (1.8–4.3)	2.5 (1.9–3.7)	0.382
Length of stay, median (IQR), days	6.4 (4.1–15.3)	6.0 (4.1–15.2)	7.2 (4.1–17.9)	0.747
Postoperative length of stay, median (IQR), days	5.1 (3.2–10.8)	4.9 (3.2–10.0)	6.2 (3.2–12.2)	0.643
Hospital Cost, median (IQR), thousand USD	24.0 (14.5–48.4)	22.0 (15.0–49.7)	25.0 (14.4–48.2)	0.772
Complications				
Superficial SSI[a]	20 (13.8)	14 (20.6)	6 (7.8)	0.031
Intraabdominal abscess[a]	12 (8.3)	7 (10.3)	5 (6.5)	0.548
Anastomotic leak[a]	6 (4.1)	3 (4.4)	3 (3.9)	1.000
Other[a]	15 (10.3)	9 (13.2)	6 (7.8)	0.413
Readmission[a]	14 (9.7)	11 (16.2)	3 (3.9)	0.021
Reoperation[a]	16 (11.0)	9 (13.2)	7 (9.1)	0.441
Mortality[a]	2 (1.4)	2 (2.9)	0	0.218

Outcomes are compared after the implementation of a standardized colon bundle. Significance is defined as $p < 0.05$. IQR: interquartile range. USD: United States Dollars. SSI: surgical site infection.

[a] Fisher exact test performed.

procedures (77%) were performed by 5 pediatric surgeons with a median of 14 procedures per surgeon during the study period.

2.2. Outcomes

The incidence of superficial SSI decreased significantly, from 21% prior to implementation to 8% after application of a standardized colon bundle ($p = 0.031$). In an analysis of secondary outcomes, readmission following protocol implementation was also noted to decrease significantly (16% pre- vs. 4% post-, $p = 0.021$). Median operative time, total and postoperative length of stay, and hospital cost were not statistically different between the pre- and postprotocol groups (Table 2). Similarly, incidence of intraabdominal abscess, anastomotic leak, reoperation or other complications were not statistically different after protocol implementation. Protocol compliance was 57%. The most common protocol deficiencies were absence of documentation of the intraoperative components of the bundle (52%), primary wound closure with placement of a sterile dressing over a contaminated wound (35%), and failure to maintain normothermia (17%). Compliance with perioperative antibiotic provisions of the protocol (ceasing antibiotics within 24 h of the procedure) was 84%. Procedure specific rates of SSI are reported in Supplemental Table 1 and were not significantly different following protocol implementation (all $p > 0.05$).

Duration of antibiotic usage after initiation of the colon bundle significantly decreased. Following protocol implementation, extended duration postoperative antibiotic prophylaxis decreased from 23% to 10% ($p = 0.037$) pre- and postprotocol, respectively.

Owing to the observed differences in the number of infants included in each group, a bivariate subgroup analysis of only infants, before and after protocol implementation was performed. There were 31 infants, 8 in the preprotocol group and 23 in the postprotocol group. Infant sex (75% vs 47.8% females, $p = 0.240$), percentage of emergent procedures (37.5% vs. 30.4%, $p = 1.000$), and percentage of contaminated or infected cases (33.3% vs 57.1%, $p = 0.385$) were statistically similar between pre- and postprotocol groups. Among infants, superficial SSI (12.5% vs. 13.0%, $p = 1.000$), reoperation (25.0% vs. 13.0%, $p = 0.583$), readmission (0 vs 4.3%, $p = 1.000$), and postoperative antibiotic usage less than 24 h (37.5% vs. 21.7%, $p = 0.393$) were no different before or after protocol implementation, respectively.

To determine the influence of undercurrent changes to best surgical practices over the period of our study, we performed a bivariate lead-in analysis to identify SSI risk factors to include in a multivariable logistic regression. Identified risk factors with a bivariate $p < 0.20$ and the biannual epoch of the procedure were included in the multivariable regression to account for confounders in our primary analysis. Biannual epoch, type of procedure, emergent procedure, and wound classification were associated with SSI and included in the multivariable model (Table 3). On multivariable analysis, none of these factors, with the exception of wound contamination, was significantly associated with SSI (Table 4).

Table 3
Bivariate analysis of risk factors for surgical site infection (SSI).

	SSI		p
	No	Yes	
	$N = 125$	$N = 20$	
Age (category)			0.421
<1 year	27 (21.6)	4 (20.0)	
1–4 years	20 (16.0)	6 (30.0)	
5–11 years	41 (32.8)	4 (20.0)	
>11 years	37 (29.6)	6 (30.0)	
Female	64 (51.2)	10 (50.0)	1.000
Biannual Epoch of Procedure			0.057
June–December 2013	14 (11.2)	6 (30.0)	
January–May 2014	15 (12.0)	1 (5.0)	
June–December 2014	25 (20.0)	7 (35.0)	
May–December 2015	28 (22.4)	1 (5.0)	
January–May 2016	18 (14.4)	1 (5.0)	
June–November 2016	25 (20.0)	4 (20.0)	
Diagnosis			0.372
Inflammatory bowel disease	23 (18.4)	2 (10.0)	
Benign colon disease	41 (32.8)	4 (20.0)	
Malignancy	6 (4.8)	1 (5.0)	
Threatened bowel	24 (19.2)	7 (35.0)	
Hirschsprung's disease	13 (10.4)	1 (5.0)	
Anorectal Malformation	18 (14.4)	5 (25.0)	
Procedure			0.08
Colostomy creation	16 (12.8)	1 (5.0)	
Colostomy closure	21 (16.8)	7 (35.0)	
Open colectomy	32 (25.6)	8 (40.0)	
Laparoscopic colectomy	26 (20.8)	3 (15.0)	
Other	30 (24.0)	1 (5.0)	
Emergent Procedures	38 (30.4)	9 (45.0)	0.195
Wound classification			0.011
Clean or clean–contaminated	66 (64.1)	5 (27.8)	
Contaminated	25 (24.3)	10 (55.6)	
Dirty or infected	12 (11.7)	3 (16.7)	

Preoperative risk factors are compared based on their association with SSI. Significance is defined as $p < 0.05$.

3. Discussion

In this study we demonstrate that the implementation of a standardized perioperative bundle can reduce SSI in children undergoing colorectal procedures. We report a significant absolute reduction of 13% in superficial SSI following implementation of a colon bundle without significantly increasing operative time, length of stay, or hospital cost. Additionally, we found bundle implementation was associated with a 12% decrease in readmission and a 13% reduction in the number of patients receiving antibiotics outside of traditional perioperative prophylaxis.

The identification of surgical site infections, following colectomy as the number one contributor to adverse events in general surgery [3], has prompted a considerable number of initiatives to reduce their occurrence [5,6,19]. In adults, the introduction of bundles has been successful at reducing colorectal SSI from 19% to 6% in one study [20]. Similar efforts in pediatric surgery are now evolving [4] but a focus on pediatric colorectal procedures has been lacking, perhaps because of their relatively low reported SSI rate of 6% [21]. Nordin et al. [14] recently reported on the first application of a standard gastrointestinal bundle, documenting a decrease in SSI – in midgut and hindgut procedures – from 11% to 8%, with an even greater absolute reduction of 14% in SSI following stoma closure procedures. That study, however, looked at all gastrointestinal procedures without documenting the specific operations, potentially including a large cohort of 'clean' cases. While this study represents a fundamental first step towards surgical standardization in pediatric colorectal surgery, further, more detailed

Table 4
Multivariable logistic regression for preoperative risk factor association with surgical site infection (SSI).

	OR	95% CI	p
Biannual Epoch of Procedure	0.81	0.576–1.140	0.228
Procedure			0.517
Colostomy creation	1.000	ref	
Colostomy closure	3.609	0.330–39.415	0.293
Open colectomy	2.459	0.237–25.559	0.451
Laparoscopic colectomy	2.023	0.174–23.492	0.573
Other	0.57	0.029–11.063	0.711
Emergent Procedures	1.144	0.249–5.259	0.862
Wound classification			0.084
Clean or clean–contaminated	1.000	ref	
Contaminated	3.979	1.174–13.489	0.027
Dirty or infected	2.811	0.480–16.476	0.252

Variables included in the model were based on a bivariate $p < 0.20$. Biannual epoch of procedure was included as a continuous variable. Significance is defined as $p < 0.05$. OR: odds ratio. 95% CI: 95% Confidence Interval.

analyses are needed to confirm these findings. Our study addresses this gap through a detailed analysis of only colorectal procedures. We differentiate superficial, deep and organ/space infections, reporting a superficial SSI rate of 8%, which is similar to previously reported pediatric SSI rates. Similarly, our 62% relative SSI reduction (from 21% to 8%) after protocol implementation, is similar to the 39%–73% relative reduction cited in the seminal adult studies evaluating the efficacy of colorectal SSI bundles [22,23]. Prior to the introduction of the colon bundle, there was no standard practice at our institution regarding skin closure and 79% of all contaminated cases received a subcuticular closure with an occlusive dressing, likely contributing to the 21% rate of SSI during this time period. Our reported 12% reduction in readmission is likely attributable to the associated reduction in SSI, as 45% of the preprotocol readmissions were for wound related complications.

The impact that bundled interventions in surgical care have had on outcomes is notable. Standardization of increasingly complex surgical practices has resulted in improved outcomes beyond SSI reduction. In adults, the introduction of enhanced recovery protocols after colorectal surgery has been associated with decreased length of stay, hospital costs and surgical morbidity [24–27]. Additionally, surgical unity through adherence to evidence-based protocols has resulted in improved pathologic outcomes following surgical resection [28] and long-term oncologic outcomes in rectal cancer [29]. Our findings contribute to this growing narrative, demonstrating that the use of bundled interventions in pediatric surgery can improve both patient-specific and system-wide outcomes.

Regarding the exclusion of preoperative enteral antibiotics in our bundle: at the time of protocol development the scientific consensus regarding their use in children was unclear [30–32], despite a growing consensus in the adult literature [33,34]. It was not until 2015 that the American Pediatric Surgical Association published a comprehensive review [35] highlighting the evidence in adults that suggests the benefits of enteral antibiotics, although without making a formal recommendation. Additionally, in contrast to evidence in the adult literature, some studies document no association between the use of mechanical bowel preparation alone and adverse events in children [36,37].

The reported compliance to our protocol was poor (57%). With variable compliance the impact of protocol usage on the subsequent rate of SSI is difficult to ascertain. However, as a retrospective review, our study is dependent on documentation in the electronic medical record, likely resulting in an underreporting of compliance to portions of the protocol already ubiquitously employed (e.g. preoperative umbilical cleaning).

Interpretation of our findings in light of the limited reported protocol compliance led us to explore our data for other confounders possibly contributing to our reduction in SSI. To explore the impact of time and resultant changes in best surgical practice on our SSI rate, we performed a multivariable logistic regression with a bivariate lead-in, including other preoperative risk factors for SSI along with a time component divided in 6-month intervals or biannual epochs. Our multivariable analysis identified no significant association between time period, procedure performed, emergent classification, or wound classification with rate of SSI, although contaminated wounds were associated with increased rates of SSI. These findings support our primary analysis demonstrating a decrease in SSI after protocol implementation.

Our study has a number of limitations, principally associated with its retrospective design. Additionally, the small number of patients analyzed increases the influence of random error. However, the significance of our findings within a small population highlights the efficacy of the colon bundle and argues for its broader adoption. Additional limitations of this study include its use of multiple interventions and the unique environment in which it was performed, potentially limiting the broader application of the study to alternative sites. As is true with any quality improvement initiative, with introduction of multiple simultaneous bundled interventions, the precise influence of any specific intervention on the primary outcome is difficult to determine. Lastly, our control and protocol cohorts are not contemporary groups. Although our regression analysis did not demonstrate time period to be a significant confounder in our findings, there is still a chance that changes in surgical care, including antibiotic practices, may have influenced our outcomes in addition to protocol implementation. Future institutional directions include implementation of colon bundle documentation directly in the perioperative electronic medical record to improve data collection efforts. Initiation of colon bundle documentation in the perioperative nursing workflow should improve protocol noncompliance, along with an ongoing enterprise-wide educational initiative to reduce SSI in the operating room.

4. Conclusions

Introduction of a standard perioperative pediatric colon bundle can substantially reduce superficial SSI and readmission after colorectal surgery without significantly increasing operative time, length of stay or hospital cost. Further investigation, perhaps through larger prospective studies in regional research consortiums, is needed to evaluate the efficacy of pediatric colon bundles in standard surgical practice.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpedsurg.2020.01.004.

Patient consent

This study was exempted from obtaining individual patient consent as approved by our Institutional Review Board. This report does not contain any personal information that could lead to identification of any patients.

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Authorship

All authors attest that they meet the current ICMJE criteria for Authorship.

Conflict of interest

The above authors have no financial disclosures.

Declarations of interest

None

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