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Original Article

Pediatric surgical site infection (SSI) following ambulatory surgery: Incidence, risk factors and patient outcomes

Michael L. Rinke MD, PhD[1,2], David G. Bundy MD, MPH[3], Moonseong Heo PhD[4], Lisa Saiman MD[5], Barbara Rabin MHA[6], Philip Zachariah MD[5], Rebecca E. Rosenberg MD[7], Patricia DeLaMora MD[8], Parsa Mirhaji MD, PhD[2], Michael Drasher BA[9], Elizabeth Klein BA[2], Oghale Obaro-Best BA[10], William J.H. Ford BA[8], Diana Zarowin BA[2], Alexandre Peshansky MSc[2] and Suzette O. Oyeku MD, MPH[1,2]

[1]Children's Hospital at Montefiore, Bronx, New York, [2]Albert Einstein College of Medicine, Bronx, New York, [3]Medical University of South Carolina, Charleston, South Carolina, [4]Clemson University, Clemson, South Carolina, [5]Columbia University Irving Medical Center, New York, New York, [6]Icahn School of Medicine at Mount Sinai, New York, New York, [7]New York University School of Medicine, New York, New York, [8]Weill Cornell Medical College, New York, New York, [9]Wayne State University School of Medicine, Detroit, Michigan and [10]State University of New York Upstate Medical University, Syracuse, New York

Abstract

Background: Inpatient surgical site infections (SSIs) cause morbidity in children. The SSI rate among pediatric ambulatory surgery patients is less clear. To fill this gap, we conducted a multiple-institution, retrospective epidemiologic study to identify incidence, risk factors, and outcomes.

Methods: We identified patients aged <22 years with ambulatory visits between October 2010 and September 2015 via electronic queries at 3 medical centers. We performed sample chart reviews to confirm ambulatory surgery and adjudicate SSIs. Weighted Poisson incidence rates were calculated. Separately, we used case–control methodology using multivariate backward logistical regression to assess risk-factor association with SSI.

Results: In total, 65,056 patients were identified by queries, and we performed complete chart reviews for 13,795 patients; we identified 45 SSIs following ambulatory surgery. The weighted SSI incidence following pediatric ambulatory surgery was 2.00 SSI per 1,000 ambulatory surgeries (95% confidence interval [CI], 1.37–3.00). Integumentary surgeries had the highest weighted SSI incidence, 3.24 per 1,000 ambulatory surgeries (95% CI, 0.32–12). The following variables carried significantly increased odds of infection: clean contaminated or contaminated wound class compared to clean (odds ratio [OR], 9.8; 95% CI, 2.0–48), other insurance type compared to private (OR, 4.0; 95% CI, 1.6–9.8), and surgery on weekend day compared to weekday (OR, 30; 95% CI, 2.9–315). Of the 45 instances of SSI following pediatric ambulatory surgery, 40% of patients were admitted to the hospital and 36% required a new operative procedure or bedside incision and drainage.

Conclusions: Our findings suggest that morbidity is associated with SSI following ambulatory surgery in children, and we also identified possible targets for intervention.

Keywords: SSI; pediatric; ambulatory

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Inpatient surgical site infections (SSIs) are the second most common type of healthcare- associated infection (HAI).[1] SSIs are also one of the most prevalent serious adverse events of hospitalized patients, with potentially 800,000 SSIs occurring annually in the United States.[1–5] In the United States, these infections increase hospital stays by a mean of 10 days and increase the mean total cost of an admission by $27,000. Cumulatively, SSI expand annual healthcare expenditures by $3.5 to $10 billion and confer a potential 3% mortality rate.[5–11] However, in the United States, ambulatory surgeries now outnumber inpatient surgeries (5,600 vs 4,100 surgeries per 100,000 people, respectively), but significantly less is known about SSI following ambulatory surgery, particularly among children.[12]

An 8-state administrative database study on SSI following ambulatory surgery in 284,098 adult patients reported a rate of 3.09 postsurgical visits for clinically significant SSI per 1,000 procedures.[7] In pediatric and adult patients with SSI following hernia repair and anterior cruciate ligament reconstruction (2 common ambulatory surgeries), rates of serious SSI were 5 and 2 per 1,000 surgeries, respectively.[13] SSI following pediatric and adult ambulatory inguinal hernia surgery rates are between 0.5% to 4.8%,[14–17] with rates significantly higher in children and females.[17] In a single center study by this research group investigating SSI following pediatric ambulatory surgery with different case-finding

Author for correspondence: Michael L. Rinke, E-mail: mrinke@montefiore.org

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methods, the SSI rate following pediatric ambulatory surgery was 2.9 per 1,000 surgeries, or 10 times lower than SSI the rate following pediatric inpatient surgeries[18] but comparable with SSI rates following adult ambulatory surgery. The study's power precluded identification of risk factors. Another study of pediatric SSIs following ambulatory surgery that investigated 3 ambulatory surgical facilities and 1 hospital-based facility in a single pediatric healthcare network reported an SSI rate following ambulatory surgery of 2.5 per 1,000 ambulatory surgeries.[19] When the authors supplemented administrative data with parental interviews, this rate was possibly as high as 48 per 1,000 ambulatory surgeries using a 60-day window following surgery.[19] This study also found an association between older age and reduced odds of infection.[19] Despite unclear rates, data from the database used in this study indicated that costs of SSI following ambulatory surgery in pediatric patients were $6,370 per infection (95% confidence interval [CI], $4,022–$8,719).[20]

Rates of SSI following pediatric ambulatory surgery in all surgery types and in a multicenter cohort have never been clarified, and risk factors for this type of infection as well as outcomes remain unclear. To fill this knowledge gap, we conducted a multi-institution retrospective epidemiologic study to identify and analyze incidence, risk factors, and outcomes associated with SSIs following all types of ambulatory surgery in pediatric patients. The results of this work can be used to identify high-yield targets for efforts aimed at reducing these harmful and costly infections.

Methods

Setting

This retrospective epidemiological analysis was performed in 3 urban, pediatric, tertiary-care academic medical centers. These institutions were brought together as part of the New York City Clinical Data Research Network (NYC-CDRN).[21] The NYC-CDRN organized the creation of electronic queries (described below), although all queries were run at the 3 individual institutions on their site-specific databases. All pediatric patients aged <22 years[22] with ambulatory visits between October 1, 2010, and September 30, 2015, were eligible for inclusion. The study period was chosen to precede the change from the *International Statistical Classification of Diseases and Related Health Problems, Ninth Edition* (ICD-9) to ICD-10, which occurred in October 2015. This study was approved by the Biomedical Research Alliance of New York (BRANY) and by the individual site-specific institutional review boards of the 3 participating academic medical centers.

Surgical site infection following ambulatory surgery and control patient identification

To obtain maximal event capture, pediatric patients who may have had an ambulatory surgery and therefore may have been at risk for SSI following ambulatory surgery were identified with 3 increasingly broad electronic medical record (EMR) queries. The first query identified patients with ICD-9 billing codes specific for SSI in the 30 days following initial surgery. The second query excluded patients from the first query and searched for patients with >1 clinic visit or any admission, reoperation, emergency department visit, complete blood count ordered, wound culture ordered, or antibiotic prescription from the day following their initial ambulatory surgery through 30 days following surgery. These postoperative healthcare utilizations were only identified in the site where the patient had surgery. The third query excluded patients from the first and second queries and included all patients with an ambulatory surgery billing code. Notably, many of these codes included endoscopies and bedside procedures that did not meet the surgical definition discussed below. Complete query parameters are listed in the Appendix (online).

Due to the large number of patients identified by the broader second and third queries, a random sample of ˜20% of patients from each of those queries, but 100% of EMRs of patients identified from the first query were thoroughly reviewed to confirm ambulatory surgery and to adjudicate whether an SSI following ambulatory surgery occurred (definition below). As described below, only 2 SSIs following pediatric ambulatory surgery were identified from the second query and none from the third. Charts were reviewed for 30 days following the initial surgery. Trained abstractors entered data into a REDCAP database.[23] Abstractors were trained by a pediatric hospital epidemiologist (L.S.) who was available for questions and consultation throughout the project.

After all SSIs following ambulatory surgery were adjudicated, the first SSI in the study window for each unique patient was matched up to 1:3 with controls. The cohort of potential controls were patients who had a confirmed ambulatory surgery via EMR review but did not experience an SSI. Matching was completed according to (1) primary surgery organ system (eg, cardiac, pulmonary, neurologic, etc), (2) study site and (3) surgery coincident in time plus or minus 60 days with the case patient's SSI. This matching scheme accounted for changes in prevention strategies throughout the study period and allowed for broad evaluation of potential risk factors. Matching based on specific surgical procedures compared to primary surgery organ system was considered and rejected due to the lower relative incidence of SSIs following ambulatory surgery in children at any given site, and the variation in application of administrative billing codes between surgeons.

We tried to match all case patients with at least 1 control patient before a second control patient could be matched with any case patient. In addition, by examining each patient's first SSI following pediatric ambulatory surgery in the study time window, we reduced the risk of bias from patients who had >1 SSI. Notably, no control patients were identified that met all 3 matching criteria at 1 site that only had 1 patient with an SSI following ambulatory surgery. Risk factors were hypothesized based on prior inpatient and ambulatory SSIs studies, and other ambulatory HAI studies and included patient demographics, patient diagnoses, and medical utilization. Due to ambiguous applications of race and ethnicity data in these databases, and uncertainty of relevance, these characteristics were not included in the risk-factor analysis.

Definitions

The 2015 National Healthcare Safety Network (NHSN) definition for SSI was used and modified for the ambulatory setting.[24] The NHSN's list of applicable surgeries for SSI surveillance are almost exclusively inpatient-based surgeries.[24] For this reason, all operative procedures that were performed on pediatric ambulatory patients were included to provide a comprehensive view of SSIs following ambulatory surgery. Patients were considered to have an ambulatory surgery if they were not admitted to the hospital or not in a hospital bed at midnight on the same day of their surgery. According to NHSN guidelines, an operative procedure included

Table 1. Weighted Surgical Site Incidence (SSI) Following Pediatric Ambulatory Surgery

Surgical Organ System	Surgical Site Infections	Eligible ambulatory surgeries	Weighted SSI Rate per 1000 Ambulatory Surgeries (95% CI)
Total	45	5,411	2.00 (1.4–3.0)
Cardiovascular	0	16	0.00 (0–260)
Diagnostic/ Therapeutic	1	4	65.2 (1.7–1,040)
Digestive	1	572	0.36 (0.01–5.8)
ENT	8	1,815	1.28 (0.4–3.6)
Endocrine	2	19	23.0 (2.8–207)
Eye	1	356	0.58 (0.01–9.3)
Female genital	0	45	0.00 (0–87)
Integumentary	4	485	3.24 (0.32–12)
Lymphatic	1	34	7.76 (0.2–124)
Male Genital	10	764	2.72 (1.2–7.4)
Musculoskeletal	15	1,209	2.64 (1.5–6)
Nervous	2	45	9.84 (1.2–89)
Respiratory	0	3	0.00 (0–1,782)
Urinary	0	44	0.00 (0–89)

Note. CI, confidence interval; ENT, ear, nose and throat. Incidence rates and their 95% CIs were computed based on the exact distribution of weighted sum of Poisson counts. A weight was assigned to each of the 3 cohorts as the inverse of its sampling fraction. Second, we multiply both the number of SSIs and number of surgeries for each cohort with its corresponding weight. Third, we summed up the 3 weighted numbers of SSI and number of surgeries, separately. Finally, we estimated the weighted incidences rates as the weighted sum of SSI numbers divided by the weighted sum of surgery numbers, multiplied by 1,000. For the computation of 95% CIs, we applied equation 11 from Fay and Feuer.[25]

any procedure in which at least 1 incision (including laparoscopic approach) was made through the skin or mucous membranes and the procedure was performed in an operating room.[24] This criteria excluded endoscopies and other tissue-sampling procedures.

Statistical analysis

Descriptive statistics were used to present the incidence, risk factors, and outcome data of SSIs following ambulatory surgery in pediatric patients. Incidence rates and their 95% confidence intervals (95% CIs) were computed based on the exact distribution of weighted sum of Poisson counts[25] accounting for the 20% random sampling of patients identified in the second and third electronic queries. The weights were assigned as the inverses of the sampling probabilities (Table 1). Incidence rates are presented cumulatively and by primary surgery organ system. For risk factor analyses, bivariate exact conditional logistic regression tested each SSI following ambulatory surgery risk factor between case and matched control patients to identify factors potentially significantly associated with SSI. Significant factors ($P < .05$) were then evaluated for association with SSI in a multivariable exact conditional logistic regression with backward elimination to test and identify significant factors adjusting for or independent from other variables in a model. Outcomes for SSI following ambulatory surgery in pediatric patients are presented for all SSIs in the study window (ie, unique patients with more than one SSI are included more than once). The 2-tailed significance level was set at .05, and all statistical analyses were completed using SAS version 9.4 software (SAS Institute, Cary, NC).

Results

Electronic queries from the 3 participating sites over 5 years yielded 65,056 patients. (Fig. 1) 13,795 patients received EMR chart reviews for the time frame surrounding the surgery, including all 286 patients from the first query using ICD-9 billing codes for SSI, 4,428 (23% random sample) from the second query using increased healthcare utilization following surgery, and 9,081 (20% random sample) from the third query. Among this sample, 5,411 patients with an eligible ambulatory surgery and 45 SSIs following ambulatory surgery were identified. One patient had 2 SSIs during the study window.

We calculated a weighted incidence of SSI following pediatric ambulatory surgery of 2.00 SSI per 1,000 ambulatory surgeries (95% CI, 1.37–3.00). Among the 6 surgical organ systems that had >50 surgeries, the highest weighted SSI incidence was in integumentary surgeries (3.24 per 1,000 ambulatory surgeries; 95% CI, 0.32–12), male genital surgeries (2.72; 95% CI, 1.3–7.4), and musculoskeletal surgeries (2.64; 95% CI, 1.5–6.8) (Table 1).

In total, 44 unique patients with SSI following ambulatory surgery were identified and 40 of these were able to be matched to controls: 38 cases matched with 3 controls, and 1 case each had 2 and 1 controls, respectively. Using bivariate conditional logistic regression to analyze risk factors, 4 variables were significantly associated with SSI following ambulatory surgery (Table 2). We used multivariable conditional logistic regression with backward elimination including these risk factors to identify the following variables that carry increased odds of infection: wound class of clean contaminated or contaminated compared to clean (odds ratio [OR], 9.8; 95% CI, 2.0–48), other insurance type compared to private (OR, 4.0; 95% CI, 1.6–9.8) and surgery on weekend day compared to weekday (OR, 30; 95% CI, 2.9–315).

Of the 45 instances of SSI following ambulatory surgery identified in this study, there was significant clinical sequelae. The mean number of days between pediatric ambulatory surgery and SSI identified was 13.3 days; the median was 12 days (interquartile range [IQR], 7–20). Also, 40% of patients were admitted to the hospital, with a median length of stay of 4.5 days. Of patients with an SSI following ambulatory surgery, 36% required a new operative procedure or bedside incision and drainage, 2% became bacteremic following the SSI, 11% of patients received some type of imaging, and 91% received antibiotics (Table 3).

Discussion

In a sampled patient cohort, 44 pediatric patients contracted 45 SSIs following ambulatory surgeries, for an incidence of 2.00 SSI per 1,000 ambulatory surgeries (95% CI, 1.37–3.00). Clean contaminated or contaminated wound class, nonprivate insurance, and surgery on weekend day carried significantly increased odds of infection adjusting for or independent from other variables in the model. Also, 40% of patients were admitted to the hospital and 36% required a new operative procedure or bedside incision and drainage. The identified morbidity associated with SSI following pediatric ambulatory surgery suggests the need for interventions to reduce the harm from SSIs.

In this 5-year, multicenter study, SSI rates following pediatric ambulatory surgery were ˜10 times lower than SSI rates following pediatric inpatient surgeries,[16,26,27] but they were comparable with SSI rates following adult ambulatory surgery.[7,28,29] The weighted incidence of SSI following pediatric ambulatory surgery of 2.00 SSI per 1,000 ambulatory surgeries in this study was ˜30% lower than the incidence of 2.9 SSI per 1,000 ambulatory surgeries

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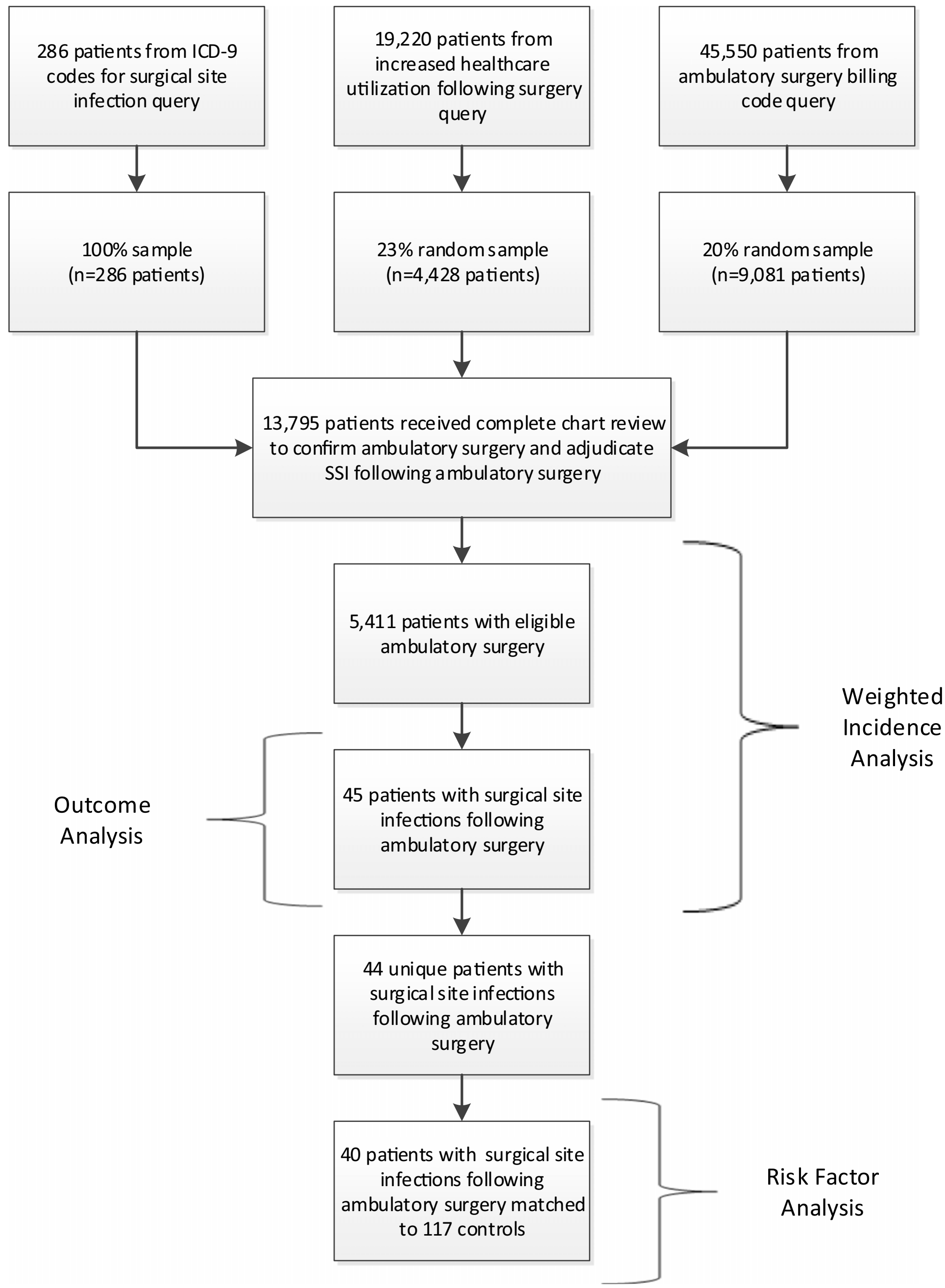

Figure 1. Flow Diagram of Patients Entered into the Study: 2010-2015

reported a single-center study with different methodology.[18] Notably, that study identified endocrine surgeries as incurring the greatest SSI incidence rather than the higher rates of integumentary, male genital, and musculoskeletal surgeries identified here.[18] The differences could be due to differing cohorts between multicenter versus single-center methodologies, and/or the more exhaustive search criteria used in this current study.

The 3 risk factors for SSI following pediatric ambulatory surgery identified in this study were more contaminated wound class (clean contaminated or contaminated), nonprivate insurance, and surgery on weekend day. A prior pediatric study identified older age as significantly associated with reduced odds of SSI following ambulatory surgery, although that study identified SSI up to 60 days following surgery.[19] An adult SSI following ambulatory surgery study identified open as opposed to laparoscopic hernia repair as being associated with increased incidence of SSI. This characteristic was not measured in this study.[7] Inpatient pediatric SSIs have been associated with surgical duration.[27] This risk factor was associated in a bivariate but not multivariable analysis in this study. This difference could be inherent due to longer inpatient surgeries or suggest that the association of surgical duration is confounded by other variables. Knowledge of these risk factors presents us with tangible targets on which to focus future analysis and improvements. We hypothesize that weekend surgeries and/or surgeries with clean contaminated or contaminated wound classes may be more emergent surgeries. If so, further research is needed to determine whether these risk factors are markers for situations in which risk is increased, and/or causative risk factors in and of themselves.

Although it was not an explicit goal of this study, 43 of the 45 SSIs were identified in the first query (15% accuracy), 2 SSIs were

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Table 2. Risk Factors for SSI Following Pediatric Ambulatory Surgery in Bivariate Analysis

Risk Factor	SSI (N=40), No. (%)[a]	Controls (N=117), No. (%)	Odds Ratio (95% CI)	*P* Value[b]
Demographics				
Age at visit, mean y (SD)	10.3 (7.2)	10.9 (7.2)	0.98 (0.93, 1.0)	.54
Sex, female	16 (40)	35 (30)	1.85 (0.72, 4.9)	.23
Language: non-English preferred	3 (8)	16 (14)	0.49 (0.09, 1.9)	.42
Private insurance versus all others	19 (48)	85 (73)	0.35 (0.15, 0.77)	**.008**
Body mass index, mean (SD)	21.4 (5.2)	21.3 (5.1)	1.02 (0.93, 1.1)	.68
Diagnoses[c]				
Comorbidities: mean (SD)	1.4 (0.7)	1.3 (0.6)	1.06 (0.57, 1.9)	.92
Complex chronic condition[30]	7 (18)	12 (10)	1.84 (0.58, 5.4)	.33
Developmental delay	1 (3)	7 (6)	0.40 (0.008, 3.5)	.71
Neuromuscular disorder	1 (3)	2 (2)	1.50 (0.03, 29)	.00
Premature birth	3 (8)	6 (5)	1.63 (0.23, 10)	.80
Presence of concurrent infection[d]	1 (3)	3 (3)	1.00 (0.02, 12)	1.00
Wound class: clean contaminated or contaminated vs clean	16 (43)	32 (28)	4.84 (1.13, 30)	**.03**
Medical utilization				
Surgery duration, min (SD)	90 (70)	59 (52)	1.009 (1.03–1.02)	**.004**
Surgery on weekend vs weekday	6 (15)	1 (1)	18.0 (2.2–827)	**.003**
Feeding tube (oral, nasogastric, gastric, jejunal tube, etc)	1 (3)	0	3.0 (0.16–infinity)	.25
Hospitalization within preceding 30 d	2 (5)	3 (3)	2.30 (0.16–34)	.73
Clinic visit within preceding 30 d	21 (53)	62 (53)	0.94 (0.4–2.2)	1.0
Emergency department visit within preceding 30 d	3 (8)	2 (2)	3.71 (0.4–46)	.31
Contact precautions at prior admission(s)	1 (3)	1 (1)	1.73 (0.02–157)	1.00
Antibiotics within 7 d to treat an infection related to the surgery	1 (3)	0	3.00 (0.16–infinity)	.25
Antibiotics within 7 d to treat an infection not related to the surgery	0	1 (1)	3.00 (0–57)	.75
Antibiotics within 7 d as prophylaxis to prevent an infection	2 (5)	4 (3)	1.30 (0.12–9.2)	1.0
Antibiotics administered within 60 min before surgery	6 (15)	20 (17)	0.87 (0.24–2.8)	1.0
Antibiotics administered during surgery	8 (20)	29 (25)	0.71 (0.24–2.0)	.64
Hardware placed during surgery	8 (20)	18 (15)	1.52 (0.46–4.6)	.57
Urinary catheter not placed at all versus placed during surgery	36 (90)	112 (96)	0.38 (0.07–2.1)	.31
Central line placed or present before surgery versus no central line	3 (8)	1 (1)	9.0 (0.72–470)	.10

Note. CI, confidence interval; SD, standard deviation. Missing data varied by risk factor so total N varies. Multivariable conditional logistic regression identified the following variables significantly associated with SSI: wound class, insurance type and surgery on weekend day

[a]4 unique patients with SSI following ambulatory surgery were unable to be matched to any control patients and are excluded. 1 patient had 2 SSIs during the study window and is only included once.

[b]Bold indicates statistical significance.

[c]The following diagnoses had no patients in either case or control groups identified: intensive care unit admission in last 30 days, central line placement in the last 30 days, positive blood cultures in last 2 years, bone marrow transplant in last 100 days, primary immunodeficiency, cystic fibrosis, neutropenia, abnormal albumin, technology dependence, bowel resection.

[d]Concurrent infections included conjunctivitis, urinary tract infections, otitis media and infected cyst.

identified in the second query (0.05% accuracy), and none in the third query. This finding may suggest that a query based on healthcare utilization after surgery may not be sensitive for SSI following pediatric ambulatory surgery. Many patients coded as having "ambulatory surgery" instead had bedside incision and drainage or endoscopic procedures. These procedures could be explicitly excluded in future research efforts.

This study has several potential limitations. Possible misclassification bias exists because charting and coding may not have been consistent across care providers or electronic medical record documentation at the 3 institutions. Additionally, healthcare utilization occurring outside a patient's primary surgery site were not able to be searched, and more patients may have qualified for the second query if these data were available. Although extensive efforts were made to both standardize and monitor chart reviews, some variation between chart abstractors may have remained. The assessment of risk factors may also be biased because 9% of cases were unable to be matched to controls. The NHSN definition for SSI was not

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Table 3. Outcomes for All Surgical Site Infections (SSIs) following Ambulatory Surgery

Outcome	All SSIs in Window, No. (%) (N=45)
Days from surgery to SSI diagnosis: median (IQR)	12 (7–20)
Hospital admission in 30 d following SSI[a]	18 (40)
Length of stay, median d (IQR)	4.5 (2–6)
Emergency department visit in 30 d following SSI	14 (31)
SSI required new operative procedure	9 (20)
SSI required incision and drainage not in operating room	7 (16)
SSI patient became bacteremia	1 (2)
SSI led to drain being placed	8 (18)
Antibiotics to treat SSI	41 (91)
Antibiotics route[b]	
Intravenous	22 (49)
Oral/nasogastric/gastric/jejunal tube	32 (71)
Imaging relating to SSI[c]	5 (11)
Radiographs	1 (2)
Computed tomography	1 (2)
Magnetic resonance imaging	1 (2)
Ultrasound	2 (4)

Note. IQR, interquartile range. Missing data varied by outcome, so total no. varies.
[a]There were no mortalities in the 30 d following SSI and no admissions to an intensive care unit.
[b]Patients received antibiotics by this route at any time, so the same patient may be in both categories.
[c]No patients received interventional radiology imaging or a voiding cysto-urethrogram.

developed for ambulatory infections, although prior research used similar modifications to identify SSI following ambulatory surgery.[7,18,19] Risk of SSI following pediatric ambulatory surgery may be unrelated to ambulatory surgery and may be due to risk factors not measured here. Although broad search query criteria were employed, not every eligible patient was identified through electronic searches, leading to overestimation of SSI following ambulatory surgery incidence. Because the rate of SSIs in this dataset is relatively small and heterogeneity exists between the possible surgery types included, validation with other data sets including more frequent SSI outcomes would help ascertain validity of our results. Finally, all of the involved institutions were tertiary-care, academic, pediatric medical centers; therefore, these results may not be generalizable to all pediatric ambulatory surgery patients or sites.

In conclusion, SSI following pediatric ambulatory surgery leads to substantial morbidity in pediatric populations. We identified 3 modifiable risk factors, and we have and suggested high yield targets for additional interventions. Further research is needed to reduce the burden of SSI following pediatric ambulatory surgeries nationally.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/ice.2021.279

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