Infection Control & Hospital Epidemiology (2024), **45**, 21–26
doi:10.1017/ice.2023.150

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Original Article

Reportable infections following colon surgery in a large public healthcare system in New York City: The consequences of being a level 1 trauma center

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Abstract

Objectives: To examine differences in risk factors and outcomes of patients undergoing colon surgery in level 1 trauma centers versus other hospitals and to investigate the potential financial impact of these reportable infections.

Design: Retrospective cohort study between 2015 and 2022.

Setting: Large public healthcare system in New York City.

Participants: All patients undergoing colon surgery; comparisons were made between (1) all patients undergoing colon surgery at the level 1 trauma centers versus patients at the other hospitals and (2) the nontrauma and trauma patients at the level 1 trauma centers versus the nontrauma patients at other hospitals.

Results: Of 5,217 colon surgeries reported, 3,531 were at level 1 trauma centers and 1686 at other hospitals. Patients at level 1 trauma centers had significantly increased American Society of Anesthesiology (ASA) scores, durations of surgery, rates of delayed wound closure, and rates of class 4 wounds, resulting in higher SIRs (1.1 ± 0.15 vs 0.75 ± 0.18; $P = .0007$) compared to the other hospitals. Compared to the nontrauma patients at the other hospitals, both the nontrauma and trauma patients at the level 1 trauma centers had higher ASA scores, rates of delayed wound closure, and of class 4 wounds. The SIRs of the nontrauma patients (1.16 ± 1.29; $P = .008$) and trauma patients (1.26 ± 2.69; $P = .066$) at the level 1 trauma center were higher than the SIRs of nontrauma patients in the other hospitals (0.65 ± 1.18).

Conclusions: Patients undergoing colon surgery at level 1 trauma centers had increased complexity of surgery compared to the patients in other hospitals. Until there is appropriate adjustment for these risk factors, the use of infections following colon surgery as a reportable quality measure should be re-evaluated.

(Received 13 April 2023; accepted 12 June 2023; electronically published 18 July 2023)

Infections related to colon surgery are associated with considerable adverse clinical outcomes. Increased lengths of hospital stay and readmissions have been reported with surgical-site infections (SSIs) following colon surgery.[1–3] In particular, deep incisional and organ-space infections have been associated with the greatest clinical burden, including increased mortality.[1,4]

Colon SSIs are associated with substantial monetary burden. SSIs increase lengths of hospital stay resulting in increased hospital expenditures.[3] SSIs are reportable to the National Healthcare Safety Network (NSHN) and to the Centers for Medicare and Medicaid Services (CMS). Rates of SSI are factored into the Hospital-Acquired Condition Reduction and Hospital Value-Based Purchasing Programs; therefore, considerable financial penalties exist for the "low-performing" hospitals.[5] As a result, "bundles" and other programs to reduce SSIs have become priorities at many medical centers, with varying degrees of success.[6–13] Bundles often emphasize preoperative colon preparations, appropriate perioperative antibiotics, standardized surgical field preparation, hand hygiene, and perioperative normothermia and euglycemia.[12,13]

Frequently cited risk factors for the development of SSI following colon surgery include elevated body mass index (BMI), substance abuse, trauma, and underlying medical conditions including diabetes mellitus, emphysema, chronic renal failure, cancer, and drug-induced immunosuppression.[14,15] Also, timing and duration of perioperative antibiotics, laparoscopic versus open approach, wound contamination class, and need for drains or ostomy are recognized as important factors.[16–18] Factors beyond the individual patient and procedure are important risk factors;

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Cite this article: Fornek ML, Ata S, Jimenez E, *et al*. Reportable infections following colon surgery in a large public healthcare system in New York City: The consequences of being a level 1 trauma center. *Infect Control Hosp Epidemiol* 2024. 45: 21–26, doi: 10.1017/ice.2023.150

patients of low socioeconomic status have been identified as having higher odds for colon SSIs.[19]

In this study, we examined the differences in patients undergoing colon surgery in level 1 trauma centers versus other acute-care hospitals as well as their impact on NHSN reporting.

Methods

The New York City Health + Hospitals System consists of 11 acute-care urban medical centers with academic affiliations. All are safety-net hospitals that serve patients primarily of low socioeconomic status in the boroughs of Bronx, Brooklyn, Manhattan, and Queens. For this study, the American Trauma Society designations were used to create 2 comparison groups. The first group contained 5 of the 11 hospitals designated as level 1 trauma centers. The comparison group contained the other 6 hospitals that are not level 1 trauma centers. We conducted 2 comparisons. The first comparison involved all patients undergoing colon surgery at the level 1 trauma centers versus all patients at the other hospitals. To better understand any differences between these 2 groups, a second comparison was made that involved the nontrauma and trauma patients at the level 1 trauma centers versus the nontrauma patients at the other hospitals.

The Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN) surveillance criteria were utilized to define colon procedures and SSI events. Listings of patients that underwent colon surgery between 2015 and 2022 were obtained from the NHSN database. Detailed chart reviews were conducted for patients with SSIs reported. Additional information obtained from the chart reviews included the indication for surgery, underlying medical conditions, and laboratory data. For patients with multiple surgeries during the 30-day follow-up period, data from the initial surgery were recorded. Wound classification at the time of surgery was also documented: class 2 (clean-contaminated), class 3 (contaminated), or class 4 (dirty).

The Student *t* test and χ^2 analysis were used to compare continuous and categorical values, respectively. The Spearman correlation was used to determine the association between variables. Multinomial logistic regression analysis was performed using SPSS software (IBM, Armonk, NY) to determine variables associated with the CMS outcome measures of deep-incisional and organ-space SSIs. The following variables were included: age, BMI, operating room duration, sex, American Society of Anesthesiology (ASA) class, primary closure, diabetes mellitus, emergency surgery, endoscopic surgery, wound type, and surgery performed at a level 1 trauma center. This study was approved by the SUNY Downstate Medical Center Institutional Review Board and the Health and Hospitals Systems to Track and Approve Research program.

Results

From 2015 to 2022, some 5,217 colon surgeries were reported from the 11-hospital system. In total, 387 SSIs (7.4%) were reported, including 276 deep incisional or organ-space infections. Multivariate analysis identified 7 variables significantly associated with deep incisional or organ-space SSIs: duration of surgery ($P < .001$), male sex ($P = .008$), ASA class ($P = .02$), emergency surgery ($P = .008$), nonlaparoscopic surgery ($P = .03$), wound class ($P < .001$), and surgery performed at a level 1 trauma center ($P < .001$). Annual rates of SSI in the level 1 trauma centers were consistently greater than those of the other hospitals (4.58 ± 0.81 vs 2.07 ± 0.56 infections per 100 surgeries; $P < .0001$). Similarly, the annual standardized infection ratios (SIRs) for the level 1 trauma centers were consistently greater (1.1±0.15 vs 0.75±0.18; $P = .0007$) (Fig. 1a). The mean annual SIRs for the 5 level 1 trauma centers were 0.91, 1.39, 1.11, 0.86, and 1.55. In comparison, the mean annual SIRs for the remaining 6 hospitals were 0, 0.53, 1.37, 0.53, 0.54, and 0.94.

Comparison of hospitals: Level 1 trauma centers versus the other hospitals

In total, 3,531 cases occurred at the 5 level 1 trauma centers; 1,686 cases occurred at the 6 remaining hospitals. Characteristics of the cases from each of the 2 cohorts are given in Table 1. Compared to the other hospitals, a disproportionate distribution of wound class groups occurred among the level 1 trauma centers. Significantly fewer patients had class 2 wounds in the level 1 trauma centers: 2,134 (60%) of 3,531 surgeries versus 1,070 (63%) of 1,686 surgeries ($P = .04$). Also, significantly more patients had class 4 wounds in the level 1 trauma centers: 603 (17%) of 3,531 surgeries versus 237 (14%) of 1,686 surgeries ($P = .005$). The annual SIRs at the level 1 trauma centers strongly correlated with the percentage of cases with class 4 wounds at the time of surgery ($r_s = 0.95$; $P = .0003$) (Fig. 1b).

Comparison of patients undergoing colon surgery: Trauma and nontrauma patients at level 1 trauma centers versus nontrauma patients at the other hospitals

To better understand the reasons for the differences in infection rates and SIRs between the level 1 trauma centers and the other hospitals, the characteristics of the patients in each cohort of hospitals was examined. At the level 1 trauma centers, there were 3,531 colon surgeries: 3,014 (85%) for nontrauma patients (ie, nontraumatic indications) and 517 (15%) for trauma-related patients. At the other hospitals, there were 1,686 surgeries: 1,608 (95%) for nontrauma indications and 78 (5%) for trauma. Because of the small number of trauma cases at the other hospitals (which accounted for 5% of all SSIs at these hospitals), they were excluded from further analysis. Using the nontrauma patients at the other hospitals as a baseline, a comparison was made with the nontrauma patients and trauma patients at the level 1 centers. Compared to the nontrauma patients in the other hospitals, the nontrauma patients in the level 1 trauma centers were younger, had a lower mean BMI and a lower incidence of diabetes mellitus; however, they had higher ASA scores, longer operating times, and fewer primary wound closures (Table 2). At the level 1 trauma hospitals, 25.9% of nontrauma patients had an ASA score ≥ 4, compared to 21% of patients at the other hospitals ($P = .0001$). The distribution of patients with surgical wound classes also differed. In the level 1 centers, fewer nontrauma patients had class 2 wounds [1,847 (61%) of 3,014 vs 1,026 (64%) of 1,608; $P = .09$] and more had class 4 wounds [518 (17%) of 3,014 vs 218 (14%) of 1,608; $P = .001$]. Among the nontrauma patients with class 4 wounds, the infection rate was higher in the patients at the level 1 centers: 63 (12%) of 518 versus 16 (7.3%) of 218 ($P = .06$). The impact of these differences was evident by the SIRs for the 2 groups; the SIR for the nontrauma patients in the level 1 centers was significantly higher than that of the nontrauma patients in the other hospitals (Table 2).

A greater discrepancy was evident when the trauma patients in the level 1 centers were compared to the nontrauma patients in the other hospitals. Again, although the patients in the level 1 trauma

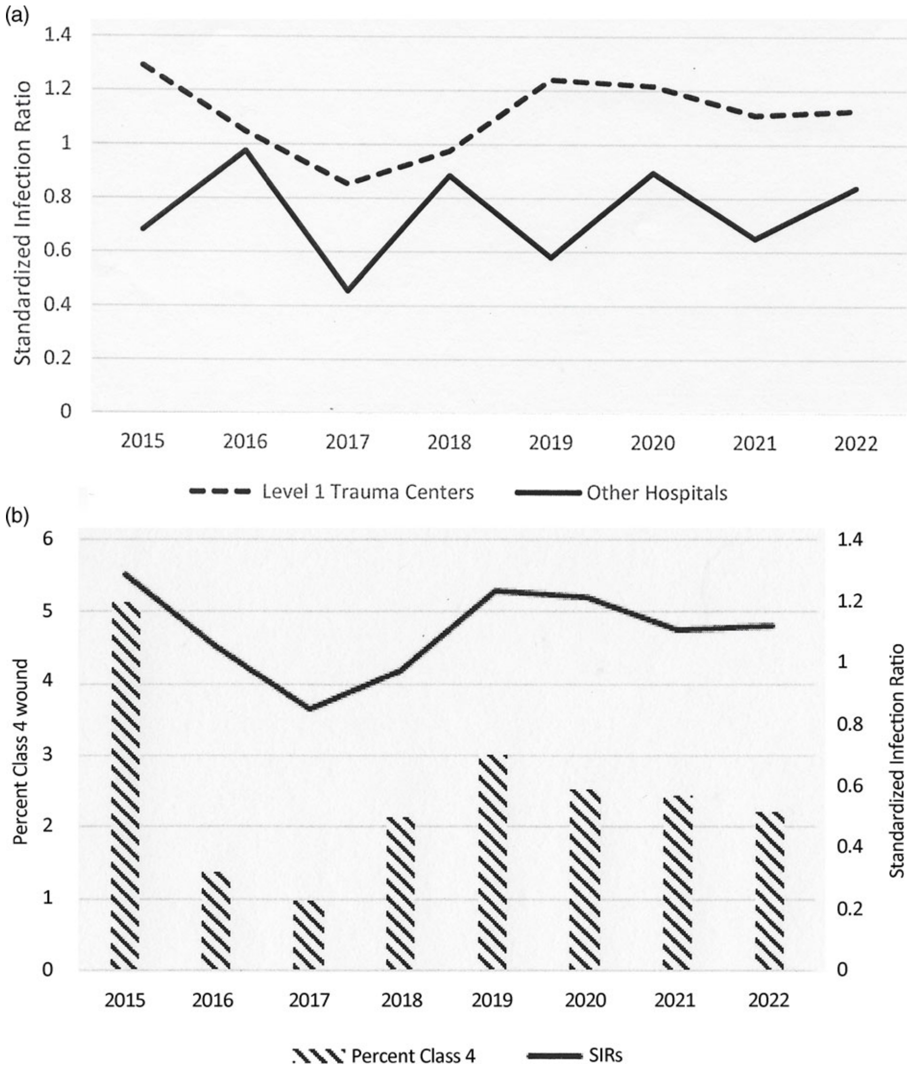

Figure 1. (a) Comparison of annual standardized infection ratios for colon surgical site infections for level 1 trauma centers versus. other hospitals. (b) Correlation between the percentage of colon surgeries with wound class 4 and standardized infection ratios at the level 1 trauma centers.

centers were younger, had a lower mean BMI, and lower rates of diabetes mellitus, the differences in ASA scores and primary closure rates were amplified (Table 2). The distribution of patients with surgical wound classes also became more disproportionate; significantly fewer trauma patients in the level 1 centers had class 1 wounds [288 (56%) of 517 vs 1,847 (61%) of 3,014; $P = .001$] and more had class 2 wounds [144 (28%) of 517 vs 364 (23%) of 1,608; $P = .02$]. For patients with class 4 wounds, the infection rate was dramatically higher in the trauma patients in the level 1 centers, compared to the nontrauma patients in the other hospitals: 22 (25.9%) of 85 versus 16 (7.3%) of 218 ($P < .0001$). Finally, the SIR for the trauma patients in the level 1 centers was double that of the nontrauma patients in the other hospitals (Table 2).

Comparison of patients with SSI: Trauma versus nontrauma patients

Of the 387 patients reported with SSIs, 375 patients had available medical records. There were 235 male patients and 140 female patients. In this group, 41% of patients were Hispanic, 34% were Black, 12% were White, and 8% were Asian. The more common indications for surgery were cancer (29%), obstruction (15%), gunshot wound (11%), and diverticulitis (9%). Most patients received recommended perioperative antibiotics: 35% received cefoxitin, 24% received a β-lactam/β-lactamase inhibitor combination, 19% received a β-lactam with an antianaerobic medication (ie, metronidazole or clindamycin), 4% received a fluoroquinolone with an antianaerobic medication, and 3% received a carbapenem. For 8% of the patients, a perioperative antibiotic was not recorded.

Among the 375 patients, 317 patients had surgery for nontraumatic indications and 58 patients had surgery for trauma-related indications. Characteristics of the patients in these groups are summarized in Table 3. For the 58 trauma patients, injuries included gunshot wounds in 43 patients, blunt trauma in 10 patients, and stab wounds in 5 patients. Surgery was considered emergent more often in the trauma patients compared to the nontrauma patients: 52 (90%) of 58 versus 131 (41%) of 317 ($P < .0001$). The ASA score was significantly higher in the trauma patients (Table 3). The need for creation of an ileostomy or colostomy was similar in each group: 16 of 58 trauma patients versus 95 of 317 nontrauma patients (P was not significant). Closure of the abdominal wound was delayed more frequently in the trauma patients; as a result, superficial incisional infections were less common, and deep intra-abdominal infections

https://doi.org/10.1017/ice.2023.150 Published online by Cambridge University Press

Table 1. Characteristics of Colon Surgery Cases at Level 1 Trauma Centers Versus Other Hospitals Across the New York City Health+Hospitals System

Characteristic	Level 1 Trauma Centers (n = 3,531), No. (%)[a]	Other Hospitals (n = 1,686), No. (%)[a]	*P* Value
Age, mean y (SD)	53.5±19.9	50.0±16.4	<.0001
Sex, male	2,053 (58)	901 (53)	.001
Diabetes mellitus	652 (18)	445 (28)	<.0001
Body mass index, mean kg/m^2 (SD)	27.1±8.3	27.6±6.6	.03
ASA score, mean (SD)	3.1±0.89	2.9±0.86	<.0001
Emergency	1,407 (40)	528 (31)	<.0001
Endoscopic	891 (25)	339 (20)	<.0001
Trauma	517 (15)	78 (5)	<.0001
Duration of operation, mean min (SD)	216±131	181±103	<.0001
Primary closure	2,820 (80)	1,486 (88)	<.0001
Wound class			
Class 2	2,135 (60)	1,070 (63)	.04
Class 3	793 (22)	378 (22)	NS
Class 4	603 (17)	237 (14)	.005

Note. SD, standard deviation; ASA, American Society of Anesthesiologists; NS, not significant.
[a]Units unless otherwise specified.

Table 2. Comparison of Nontrauma and Trauma Patients Undergoing Colon surgery At Level 1 Trauma Centers Versus Nontrauma Patients at the Other Hospitals

	Other Hospitals	Level 1 Trauma Centers			
Characteristic	Nontrauma Patients (n = 1,608), No. (%)[a]	Nontrauma Patients (n = 3014), No. (%)[a]	Significance Compared to Nontrauma Patients in Other Hospitals, *P* Value	Trauma Patients (n = 517), No. (%)[a]	Significance Compared to Nontrauma Patients in Other Hospitals, *P* Value
Sex, male	844 (52)	1,626 (54)	NS	427 (83)	<.0001
Age, mean y (SD)	60±15.8	56±18.9	<.0001	38±18.4	<.0001
Diabetes mellitus	426 (26)	623 (21)	<.0001	29 (6)	<.0001
Body mass index, mean kg/m^2 (SD)	27.6±6.7	27.1±8.6	.03	26.9±6.6	.045
ASA score, mean (SD)	2.91±0.84	3.01±0.84	.0001	3.44±1.11	<.0001
Emergency	453 (28)	948 (31)	.02	459 (89)	<.0001
Endoscopic	328 (20)	860 (29)	<.0001	31 (6)	<.0001
Duration of surgery, mean min (SD)	182±104	223±134	<.0001	177±98	NS
Primary wound closure	1,419 (88)	2,488 (83)	<.0001	332 (64)	<.0001
Wound class					
Class 2	48/1,026 (4.7)	111/1,846 (6.0)	NS	17/288 (5.9)	NS
Class 3	26/364 (7.1)	62/649 (9.6)	NS	17/144 (11.8)	NS
Class 4	16/218 (7.3)	63/518 (12)	.06	22/85 (25.9)	≤.0001
SIR, mean (SD)	0.65±1.181	1.16±1.29	.008	1.26±2.69	.066

Note. SD, standard deviation; NS, not significant; ASA, American Society of Anesthesiologists; SIR, standardized infection ratio.
[a]Units unless otherwise specified.

were more common in this group. In-hospital mortality was greater in the nontrauma patients: 24 (8%) of 317 nontrauma patients versus 0 (0%) of 58 trauma patients (P = .04). Among the 24 nontrauma patients who did not survive hospitalization, 8 patients had underlying cancer and 6 patients had mesenteric ischemia and/or underlying cardiovascular disease.

Discussion

Given the substantial clinical and economic impacts of SSIs following colon surgery, many medical centers have prioritized efforts to reduce these infections. These efforts have included the development of bundles that incorporate widely accepted strategies

https://doi.org/10.1017/ice.2023.150 Published online by Cambridge University Press

Table 3. Comparison of Nontrauma and Trauma Patients With Surgical-Site Infections Following Colon Surgery

Characteristic	Nontrauma Patients (n = 317), No. (%)[a]	Trauma Patients (n = 58), No. (%)[a]	*P* Value
Age, mean y (SD)	57.7±15.4	34.2±13.3	<.0001
Diabetes mellitus	76 (24)	2 (3.4)	.0004
Body mass index, mean kg/m^2 (SD)	28.1±7.5	27.8±5.2	NS
Initial albumin, mean g/dL (SD)	3.6±0.85	4.0±0.89	.007
ASA score, mean (SD)	3.0±0.84	3.9±1.1	<.0001
Duration of surgery, mean min (SD)	229±126	207±114	NS
Length of hospital stay, mean d (SD)	30.1±29.0	36.1±26.7	NS
Wound classification			
Class 2	151 (48)	19 (33)	.04
Class 3	86 (27)	23 (40)	.053
Class 4	80 (25)	16 (28)	NS
Primary wound closure	255 (80)	31 (53)	<.0001
Wound infection site			
Superficial incisional	101 (32)	7 (12)	.002
Deep incisional	27 (9)	4 (7)	NS
Intra-abdominal	185 (58)	45 (78)	.006
Other	4 (1)	2 (3)	NS

Note. SD, standard deviation; NS, not significant; ASA, American Society of Anesthesiologists.
[a]Units unless otherwise specified.

to reduce these infections.[20,21] Interventions that emphasize these strategies have shown varying degrees of success in preventing SSIs. Although several studies document positive outcomes in SSIs following these interventions,[6,7,12,13,16] others have not been so encouraging.[8,10,11] In particular, these interventions may not be as effective in preventing SSIs in patients following surgery for traumatic injuries.[22] Preventive preoperative measures, including bowel preparations, smoking cessation, weight loss, and hair removal, are typically not possible in an unstable patient with abdominal trauma.[15,23] In addition, anastomotic leaks are more common in hemodynamically unstable or compromised patients.[15,23] More serious intra-abdominal infections, often requiring additional procedures or surgeries, are more common in patients suffering traumatic colon injury (as demonstrated in this report).[1,15,23] As a result, increased rates of SSIs and corresponding SIRs in trauma patients, compared to patients undergoing elective surgery, have been well documented.[24]

In our report of public urban hospitals, the annual SIRs in the level 1 trauma centers were, for 8 consecutive years, consistently higher than in the remaining hospitals. Although individual surgeons have been implicated in elevated SIRs,[16] we doubt that variances in surgeon performance account for these differences; all 5 level 1 trauma centers are major teaching hospitals (as are the remaining hospitals). Protocols for prophylactic antibiotic regimens were not uniform across the hospital system. However, this is an unlikely contributor for the differences because several different regimens are accepted for colon surgery and no antibiotic regimen has been identified as being superior for trauma patients.[25,26] All of the hospitals have infection preventionists with active surveillance programs for SSIs; differences in detection of SSIs seem unlikely.[27] Rather, our data indicate that patients treated in the level 1 trauma centers, whether nontrauma or trauma patients, had greater severity of illness and overall complexity (demonstrated by greater ASA scores, more prolonged surgeries, and greater use of nonprimary closure) compared to the patients at the other hospitals.

It is becoming increasingly apparent that the current risk assessment model used by NHSN does not fully take into account the complexity of various colon surgeries, especially those involving traumatic injury.[23,24,28,29] At level 1 trauma centers, SIRs for cases involving colon surgery following trauma were significantly greater than those following nontraumatic indications.[23] Level 1 trauma centers that have high hospital quality scores have paradoxically higher SIRs for colon surgery and are labeled as “poor performers.”[29] On a similar note, the risk adjustment measures used by the CMS have also been questioned. In a report involving a large network of community hospitals, the addition of other variables to the CMS model improved SSI risk predictions, resulting in changes in hospital ranking for financial penalties.[30]

The predictions that the CMS hospital-acquired condition reduction program would unfavorably affect safety-net hospitals are being realized.[31] These federal programs have not been associated with significant improvements in the delivery of healthcare and have had no measurable benefit for patients.[32,33] Of the hospitals penalized by the federal incentive programs, there is an overrepresentation of safety-net hospitals.[34,35] The unintended consequence is increasing financial instability of safety-net healthcare systems.[32] The safety-net hospitals care for a disproportionately high percentage of uninsured and underinsured patients, with more chronic comorbidities.[22] Without appropriate risk assessment models, these incentive programs will paradoxically exacerbate inequities in healthcare in the United States.[32] Until appropriate risk assessment models are developed, the use of colon surgery SSIs as a quality measure should be re-evaluated.[28,29]

Acknowledgements.

Financial support. No financial support was provided relevant to this article.

Competing interests. All authors report no conflicts of interest relevant to this article.

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