Bowel obstructions and incisional hernias following trauma laparotomy and the nonoperative therapy of solid organ injuries: A retrospective population-based analysis

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BACKGROUND: Small bowel obstruction (SBO) and incisional hernia (IH) represent the most common long-term complications of laparotomy. They may also be more common among injured patients than for elective/nontrauma emergency scenarios. Unfortunately, the population-based incidence of SBO and IH following trauma laparotomy is unknown. The aim of this study was to define the long-term, population-based incidence of SBO and IH following both trauma laparotomy as well as the nonoperative therapy of solid organ injuries.

METHODS: All injured patients admitted to a Level 1 trauma center (2002–2013) who underwent (1) a laparotomy or nonoperative care of (2) splenic and/or (3) hepatic injuries were linked with the Alberta Health Services Discharge Database to identify all readmissions for subsequent SBO and/or IH within the province. Standard statistical methodology was used ($p < 0.05$).

RESULTS: Of 484 patients who underwent a trauma laparotomy, 29 (6%) and 42 (9%) required readmission for SBO and IH, respectively (0.13 SBO and 0.10 IH admissions per patient year). Patients who underwent nonoperative management of their liver and/or spleen injuries displayed long-term SBO rates of 1% (6 of 619) and 0.7% (4 of 606), respectively. The rate of SBO and IH in patients with unnecessary laparotomies was equivalent to therapeutic procedures ($p = 0.183$). Topical hemostatic agents, repeat laparotomies, and injury pattern did not alter SBO or IH rates ($p > 0.05$).

CONCLUSION: The population-based, long-term rate of clinically relevant SBO and IH following trauma laparotomies is 15%. This increases to 19% on a per-admission basis. Nontherapeutic scenarios, injury pattern, topical hemostatics, and open abdomens did not alter complication rates. (*J Trauma Acute Care Surg*. 2015;79: 386–392. Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic study, level IV.

KEY WORDS: Trauma laparotomy; bowel obstruction; incisional hernia; solid organ injuries.

Long-term complications following laparotomy are dominated by small bowel obstruction (SBO) and incisional hernia (IH). Although SBO is an accepted risk for all abdominal surgeries, it is generally felt that the rate of postoperative SBO is proportional to the magnitude of the index operation.[1] As a result, the incidence of SBO after trauma laparotomy has anecdotally been considered to be substantial.[1] While there is a paucity of population-based studies available for review, it has been proposed that specific risk factors for *early* postoperative trauma SBO include gunshot wounds and gastrointestinal perforation.[2, 3] More specifically, although the long-term rate of SBO is unstated in the literature, *early* SBO after trauma seems to approximate 4% in a recent study of 22 patients,[3] with a published range of 0% to 7%.[1–7]

Similar to SBO, the long-term incidence of IH following trauma laparotomy is also unknown on a true population basis.[5,8] Given the critically ill nature of many of these patients, in conjunction with requirements for open abdominal therapy (repeat laparotomies and temporary abdominal closures), this cohort should be at significant risk for postoperative IH. In addition to the clinical and psychological issues surrounding patient morbidity, the combination of SBO and IH is clearly a significant economic and societal burden to the health care system.[9–15]

Given the small sample size and single-center nature of the current literature, the primary aim of this study was to provide a population-based, long-term analysis of the incidence of both SBO and IH following laparotomy for trauma. The secondary aim was to evaluate the role of previously unanalyzed potential risk factors for SBO including nonoperative care for splenic and hepatic injuries, the use of topical hemostatic agents during surgery, the role of nontherapeutic laparotomies, and the interaction between SBO and IH with regard to open abdomen management.

PATIENTS AND METHODS

Ethics approval for this study was obtained from the University of Calgary Institutional Review Board. Patients admitted to the Foothills Medical Center (FMC) between May 25, 2002, and July 8, 2013, who required (1) a laparotomy for trauma, (2) nonoperative therapy of splenic lacerations, and/or (3) nonoperative therapy for hepatic lacerations, were identified by the prospective Alberta Trauma Registry. This registry includes all adults (≥16 years) admitted after major trauma (Injury Severity Score [ISS] ≥ 12). The FMC is a university-affiliated, Level I trauma center that provides tertiary care services to southern Alberta, southeast British Columbia, and southwest Saskatchewan. It is the only adult Level I trauma center within this region with a catchment of nearly 3 million citizens.

Patients who died during the initial trauma admission and/or were referred from out-of-province regions were excluded. We also excluded patients who did not have residency data over the 11-year follow-up period to reduce the effect of loss to follow-up within the province. The remaining patients from the previously mentioned three study groups were then cross-referenced with the Alberta Health Services Discharge Database to identify *all readmissions* anywhere within the province of Alberta. This matching process used patient demographics (name, age, sex) and patient-specific numbers (Alberta Health Number, Provincial medical record number) to provide complete provincial follow-up without loss of data. All of these readmitted patients with diagnoses of bowel obstruction (ICD-10 codes K31.5, K56.0, K56.5, K56.6, and K56.6) and/or IH (ICD-10 codes K43.0, K43.1, and K43.9) were analyzed (between the date of the initial injury until February 5, 2014). All patient charts were then reviewed by three study investigators

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TABLE 1. Demographics, Injury Characteristics, and Discharge Data for Patients Who Underwent a Laparotomy for Trauma and Were Subsequently Readmitted With SBO

Patient Demographics	Mean (Range)	No. Patients (n = 29)
Age, y	33.8 (15–81)	
Sex		
Male		24 (83%)
Female		5 (17%)
Medical comorbidities		
None		12 (41%)
MI/DVT/PE		2 (7%)
Liver cirrhosis		1 (3%)
Depression		1 (3%)
Unknown		13 (45%)
Previous surgery		
Abdominal surgery		4 (14%)
Nonabdominal surgery		0 (0%)
None		22 (76%)
Unknown		3 (10%)
Injury characteristics		
ISS	28 (13–59)	
Mechanism		
MVC		13 (45%)
Recreational vehicle related		2 (7%)
Recreational activities (non-motorized)		2 (7%)
Animal related		6 (21%)
Assault		3 (10%)
Suicide		1 (3%)
Falls		2 (7%)
Admission hemodynamics		
HR	102 (52–150)	
sBP	108 (67–159)	
RR	22 (13–32)	
GCS score	12 (3–15)	
Admission and discharge data		
Length of stay		
Total, median (IQR)	20 (22)	
ICU	7.8 (0–63)	
No. ventilated days	5.8 (0–53)	
Discharge destination		
Home	17	
Acute care facility	7	
Rehabilitation facility	4	
Other	1	

DVT, deep venous thrombosis; GCS, Glasgow Coma Scale; HR, heart rate; ICU, intensive care unit; IQR, interquartile range; MI, myocardial infarction; PE, pulmonary embolism; RR, respiratory rate; sBP, systolic blood pressure.

to confirm the diagnosis and obtain information on patient demographics, details of the initial trauma admission, injury characteristics, operative techniques, any procedures, and early rates of SBO/IH. Therapeutic laparotomy was defined as having an injury that required repair or resection. Nontherapeutic laparotomy was defined as identifying an injury that did not need active intervention. Negative laparotomy was defined as a laparotomy that did not identify any clear injury within the peritoneal cavity.

Data are presented as means where appropriate using descriptive statistics. A logistic regression was used to calculate odds ratios (ORs) for each potential risk factor for developing SBO and/or IH. $p < 0.05$ was considered significant. All statistical testing was performed using Stata/IC version 12.0 (Stata Corp., College Station, TX). The occurrence rates of SBO and IH were also calculated as the number of SBO/IH readmissions per patient per year. This methodology has been previously published and verified by our group.[16]

RESULTS

Patients Undergoing a Trauma Laparotomy

Between May 25, 2002, and July 8, 2013, 608 patients admitted to the FMC for trauma required a laparotomy. Of these, 124 (20%) died during their index trauma-related admission. The remaining 484 patients constituted the trauma laparotomy cohort of interest. The overall rates of therapeutic (86%), nontherapeutic (9%), and negative (5%) laparotomies were consistent across years ($p = 0.455$). The total follow-up time interval was 11.1 years.

TABLE 2. Injuries Identified at the Index and Subsequent Laparotomies for Patients Who Were Then Readmitted With a Bowel Obstruction

	No. Patients (n = 29)
First laparotomy	
Solid organ injury	
Liver	8 (28%)
Spleen	8 (28%)
Kidney	1 (3%)
Visceral injury	
Stomach	2 (7%)
Small bowel	9 (31%)
Colon	6 (21%)
Pancreas	4 (14%)
Bladder	2 (7%)
Mesenteric and vascular injury	
Small bowel mesentery	6 (21%)
Mesocolon	6 (21%)
Named intra-abdominal vessel	6 (21%)
Diaphragm injury	3 (10%)
Omental injury	3 (10%)
Subsequent laparotomies for patients who had multiple laparotomies	n = 14
Solid organ injury	
Liver	1 (7%)
Spleen	2 (14%)
Visceral injury	
Pancreas	1 (7%)
Bladder	1 (7%)
Bowel ischemia	
Small bowel	1 (7%)
Colon	2 (14%)

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TABLE 3. Repairs and Interventions Performed at Laparotomy (Any) for Patients Who Underwent a Laparotomy for Trauma and Were Subsequently Readmitted With Bowel Obstruction

	No. Patients (n = 29)
Solid organs	
Repair of a solid organ without resection (e.g., cautery, packing)	10 (34%)
Renorraphy	1 (3%)
Partial liver resection	8 (28%)
Splenectomy	1 (3%)
Nephrectomy	1 (3%)
Viscera	
Stomach repair	1 (3%)
Stomach resection	1 (3%)
Small bowel repair	6 (21%)
Small bowel resection	6 (21%)
Colon repair	4 (14%)
Colon resection	4 (14%)
Distal pancreatectomy	2 (7%)
Bladder repair	3 (10%)
Cholecystectomy	1 (3%)
Appendectomy	1 (3%)
Repair or ligation of a named vessel	4 (14%)
Diaphragm repair	3 (10%)

Patients Readmitted With a Bowel Obstruction After a Trauma Laparotomy

Of the 484 laparotomy patients, 32 (6.6%) were readmitted with a diagnosis of SBO (Table 1). Three of these patients were excluded from the analysis because formal chart reviews identified a readmission laparotomy for reasons unrelated to their trauma (e.g., obstructing gastrointestinal cancer). These 29 remaining patients (6%) had a total of 41 readmissions specifically for bowel obstruction (mean, 1.2 per patient; range, 1–7). Six patients (21%) required operative intervention (lysis of adhesions) during their readmission. The remaining 23 patients (79%) were successfully treated with nonoperative bowel rest. Three patients (0.6%) also had an inpatient bowel obstruction during their index trauma admission. The mean length of follow-up was 6.7 years (2.3–10.8). This yielded an overall SBO occurrence rate of 6% during a mean of 6.7-year follow-up period (i.e., 0.13 SBO per patient per year).

Most patients (n = 28, 97%) underwent an initial laparotomy that was therapeutic (OR, 1.56; 95% confidence interval [CI], 0.15–15.98; $p = 0.71$). The additional patient had a positive (nontherapeutic) laparotomy (i.e., no negative laparotomies). Among these patients, 15 underwent only one laparotomy during their initial trauma admission. The remaining 14 patients had multiple laparotomies with temporary abdominal closures (5 patients with >2 laparotomies and 3 patients with >5 laparotomies). No statistically significant association occurred between patients with the highest number of laparotomies and the number of readmissions for SBO (OR, 1.08; 95% CI, 0.82–1.43; $p = 0.58$).

The injuries identified during the index and subsequent laparotomies are shown in Table 2. Injury pattern was not a predictor of subsequent long-term SBO (OR, 0.78; 95% CI, 0.31–1.97; $p = 0.61$). Table 3 details the intraoperative repairs. In total, 11 patients (38%) required topical hemostatic agents during their laparotomy (Gelfoam, 9; Surgicel, 9; Tisseel, 5).

TABLE 4. Demographics, Injury Characteristics and Discharge Data for Patients Who Underwent a Laparotomy for Trauma and Were Subsequently Readmitted With IH

Demographics	Mean (Range)	No. Patients (n = 42)
Age, y	44.6 (21–76)	
Sex		
Male		35 (83%)
Female		7 (17%)
Medical comorbidities		
CV disease		11 (26%)
Respiratory disease		1 (2%)
Endocrine disease		3 (7%)
Chronic inflammatory disease		2 (5%)
Neurologic disease		1 (2%)
Renal disease		1 (2%)
Cancer		6 (14%)
Psychiatric illness		8 (19%)
Substance abuse		19 (45%)
None		2 (5%)
Other (hepatitis B, DVT)		1 (2%)
Previous surgery		
Abdominal surgery		7 (17%)
Nonabdominal surgery		3 (7%)
None		31 (74%)
Unknown		1 (2%)
Injury characteristics		
ISS	28 (13–75)	
Mechanism		
MVC		20 (48%)
Recreational vehicle related		2 (5%)
		1 (2%)
Animal related		8 (19%)
Assault		2 (5%)
Suicide		4 (10%)
Falls		5 (12%)
Admission hemodynamics		
HR	98 (58–151)	
sBP	111 (67–170)	
RR	21 (8–33)	
GCS score	13 (2T-15)	
Admission/discharge data		
Length of stay		
Total, median (IQR)	33 (27)	
ICU	8.7 (0–42)	
No. ventilated days	6.9 (0–38)	
Discharge destination		
Home	22	
Another acute care facility	10	
Rehabilitation facility	10	

CV, cardiovascular; DVT, deep venous thrombosis; GCS, Glasgow Coma Scale; HR, heart rate; ICU, intensive care unit; IQR, interquartile range; RR, respiratory rate; sBP, systolic blood pressure.

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TABLE 5. Injuries Identified at the Index and Subsequent Laparotomies for Patients Who Were Then Readmitted With an IH

	No. Patients (n = 42)
First laparotomy	
Solid organ injury	
Liver	5 (12%)
Spleen	15 (36%)
Kidney	3 (7%)
Visceral injury	
Stomach	3 (7%)
Small bowel	7 (17%)
Colon	10 (24%)
Bladder	1 (2%)
Mesenteric and vascular injury	
Small bowel mesentery	7 (17%)
Mesocolon	2 (5%)
Named intra-abdominal vessel	1 (2%)
Diaphragm injury	2 (5%)
Omental injury	1 (2%)
Abdominal wall disruption	7 (17%)
Abdominal compartment syndrome	1 (2%)
Subsequent laparotomies for patients who had multiple laparotomies	
Solid organ injury	
Liver	1 (2%)
Spleen	4 (10%)
Visceral injury	
Bladder	1 (2%)
Bowel ischemia	
Small bowel	1 (2%)
Colon	2 (5%)
Abscess	3 (7%)
Named vessel bleeding	1 (2%)
Internal hernia	1 (2%)

The use of these commercial hemostatic agents did not correlate with readmissions for SBO (OR, 0.80; 95% CI, 0.31–2.06; $p = 0.65$).

Patients Readmitted With a Bowel Obstruction After Nonoperative Liver and Spleen Injuries

A total of six patients (0.96%) with nonoperative management of their liver injuries (total patients, 619) were readmitted with an SBO/ileus. These patients had a total of nine readmissions for SBO/ileus (mean, 1.5 per patient; range, 1–4). Three patients also had an initial in-hospital SBO that occurred during their index trauma admission. Of these six patients, two had documented abdominal surgery before their injury. Three of these six patients required operative therapy (lysis of adhesions) during their readmission for SBO/ileus. The mean age was 51 years (range, 22–79 years), with a female predominance (5:1). The mechanism of injury was motor vehicle crash (MVC) for five patients and shock by a high-voltage power line for one patient. The mean length of follow-up was 7.8 years (range, 4.7–10.5 years).

A total of four patients (0.66%) with nonoperative spleen injuries were readmitted with SBO/ileus (total, 606 patients). Two of these patients also had concurrent nonoperative liver injuries. Each of these, four patients had one SBO/ileus readmission (total, four readmissions). One of these four patients required operative therapy (lysis of adhesions) during their readmission. One patient also had an in-hospital obstruction during the initial trauma admission. The mean age for this cohort was 79 years (range, 73–89 years). None of these patients had a documented history of abdominal surgery. Three patients were injured in MVCs, and one had a ground-level fall. The mean length of follow-up was 6.2 years (range, 1.3–11.5 years).

Patients Readmitted With IHs After a Trauma Laparotomy

Of 484 laparotomy patients, 51 (10.5%) were readmitted with a diagnosis of IH (Table 4). Nine of these patients were excluded from the analysis because their abdominal wall fascia had not been fully closed during their initial trauma admission (i.e., open abdomen with subsequent skin graft). The remaining 42 patients (8.6%) had a total of 50 readmissions for IH issues (mean, 1.2 per patient; range, 1–3). Seven patients (1.4%) also experienced wound disruption during their initial trauma admission. The mean length of follow-up was 7.0 years (range, 1.9–11.8 years). This yielded an overall IH occurrence rate of 9% during a mean of 7.0-year follow-up period (i.e., 0.11 IH per patient per year). Furthermore, five of these patients were also found to have had readmissions for SBO.

Most patients (n = 40, 95%) received an initially therapeutic laparotomy (OR, 1.41; 95% CI, 0.14–14.49; $p = 0.77$). Only two patients (5%) underwent a negative laparotomy. Among these patients, 26 had only one laparotomy during their initial trauma admission. The remaining 16 patients underwent multiple

TABLE 6. Repairs and Interventions Performed at Laparotomy (Any) for Patients Who Underwent a Laparotomy for Trauma and Were Subsequently Readmitted With IH

	No. Patients (n = 42)
Solid organs	
Repair of a solid organ without resection (e.g., cautery)	11 (26%)
Partial liver resection	1 (2%)
Splenectomy	10 (24%)
Nephrectomy	1 (2%)
Viscera	
Stomach repair	2 (5%)
Stomach resection	1 (2%)
Small bowel repair	6 (14%)
Small bowel resection	4 (10%)
Colon repair	5 (12%)
Colon resection	6 (14%)
Bladder repair	2 (5%)
Repair or ligation of a named vessel	4 (10%)
Diaphragm repair	2 (5%)
Abscess drainage	3 (7%)
Abdominal wall repair	7 (17%)

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laparotomies with temporary abdominal closures (2 patients with >2 laparotomies and 4 patients with >5 laparotomies). No statistically significant association occurred between patients with the highest number of laparotomies and the number of readmissions for IH (OR, 01.48; 95% CI, 0.60–3.66; $p = 0.40$). The injuries diagnosed during laparotomy are shown in Table 5. Injury pattern was not a predictor of subsequent long-term IH (OR, 0.81; 95% CI, 0.33–2.12; $p = 0.68$). Table 6 reports the repairs and interventions.

DISCUSSION

Laparotomies for acutely injured patients are often required within austere and challenging scenarios in the context of patients approaching physiologic extremis. Not surprisingly, the well-documented short-term morbidity among these patients can be substantial. Unfortunately, long-term complications including SBO and IH are poorly reported across single-center case series with short-term follow-up.[1–15]

SBO is a common complication following laparotomy with reported rates varying between 3% and 11%, depending on the technique and pathology of the index surgery.[1–16] The population-based, long-term rate of SBO following a trauma laparotomy in the current series was 6%. Given that these patients often had more than one SBO readmission per person (41 readmissions), the occurrence rate was 0.13 SBO per patient per year. This rate compares poorly with other disease states such as appendicitis (3%).[16] Given the tremendous costs associated with inpatient care, this high rate of long-term SBO represents a significant economic and societal burden.[9–11] This is highlighted even further by the high rate of operative intervention (21%) required during readmission. It is also interesting to note that the rate of *early* SBO during the initial hospital stay following trauma was only 0.6%. This is significantly lower than some previous reports within the literature.[1–3, 5–7] The pattern of injury among patients who underwent a laparotomy was also not predictive of either long-term SBO or IH. This may potentially be explained by the low number of penetrating injuries within this study cohort. It is also notable that despite the anecdotal belief that topical hemostatic agents may lead to an increased incidence of SBO because of their adhesive nature, this was not supported by our data. Similarly, the rate of long-term SBO among nontherapeutic and negative laparotomy groups was consistent with the therapeutic majority. Given that early morbidity rates associated with unnecessary laparotomies are more than 40% based on prospective observational studies,[6, 8] these data confirm that all negative and nontherapeutic laparotomies carry at least the same long-term clinical and economic burden as therapeutic explorations. As a comparator to operative intervention, this study is also the first to define the rate of long-term SBO/ileus following nonoperative management of both liver and spleen injuries. Overall, SBO/ileus was reassuringly rare (0.7%).

IHs continue to present significant patient, system, and economic challenges at a rate of approximately 2% to 11% across all reports.[17–19] Given the complexity of many trauma laparotomies, it has been postulated that these patients are at higher risk than "elective" laparotomies for developing wound disruptions.[20–23] The long-term rate of IH was 9% following a trauma laparotomy in our study. Similar to SBO, some patients required multiple readmissions (50 admissions) for issues relating to their IH, which resulted in an occurrence rate of 0.10 IH per patient per year. The risk of developing an IH was also similar regardless of the efficacy of the procedure (i.e., therapeutic vs. nontherapeutic) and further highlights the need to avoid unnecessary laparotomies. This is especially true upon reflection that many patients with minimally symptomatic hernias may not present to the health care system (i.e., underestimation).

The use of the damage-control surgery and temporary abdominal closures in the context of the open abdomen is common among our most severely injured patients. Although one of the dominant tenants among this group is the preservation of fascial integrity during each laparotomy, concerns remain about a potentially higher long-term risk of developing IH.[7, 20–23] This study did not identify any increased risk in the occurrence of either long-term SBO or IH as a result of an increasing number of laparotomies. This is interesting given the higher observed incidence of *early* SBO rates following the use of temporary abdominal closures (i.e., failure to achieve fascial closure at the first or second laparotomy) in other studies.[7, 20–23] Given the lifesaving nature of an appropriately indicated open abdomen, this is reassuring.

Our study has several limitations. First, although we cannot be completely certain that a small number of patients did not move out of the province of Alberta and therefore become lost to follow-up, the rate of emigration from Alberta has been at historical lows during the past decade. Furthermore, all patients except two within the laparotomy group had subsequent and updated data within the provincial electronic medical record, indicating they were still residents within the province. Second, we have potentially underreported minimally symptomatic SBO and IH in our study groups. More specifically, although we captured all relevant reengagements to the health care system (readmissions), short and self-limiting SBO episodes treated within a patient's home would be missed. From an economic and patient point of view however, we believe it is the readmission events that are of most relevance. Third, because this study is reliant on large population-based discharge databases, it is also dependent on the accuracy of its coding. Fortunately, all of these issues should have been rectified during the subsequent chart reviews. Fourth, because this was a retrospective study, it was not specifically powered to define the differences in SBO/IH rates between differing laparotomy types (e.g., nontherapeutic, open abdomens). Given the paucity of long-term studies available within the literature however, this methodology was believed to be the best starting point. Finally, given our long-term average follow-up period of 7.1 years (11.1 years total), our reported rates may still underestimate the lifetime risk of SBO/IH. Given that almost half of all SBO present within the first 5 years however, we believe we have captured the majority of occurrences.[15] Similarly, most IHs are detected within the first 2 years after laparotomy.

CONCLUSION

The population-based, long-term rate of clinically relevant SBO and IH following trauma laparotomies is 15%. This

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increases to 19% on a per-admission rather than per capita basis. Nontherapeutic scenarios, injury patterns, topical hemostatics, and open abdomen management did not alter these complication rates. Given these findings, prevention of long-term SBO and IH must target the avoidance of nontherapeutic laparotomies. Education of patients before discharge with regard to the specific risk and symptoms associated with delayed SBO and IH is also essential.

AUTHORSHIP

All authors were instrumental in the creation of the study, data analysis, manuscript writing, and editing. C.G.B., T.L., and C.R.-M. were also responsible for the data collection.

DISCLOSURE

The authors declare no conflicts of interest.

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