Associations Between Structural and Social Determinants of Health with Pediatric Surgical Site Infections

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Abstract

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Abstract

Objective: Determine if disparities exist in surgical site infections (SSI) for pediatric patients from minoritized language and racial and ethnic groups, and for those with a public insurance payor.

Design, Setting, and Participants: This single-center cohort study retrospectively examined outcomes of patients undergoing eligible inpatient and outpatient surgical procedures from October 1, 2015 to September 30, 2020 at a freestanding children's hospital and regional referral center; procedures without skin incisions were excluded.

Methods: SSI cases were identified via an internally developed and validated surveillance algorithm. Models were constructed for each exposure: language of care, race and ethnicity, and insurance payor. Adjusted risk ratios were generated using log-binomial regression with clustering at the patient. All models were adjusted for patient and procedure factors known to affect SSI risk.

Results: 39,508 patients contributed 52,529 eligible surgeries with 800 SSIs (1.52%). Language did not have an association with SSI (aRR for LOE group compared to English, 1.03, 95% CI

0.80-1.29, P=0.91); an association with higher SSI risk was seen for patients with race and ethnicity of America Indian and Alaska Native (aRR 1.47, 95% CI 1.01-2.15, P= 0.044) and those with Medicaid insurance (aRR 1.29, 95% CI 1.11-1.50, P= 0.001).

Conclusions: We observed a similar SSI risk for patients using a language other than English but identified disparities with a higher SSI risk in those identifying as American Indian and Alaska Native and those with Medicaid insurance. Assessing for disparities through infection prevention work is essential so strategies can be optimized to better serve disproportionately impacted groups.

Introduction

Surgical site infections (SSIs) are one of the most common causes of healthcare-associated infection (HAI), and result in significant morbidity and mortality. SSIs occur in 2-4% of patients who undergo inpatient surgery and are the leading cause of readmission after surgery.[1] Risk factors for SSI include patient factors such as nutritional status, immune system function, and microorganism colonization, as well as surgical factors such as procedure type and wound classification.[1-3] Multiple interventions before, during, and after surgery contribute to SSI prevention, including preoperative bathing, preoperative antibiotic administration when indicated, intraoperative skin preparation, sterile operative procedures, and perioperative temperature control.[2-4] However, despite these known best practices, SSIs still occur and are largely preventable.

Health disparities, a "particular type of health difference that is closely linked with economic, social, or environmental disadvantage"[5], affect patients of minoritized groups. Such disparities may affect patients and families who use languages other than English (LOE) for medical care, as it has been demonstrated that the medical system often provides suboptimal interpretation support and opportunities for these patients and their families.[6, 7] In the pediatric population, children whose parents endorsed limited comfort with English demonstrated a higher risk of adverse events during hospitalization.[8-10] Further, it is well established that systemic racism contributes to poorer health outcomes in many domains.[11, 12] Such disparities have been demonstrated in pediatric postsurgical outcomes, with African American children having a higher odds of death and postoperative complications after surgery.[13]

Evidence on disparities specific to pediatric SSI is lacking. Moreover, given that SSIs continue to occur despite established prevention practices, investigation of additional contributing factors is essential. Due to the widespread documentation of racism and bias in healthcare, and prior disparities in other HAIs at our institution,[14] our objective was to assess for

potential disparities in SSIs with the eventual goal of developing mitigations for any observed disparities. In this study, we aimed to determine if disparities exist in SSIs at our institution for patients from minoritized language, racial, and ethnic groups, and for those with a public insurance payor. Race and ethnicity are used here as a proxy for experienced systemic racism. We hypothesized that higher rates of SSIs would be seen for patients and families who speak a language other than English (LOE), those identifying as belonging to minoritized racial and ethnic groups, and those with a public insurance payor.

Methods

Setting

Seattle Children's Hospital (SCH) is a 364-bed freestanding children's hospital serving as a pediatric referral center for several states in the Pacific Northwest, including Washington, Alaska, Montana, and Idaho. SCH conducts both inpatient and outpatient surgical procedures at the main hospital campus and an additional outpatient surgery center. As part of infection prevention practices, active surveillance for SSI is performed for a subset of surgical procedures. Additionally, an internally developed and validated algorithm to identify SSI based on administrative data[15] (herein referred to as "passive surveillance algorithm") is utilized to track SSI rates.

Study Design and Subjects

We conducted a retrospective cohort study with the primary aim to examine the association between patient language for care and SSI. In further analyses, we also examined the associations between both patient language of care and patient race and ethnicity and SSI.

Subjects consisted of patients who underwent an eligible surgical procedure within the SCH system from 10/01/2015 to 9/30/2020 (with follow up through the 90 days after procedure).

Eligible surgical procedures consisted of an SCH-developed list used for SSI surveillance and excluded those without skin incisions (such as bronchoscopy or cystoscopy, myringotomy tubes, tonsillectomy) given a differential risk of surgical site infections in these patients as well as incision and drainage procedures, as patients undergoing these procedures were already likely to have infections. Supplemental Table 1 lists excluded procedures.

Data and Definitions

Data was collected from the EHR and was organized at the unit of the surgical encounter for this analysis. If a single patient underwent multiple surgical encounters during the study period, each surgical encounter was considered an eligible observation. Patient language group, race, and ethnicity are collected routinely at the time of hospital system registration for clinical and demographic purposes by self-report from patient or parent/guardian. At Seattle Children's, approximately 10% of patients use a LOE. In fiscal year 2022, the most frequently reported languages for inpatients included: Spanish (7.0%), Somali (0.6%), Vietnamese (0.5%), Mandarin (0.3%), Arabic (0.2%), Amharic (0.2%), Russian (0.2%), and Tigrinya (0.2%). During the study period, race and ethnicity were categorized using the following groups: American Indian and Alaska Native (AIAN), Asian, Black or African American (BOAA; hereafter referred to as "Black"), Hispanic, Native Hawaiian and Other Pacific Islander (NHPI), non-Hispanic White, other, unknown or refused, and two or more races.

The identification of an SSI using the internally developed passive surveillance algorithm requires either 1) a diagnosis code of "infection following a procedure", or 2) a qualifying procedure plus a combination of *all* of the following a) a qualifying diagnosis of infection associated with the index surgery within 90 days of the index surgery, b) qualifying microbiology culture after the index surgery, c) antibiotic administration 3-90 days after the index surgery, and d) hospital admission or a qualifying surgery related to infection within 90 days after the index surgery. In validation compared to institutional National Surgical Quality Improvement Program

Pediatric (NSQIP Peds) data, the algorithm displayed a sensitivity of 44%, specificity of 99%, NPV of 99%, PPV of 59%, and Cohen's kappa of 0.5.[15] The passive algorithm is the only feasible way to do surveillance on this scale, as chart review would be a barrier to completing large-scale surveillance efforts.

Additional variables collected at the patient level included zip code of residence, age, sex, body mass index (BMI), and American Society of Anesthesiologists (ASA) physical classification system. Variables collected at the procedure level included surgery location, surgical service, and Centers for Disease Control (CDC) surgical wound classification system. Zip codes were used to create a binary variable for those living in the counties comprising the Seattle-Tacoma metropolitan area in order to account for how local access to specialty care may affect SSI. The variable for sex was obtained using legal sex as listed in the EHR which is defined as the sex used for legal purposes and usually reflects the sex listed on the patient's birth certificate or ID. BMI categories were created using BMI Z-score by sex and age. SSI prevention bundle compliance was assessed using EHR data; compliance was defined as administration of both 1) a bath or chlorhexidine treatment on the day of surgery and 2) preoperative antibiotics if indicated. In an effort to account for procedures with a higher risk of SSI, a procedure category variable (ordinal with three levels) was derived from our hospital's procedure risk category, a locally developed classification system used to inform SSI prevention practices, such as number of chlorhexidine treatments and use of pre-operative antibiotics.[16] Procedure category is assigned by the surgeon; generally, procedures in the high-risk group include cardiac surgery, neurosurgery, and surgery with implants. Given the numbers of patients with missing values for BMI and procedure category, these observations were retained and grouped as a discrete missing category for these variables. We created conceptual diagrams (Supplemental eFigures 1 and 2) using DAGitty[17, 18] to provide a conceptual representation and to assist in determining adjustment variables for multivariable analysis below.

Analysis

Descriptive statistics were performed to describe characteristics of procedures and clinical characteristics of the patients represented in the dataset. We conducted log-binomial regression analyses to estimate adjusted risk ratios (aRR) and 95% confidence intervals of the associations between our exposures of interest (language of care, race and ethnicity, and insurance payor) and SSI. Clustering occurred at the level of the patient to account for patients who had multiple surgical procedures during the study period. Complete case analysis was used. A 2-sided $P < .05$ was considered statistically significant.

Three models were constructed, one for each exposure variable: language of care, race and ethnicity category, and insurance payor. Adjustment variables included in the model were determined *a priori* based on factors plausibly associated with our exposures of interest and known to affect the risk of surgical site infection;[2, 3, 19] all models included surgical wound classification, procedure category, bundle compliance, ASA classification, BMI category, age, and sex. The language model was additionally adjusted for race and ethnicity and the race and ethnicity model was additionally adjusted for language. Insurance payor was not included in these models as it serves as a proxy for socioeconomic status (SES), which we hypothesized acts as a mediator for some of the potential effects of racism and bias on SSI.[20, 21] The insurance model was adjusted for race and ethnicity and language.

Additionally, among the sub-set of patients who language was LOE, we explored differences in the risk of SSI by race and ethnicity by calculating and qualitatively comparing the risk of SSI (proportion and exact 95% CIs) within each race and ethnicity stratum and the whole LOE group. The purpose of this analysis was to explore the potential effects of having multiple marginalized identities on SSI. We did not perform statistical testing across groups because our interest was in describing the differences rather than formal hypothesis testing. Additionally, we recognize that each individual stratum as defined by race and ethnicity may include small

numbers of surgeries. Analyses were conducted using Stata 14 (StataCorp, College Station, TX). The study was reviewed by the Seattle Children's Institutional Review Board (IRB) and designated IRB exempt.

Results

From 10/01/2015 to 9/30/2020, there were 53,751 eligible surgeries with 817 SSIs. 1219 surgeries were excluded due to missing data for one or more of the model variables; 3 surgeries were excluded due to implausible age or occurring for the purposes of organ donation. The remaining 52,529 surgeries with 800 SSIs were included and represented 39,508 patients. Demographic characteristics (Table 1) were similar to that of our healthcare organization patient population, though with a higher percentage of male patients represented in surgical patients compared to organization-wide patient visits. Approximately two-thirds of patients were from the Seattle-Tacoma metropolitan area, with a higher percentage of patients with LOE from the local area.

Table 2 presents the risk of SSI by language for care, race and ethnicity, and insurance. Overall, the percentage of surgical procedures with an SSI was 1.52%. The percent of patients with an SSI was similar for patients who spoke English compared to patients who spoke LOE (1.50% vs. 1.71%, respectively). In adjusted multivariable regression analyses, language for care was not significantly associated with the risk of SSI (aRR for LOE group compared to English 1.03, 95% CI 0.80-1.29, P=0.91. For patient race and ethnicity, a self-reported race and ethnicity of America Indian and Alaska Native was associated with a higher risk for SSI (3.11% with SSI; aRR 1.47, 95% CI 1.01-2.15, P= 0.044) compared to a self-reported race of white; the aRR of the association between race and ethnicity and SSI was not statistically significant for other race and ethnicity groups. Coverage from Medicaid insurance was also associated with a higher risk for SSI (1.87% with SSI; aRR 1.29, 95% CI 1.11-1.50, P= 0.001) compared to commercial or other insurance types (1.26% with SSI).

We explored differences in the risk of SSI by race and ethnicity among patients with LOE (Table 3). Compared to the overall rate of SSI for patients with LOE (1.71%), we observed a higher risk of SSI for patients with LOE who identified as Black (2.46%), and patients with LOE identifying as 2 or more races (4.76%).

Discussion

In our single-center retrospective cohort study of a pediatric hospital, we did not observe an association between patient language for care and the risk of SSI. We observed a higher risk of SSI in patients with a self-identified race and ethnicity of American Indian and Alaska Native, (AI/AN) as well as those patients with Medicaid insurance coverage. These findings suggest that social and structural determinants of health can contribute to SSI.

We did not identify significant disparities in SSI for patients using a LOE during our study period; this may be indicative that disparities in our SSI rates truly do not exist, or that our methods of analysis did not effectively identify disparities. Limitations to the passive surveillance algorithm that we used and possible misclassification of language for care could have affected our ability to identify disparities. It is well-known that patients and families using a LOE can experience significant barriers when receiving healthcare, and other disparities in HAIs for those with LOE have been observed in our hospital. [14] Thus, ongoing tracking will be needed to ensure no newly identified disparities are seen and to ensure SSI prevention practices are appropriately tailored to this population's needs.

In our hospital system population, disparities in SSI existed for patients identifying as AI/AN. Given that we adjusted for multiple variables that affect the risk of SSI, our findings suggest that other factors such as racism, bias, and health system access play a role in creating inequities in SSIs. The impacts of health inequities experienced by those in AI/AN populations are well-documented, with origins in racism, bias, and historical trauma.[22-24] AI/AN children

experience disproportionately high burdens of other conditions such as dental caries and chronic otitis media.[22] Recently, a study of general surgery procedures through the National Surgical Quality Improvement Program demonstrated higher odds of major postoperative complications for AI/AN patients.[25] The roles of racism, bias, and access in driving inequities in HAIs likely occur at multiple levels- societal and structural, institutional, and interpersonal.[26] Next steps in response to our findings will include work to understand the ways that AI/AN patients and families experience surgical care at our facility and potential drivers of inequities in order to develop mitigations. We also observed higher unadjusted rates of SSI for those in the Native Hawaiian and Pacific Islander group compared to overall SSI rates; however, in multivariable analysis, the aRR did not meet statistical significance. This could be due to small surgery and SSI numbers in this group; we will pursue ongoing attention to potential disparities for this group.

Additionally, we observed higher rates of SSI for children with Medicaid insurance. Similar disparities were identified in SSIs after Cesarean delivery in those with Medicaid insurance compared to private insurance.[27] In our study, insurance payor served as a proxy for patient and family socioeconomic status (SES), though issues related to care access also likely play a role in the pathway for how patients with differing insurance payors experience disparities. Though our study focused primarily on factors at the patient and family level, community-level factors also have significance; a recent study found associations between pediatric trauma surgery patients living in areas with high social vulnerability index (SVI)[28] and higher risk of SSI.

In our exploration of the effects of race and ethnicity on the association of LOE and SSI risk, we found higher rates of SSI for those patients who use an LOE and identified as 2 or more races or as Black. Though these findings are limited by the small event sizes and wide confidence intervals, they highlight the potential additive barriers that may be experienced by

those with multiple marginalized identifies and the importance of considering intersectionality in healthcare equity work.

This study was strengthened by our large sample size of surgical procedures and ability to assess multiple patient and procedure factors from EHR data. Our study also has several important limitations. First, this was a single center study and may not be generalizable to all healthcare settings or patient populations. Second, the passive surveillance algorithm used for case identification of the primary outcome has a high specificity (99%) but a limited sensitivity (44%). This is likely to result in non-differential misclassification of the outcome, which would be expected to bias towards the null. Third, this surveillance algorithm will only detect SSIs when patients were followed within the SCH system, and not those where patients were followed externally. Fourth, given that we used retrospective EHR data, we were not able to collect data on all relevant factors that may affect SSI such as immunosuppressed status, and even data for which we could collect data on may not have been completely or accurately measured, resulting in residual confounding. Additionally, we were unable to assess full SSI prevention bundle practices throughout the entire study period due to limitations of these data not being available at the patient level. Fifth, we used hospital demographic data to obtain patient race, ethnicity, and language. Though these are self-identified data, nuance such as varying language needs among patients and caregivers may not be reflected. Sixth, LOE was analyzed in dichotomous form, though in reality this is a heterogeneous category with variability likely based on the exact languages used by patients and families. Finally, the racial and ethnic categories used require identification into socially constructed categories which may not accurately reflect individual experiences.[29]

In summary, we utilized an infection prevention-based surveillance system to assess for disparities in SSI for pediatric patients and found no association between language of care and risk of SSI. However, we observed a higher risk of SSI for patients identifying as American

Indian and Alaska Native, and those with Medicaid insurance. The identification of the described disparities is only an initial step which will be followed by essential work to better understand these disparities and to engage patients and community members from disproportionately affected groups.[30] Learnings from these steps will subsequently inform equity-informed quality improvement strategies with the aim of reducing disparities. This work will involve a collaborative process focused on how patients and families experience care throughout pre-, peri-, and postoperative care. Assessing for disparities in HAIs such as SSI is an essential step of infection prevention work so that prevention strategies can be optimized to better serve disproportionately impacted groups and subsequently move towards equity in the prevention of healthcare-associated harms.

Table 1. Patient and Procedure Characteristics of Surgical Procedures at Seattle Children's Hospital from 10/01/2015 to 9/30/2020 Included in Analyses

Patient Characteristic[a]	**Language for Care: English** (n= 35,190; 89%)	**Language for Care: LOE** (n= 4318; 11%)	**Total Population** (n= 39,508)
Age, years[b] (median [IQR])	6.9 (1.6-13.1)	8.4 (3.3-13.2)	7.1 (1.7-13.1)
Sex			
Male	21,574 (61%)	2678 (62%)	24,252 (61%)
Female	13,611 (39%)	1640 (38%)	15,251 (39%)
Non-binary	5 (0.01%)	0	5 (0.01%)
Insurance coverage			
Non-Medicaid	22,445 (64%)	417 (9.7%)	22,862 (58%)
Medicaid	12,745 (36%)	3901 (90%)	16,646 (42%)
Race and ethnicity			
Non-Hispanic White	19,413 (55%)	304 (7%)	19,717 (50%)
Hispanic	4489 (13%)	2636 (61%)	7125 (18%)
Asian	2877 (8.2%)	570 (13.2%)	3447 (8.7%)
Unknown/Refused	2341 (6.7%)	170 (3.9%)	2511 (6.4%)
2 or more races	2271 (6.5 %)	47 (1.1%)	2318 (5.9%)
Black or African American	1635 (4.7%)	326 (7.6%)	1961 (5.0%)
Other[c]	1,293 (3.7%)	238 (5.5%)	1531 (3.9%)
American Indian & Alaska Native	532 (1.5%)	4 (0.09%)	536 (1.4%)
Native Hawaiian & other Pacific Islander	339 (0.96%)	23 (0.53%)	362 (0.92%)
BMI Z-Score category			
Below -2	800 (2.3%)	112 (2.6%)	912 (2.3%)
-2 to 2	19,526 (55%)	2424 (56%)	21,950 (56%)
2 to 3	1940 (5.5%)	465 (11%)	2405 (6.1%)
3 and above	1296 (3.7%)	209 (4.8%)	1505 (3.8%)
N/A: Under 2 years of age	9465 (27%)	781 (18%)	10,246 (26%)
Missing	2163 (6.2%)	327 (7.6%)	2490 (6.3%)
Residence			
Local metropolitan area	23,458 (67%)	3195 (74%)	26,653 (67%)
Other	11,732 (33%)	1123 (26%)	12,855 (33%)
Surgery Characteristic	**Language for Care: English** (n= 46,792; 89%)	**Language for Care: LOE** (n= 5737; 11%)	**Total Population** (n= 52,529)
ASA Classification			
1	17,579 (38%)	2242 (39%)	19,821 (38%)
2	15,909 (34%)	1906 (33%)	17,815 (34%)
3	10.782 (23%)	1294 (23%)	12,076 (23%)
4	2454 (5.2%)	287 (5.0%)	2741 (5.2%)
5	68 (0.15%)	8 (0.14%)	76 (0.14%)
Procedure Category			
Lower Risk	5978 (13%)	844 (15%)	6822 (13%)
Medium Risk	25,495 (55%)	3190 (56%)	28,685 (55%)
Higher Risk	6566 (14%)	679 (12%)	7245 (14%)
Missing	8753 (19%)	1024 (18%)	9777 (19%)
Wound Classification			
I: clean	29,386 (63%)	3367 (59%)	32,753 (62%)
II: clean contaminated	15,487 (33%)	2050 (36%)	17,537 (33%)
III: contaminated	1308 (2.8%)	215 (3.8%)	1523 (2.9%)

IV: dirty	611 (1.3%)	105 (1.8%)	716 (1.4%)
Bundle Compliance	41,624 (89%)	5,041 (88%)	46,665 (89%)
Surgery Center Location			
Main Hospital Campus	34,041 (73%)	4310 (75%)	38,351 (73%)
Surgery Center	12,751 (27%)	1427 (25%)	14,178 (27%)
Surgical Service			
Cardiac	2178 (4.7%)	194 (3.4%)	2372 (4.5%)
General Surgery	11,214 (24%)	1511 (26%)	12,725 (24%)
Gynecology	350 (0.75%)	32 (0.56%)	382 (0.73%)
Neurosurgery	3521 (7.5%)	376 (6.6%)	3897 (7.4%)
Oral Surgery	566 (1.2%)	74 (1.3%)	640 (1.2%)
Orthopedics	11,042 (24%)	1178 (21%)	12,220 (23%)
Other or Missing	15 (0.03%)	2 (0.03%)	17 (0.03%)
Otolaryngology	4331 (9.3%)	767 (13%)	5098 (9.7%)
Plastic Surgery	4832 (10%)	578 (10%)	5410 (10%)
Transplant Surgery	800 (1.7%)	119 (2.1%)	919 (1.8%)
Urology	7943 (17%)	906 (16%)	8849 (17%)

[a]Described as n (%) unless noted otherwise.

[b]At first observation in dataset.

[c]Other was an available category for patients and families as an option when selecting self-identified race and ethnicity.

Table 2. Adjusted Risk Ratios (aRR) for Surgical Site Infection (SSI)

	% with SSI	**No of SSIs**	**No of Procedures**	**aRR for SSI** (95% CI)	**P-value**
Overall	1.52%	800	52,529	-	-
Language for care					
English	1.50%	702	46,792	Ref	-
Language other than English	1.71%	98	5737	(0.80, 1.29)	0.91
Race & ethnicity					
American Indian & Alaskan Native	3.11%	25	804	**1.47 (1.01, 2.15)**	**0.044**
Asian	1.32%	60	4530	1.02 (0.75, 1.39)	0.89
Black or African American	1.54%	41	2657	0.82 (0.58, 1.16)	0.27
Hispanic	1.68%	163	9680	0.98 (0.79, 1.22)	0.84
Native Hawaiian & Pacific Islander	2.84%	14	493	1.57 (0.98, 2.54)	0.063
Non-Hispanic White	1.44%	377	26,167	Ref	-
2 or more races	1.52%	47	3082	1.03 (0.77, 1.38)	0.85
Other/Unknown/Refused	1.43%	73	5116	1.04 (0.81, 1.34)	0.74
Insurance coverage					
Medicaid	1.87%	423	22,657	**1.29 (1.11, 1.50)**	**0.001**
Commercial or Other	1.26%	377	29,872	Ref	-

[a]Represents surgical procedures included in regression model.

[b]3 models were constructed, with each bolded variable as the exposure variable in a model. All models were adjuted for surgical wound classification, procedure category, bundle compliance, ASA classification, BMI category, age, and sex. The language model was additionally adjusted for race & ethnicity. The race & ethnicity model was additionally adjusted for language. The insurance model was adjusted for race & ethnicity and language. See methods text for further details.

Table 3. Surgical Site Infections in Patients Using a Language Other than English (LOE), Stratified by Race & Ethnicity

Race & ethnicity	**No. SSI/ No. Surgeries** (98/5737)	**% with SSI[a]**	**95% CI**
American Indian & Alaska Native	0/8	0%	0, 36.94%
Asian	12/721	1.66%	0.86, 2.89%
Black or African American	11/448	2.46%	1.23, 4.35%
Hispanic	60/3483	1.69%	1.32, 2.21%
Native Hawaiian & Pacific Islander	0/34	0%	0, 10.28%
Non-Hispanic White	6/389	1.54%	0.57, 3.33%
2 or more races	3/63	4.76%	0.99, 13.29%
Other	6/311	1.93%	0.71, 4.15%
Unknown/Refused	0/220	0%	0, 1.66%

[a]1.7% of procedures had an SSI in the LOE group overall.

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