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ORIGINAL ARTICLE

Differences in in-hospital outcomes and healthcare utilization for laparoscopic versus open approach for emergency inguinal hernia repair: a nationwide analysis

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Abstract

Purpose There has been a growing debate of whether laparoscopic or open surgical techniques are superior for inguinal hernia repair. For incarcerated and strangulated inguinal hernias, the laparoscopic approach remains controversial. This study aims to be the first nationwide analysis to compare clinical and healthcare utilization outcomes between laparoscopic and open inguinal hernia repair in an emergency setting.

Methods A retrospective analysis of the National Inpatient Sample was performed. All patients who underwent laparoscopic inguinal hernia repair (LIHR) and open inguinal hernia repair (OIHR) between October 2015 and December 2019 were included. The primary outcome was mortality, and secondary outcomes include post-operative complications, ICU admission, length of stay (LOS), and total admission cost. Two approaches were compared using univariate and multivariate logistic and linear regression.

Results Between the years 2015 and 2019, 17,205 patients were included. Among these, 213 patients underwent LIHR and 16,992 underwent OIHR. No difference was observed between laparoscopic and open repair for mortality (odds ratio [OR] 0.80, 95% CI [0.25, 2.61], $p=0.714$). Additionally, there was no significant difference between groups for post-operative ICU admission (OR 1.11, 95% CI [0.74, 1.67], $p=0.614$), post-operative complications (OR 1.09, 95% CI [0.76, 1.56], $p=0.647$), LOS (mean difference [MD]: -0.02 days, 95% CI [− 0.56, 0.52], $p=0.934$), or total admission cost (MD: $3,028.29, 95% CI [$− 110.94, $6167.53], $p=0.059$).

Conclusion Laparoscopic inguinal hernia repair is comparable to the open inguinal hernia repair with respect to low rates of morbidity, mortality as well as healthcare resource utilization.

Keywords Inguinal hernia · Laparoscopic · Open surgery · Incarcerated · Strangulated

Introduction

Inguinal hernia repair is one the most common procedure performed by general surgeons, and as such, there is great interest in exploring different surgical approaches to obtain optimal patient outcomes [1]. The Lichtenstein approach, an open procedure, has long been held as the gold standard for inguinal hernia repairs [2]. However, as the landscape of surgery shifts towards minimally invasive operations, laparoscopic approaches have been brought to the forefront. This has fueled a growing debate of whether laparoscopic or open surgical techniques are superior for inguinal hernia repair. Several studies and meta-analyses report lower post-operative pain and length of hospital stay in laparoscopic inguinal hernia repair when performed on an elective basis [3–5].

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As such, guidelines thus advocate for the use of the laparoscopic approach for elective inguinal hernia repairs, when the expertise is available [6, 7]. However, in cases of incarcerated and strangulated inguinal hernias, the laparoscopic approach remains contentious and even controversial, resulting in caution and reticence in adopting this technique in emergency cases [7, 8]. While there is a growing body of evidence suggesting the safety of laparoscopic surgery for emergency inguinal hernia repairs, these findings originate from studies that are small in scale and lack widespread data that is representative of the general population [8–14].

With the increasing number of surgeons gaining expertise in minimally invasive surgeries (MIS), there is a timely need to further examine whether laparoscopy is appropriate for emergency inguinal hernia repair. As such, this study aims to be the first nationwide analysis to compare clinical and healthcare utilization outcomes between laparoscopic and open inguinal hernia repair in an emergency setting.

Methods

Data source

This retrospective cohort study examined National Inpatient Sample (NIS) data from the Healthcare Cost and Utilization Project (HCUP) from October 1, 2015, to December 31, 2019. The timeline was chosen to capture the years that NIS started utilizing the International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM) codes. The NIS is the largest public all-payer in-patient database in the US; it approximates a 20% stratified sample of community hospital discharges, and its included hospitals cover more than 97% of the population, providing a nationally representative sample of the patient population and hospital characteristics [15]. It records information on roughly 7 million hospitalizations annually, including weighted data to help make population estimates. The NIS only contains data regarding hospital encounters and therefore cannot identify individual patients [16]. However, its extensive collection of administrative data makes it ideal for comparing the effectiveness of surgical procedures by looking at national estimates of outcomes, costs, and healthcare utilization. The study was reviewed and approved by the Hamilton Integrated Research Ethics Board (HiREB).

Study population

Procedure type along with hernia diagnosis and complications were identified using the ICD-10 codes, with a full list available in Supplementary Appendix 1. Patient cohorts in this study were those that underwent minimally invasive laparoscopic inguinal hernia repair (LIHR) (0YQ53ZZ, 0YQ54ZZ, 0YQ63ZZ, 0YQ64ZZ, etc.) and those that underwent open inguinal hernia repair (OIHR) (0YQ50ZZ, 0YQ60ZZ, 0YQA0ZZ). Only emergency admissions were included, with the diagnosis of incarcerated (K400, K403, K410, K413) or strangulated inguinal hernias (K401, K404, K411, K414). Use of mesh versus no mesh use was collected (0YU54JZ, 0YU64JZ, 0YUA5JZ, 0YUA0JZ, etc.). Patients were excluded if: (1) if they had a repair of inguinal hernia concurrent to other hernia repairs; (2) non-adults; (3) missing information on age, race, sex, type of hospital admission, in-hospital mortality, and length of stay.

Study variables

The following covariates were analyzed in this study: demographic and socioeconomic (SES) information, inguinal hernia characteristics, and hospital characteristics. Demographic and SES categories included sex, age, race, body mass index (BMI), insurance, income quartile, and mean Elixhauser comorbidities score of patients. Specifically, BMI data were obtained using ICD-10 codes for obesity classes 1 through 4 (Z6830, Z6831, Z6832, Z6833, etc.). Comorbidities were assessed through the Elixhauser Comorbidity Software for ICD-10-CM to distinguish them from complications [17]. The inguinal hernia characteristics examined were the type of emergency inguinal hernia diagnosis (incarcerated or strangulated), presence or absence of bowel resection, as well as use of mesh at the time of index operation. Hospital characteristics included hospital setting (urban or rural), teaching status, hospital region, and hospital bed size. All factors were examined for any association with inguinal hernia repair outcomes.

Outcomes

Our primary outcome was overall post-operative complications. Secondary outcomes included system-specific post-operative complications, post-operative mortality, post-operative intensive care unit (ICU) admission, length of stay, and total admission cost. In-hospital complications included respiratory (J9589, J189, J95821, J9582, etc.), cardiovascular (T8172XA, I9789, I26, I97811, etc.), gastrointestinal (K9130, K9131, K913, K9189, etc.), ileus (K560, K567), wound (T8183XA, L7601, L7602, L7611, etc.), infectious (K6811, K6819, K6812, K651, etc.), genitourinary (R338, R339, R330, N171, etc.), and systemic complications (T8119, T8119XA, T8110XA, T8111XA, etc.). Each system-specific composite complication was defined by previously established definition by LaPar et al. [18]. ICU admission was defined by presence of mechanical ventilation or vasopressor use post-operatively using the ICD-10 diagnosis code (Supplemental Table 1) [19]. Given the nature of data contained in the NIS, this study only evaluated in-hospital outcomes and did not infer any post-discharge outcomes.

Statistical analysis

All statistical analysis was performed using STATA (StataCorp version 17, College Station, TX). Discharge-level weight provided by HCUP was used to calculate national estimates. Data are presented as prevalence or mean (standard deviation). Normal distribution was assumed using the central limit theorem as the sample size was large ($N > 50$). The Chi-square test was used to compare dichotomous variables and the Student's *t* test was used to compare continuous variables. All statistical tests were two-sided with the threshold for significance set at $p < 0.05$. A backward stepwise regression model including patient characteristics (age, sex, BMI, Elixhauser comorbidities score, insurance status, income quartile), hospital characteristics (rurality, teaching status, region, bed size), and procedure characteristics (type of hernia diagnosis, mesh use, presence of bowel resection) was used to assess primary and secondary outcomes. The clinical importance of the covariate, as well as the Wald test with *p* value less than 0.25 as a threshold was required for entry into the multivariate analysis to account for all possible confounding. The model fit was assessed using *C* statistics. For each independent variable, the variation inflation factor (VIF) was calculated with no evidence of multicollinearity [20].

Results

Baseline characteristics

Out of the 17,205 total eligible participants in this study, 213 (1.2%) were in the LIHR cohort and 16,992 (98.8%) were in the OIHR cohort (Table 1). All study values were then survey weighted to provide national estimates. Table 1 contains data on all patient, hernia, and hospital characteristics analyzed in this study. There were no baseline differences in LIHR and OIHR groups for patient gender (36.2% vs. 31.0% female) and mean age (68.94 [± 15.70] years vs. 69.93 [± 15.68] years). Patients who underwent LIHR were more likely to have private insurance or self-pay compared to those who underwent OIHR. Both cohorts consisted mostly of white patients (LIHR: 73.7%, OIHR: 69.7%). Most of the patients were non-obese (BMI < 30; LIHR: 94.4%, OIHR: 96.0%), but the distribution of patients across obesity classes did not differ significantly between cohorts. The mean Elixhauser comorbidities score was similar for both LIHR (2.43 [2.00]) and OIHR (2.64 [2.07]) patients. Most of the patients in the LIHR and OIHR cohorts had incarcerated hernias and had no bowel resection at the time of the operation. Reporting of mesh use was lower in the OIHR compared to the LIHR group (11.3% and 52.6%, respectively). Within the LIHR cohort, 24 incarcerated hernia patients received mesh and none of the strangulated hernia patients did. For the OIHR group, 8,816 incarcerated hernia patients and 118 strangulated hernia patients received mesh. Among hospital characteristics, LIHR procedures were more commonly performed in teaching hospitals compared to OIHR (56.8% vs. 64.5%). Hospital location, region, and bed sizes were not different between cohorts.

Overall post-operative complications

Incidence of having any post-operative complications were 19.2% and 19.0% for LIHR and OIHR cohorts, respectively (Table 2). After adjusted analysis, there was no significant difference between the two cohorts for overall complications (OR 1.09 [0.76, 1.56], $p = 0.647$).

System-specific post-operative complications

When analyzing system-specific composite post-operative complications, no difference was found between groups for rates of respiratory, cardiovascular, gastrointestinal, wound, infectious, genitourinary, and systemic complications (Table 2). Rates of ileus among patients were 4.7% for LIHR and 5.8% for OIHR, however, no difference was found between groups (OR 0.81, 95% CI [0.42, 1.55], $p = 0.529$).

In-hospital mortality

In-hospital mortality incidence was 1.4% for the LIHR cohort and 1.9% for the OIHR group (Table 2). There was no difference in in-hospital mortality between the two surgical approaches after adjusted analysis (OR 0.80, 95% CI [0.25, 2.61], $p = 0.714$).

Post-operative ICU admissions

Incidence of post-operative ICU admissions for LIHR and OIHR groups were 13.1% and 13.3%, respectively (Table 2). There was no difference in ICU admissions between groups after adjusted analysis (OR 1.11, 95% CI [0.74, 1.67], $p = 0.614$).

Healthcare utilization

The mean LOS was 4.41 (± 4.24) days for the LIHR group and 4.49 (± 5.51) days for the OIHR group (Table 3). LOS did not vary significantly between the two cohorts before or after multivariate analysis (unadjusted mean difference (MD): − 0.09 days 95%CI [− 0.67, 0.50], $p = 0.774$; adjusted MD: − 0.02 days 95%CI [− 0.56, 0.52], $p = 0.934$). The

Table 1 Baseline characteristics

n (sample size) *N* (weighted population estimate)	Laparoscopic *n* = 213 *N* = 1065	Open *n* = 16,992 *N* = 84,960	*p* value
Patient characteristics, *n* (%)			
Female sex	77 (36.2%)	5272 (31.0%)	0.11
Age (mean [SD])	68.94 (15.70)	69.93 (15.68)	0.36
Race			0.41
White	157 (73.7%)	11,845 (69.7%)	
Black	26 (12.2%)	2240 (13.2%)	
Others	30 (14.1%)	2907 (17.1%)	
BMI (kg/m^2)			0.50
< 30	201 (94.4%)	16,305 (96.0%)	
30–40	9 (4.2%)	528 (3.1%)	
≥ 40	3 (1.4%)	159 (0.9%)	
Insurance			0.03
Medicare	126 (59.4%)	10,662 (62.9%)	
Medicaid	16 (7.5%)	1915 (11.3%)	
Private insurance	49 (23.1%)	2661 (15.7%)	
Self-pay	15 (7.1%)	1123 (6.6%)	
Others	6 (2.8%)	599 (3.5%)	
Residential Income			0.29
First quartile (lowest)	61 (29.2%)	4807 (28.9%)	
Second quartile	44 (21.1%)	4344 (26.1%)	
Third quartile	51 (24.4%)	3932 (23.7%)	
Fourth quartile (highest)	53 (25.4%)	3533 (21.3%)	
Elixhauser comorbidities score (mean [SD])	2.43 (2.00)	2.64 (2.07)	0.13
Hernia characteristics, *n* (%)			
Type of hernia diagnosis			0.33
Incarcerated	202 (94.8%)	16,334 (96.1%)	
Strangulated	11 (5.2%)	658 (3.9%)	
Mesh use			
Yes	8934 (52.6%)	24 (11.3%)	
No	7956 (46.8%)	189 (88.7%)	
Bowel resection			0.84
No bowel resection	210 (98.6%)	16,724 (98.4%)	
Bowel resection	3 (1.4%)	268 (1.6%)	
Hospital characteristics, *n* (%)			
Hospital location			0.76
Urban	20 (9.4%)	1496 (8.8%)	
Rural	193 (90.6%)	15,496 (91.2%)	
Teaching status			0.02
Non-teaching	92 (43.2%)	6030 (35.5%)	
Teaching	121 (56.8%)	10,962 (64.5%)	
Hospital region			0.54
Northeast	41 (19.2%)	3578 (21.1%)	
Midwest	37 (17.4%)	3218 (18.9%)	
South	91 (42.7%)	6425 (37.8%)	
West	44 (20.7%)	3771 (22.2%)	
Hospital bed size			0.39
Small	56 (26.3%)	3800 (22.4%)	
Medium	64 (30.0%)	5390 (31.7%)	
Large	93 (43.7%)	7802 (45.9%)	

All *n* are analytic sample; all % and means (SD) are survey-weighted to reflect national estimates

Table 2 In-hospital complications and healthcare utilization by payer status, Nationwide Inpatient sample 2015–2019

n (sample size) *N* (weighted population estimate)	Laparoscopic *n* = 213 *N* = 1065	Open *n* = 16,992 *N* = 84,960	Unadjusted OR	*p* value	Adjusted OR[a]	*p* value
In-hospital mortality, *n* (%)	3 (1.4%)	319 (1.9%)	0.75 [0.23, 2.40]	0.624	0.80 [0.25, 2.61]	0.714
Post-operative ICU admission, *n* (%)	28 (13.1%)	2254 (13.3%)	0.99 [0.66,1.49]	0.960	1.11 [0.74,1.67]	0.614
In-hospital complications, *n* (%)						
Any	41 (19.2%)	3226 (19.0%)	1.02 [0.71, 1.45]	0.925	1.09 [0.76, 1.56]	0.647
Respiratory	10 (4.7%)	674 (4.0%)	1.19 [0.62, 2.29]	0.597	1.26 [0.65, 2.47]	0.494
Cardiovascular	1 (0.5%)	95 (0.6%)	0.84 [0.11, 6.28]	0.864	0.84 [0.11, 6.35]	0.868
Gastrointestinal	13 (6.1%)	950 (5.6%)	1.10 [0.62, 1.96]	0.752	1.12 [0.63, 2.00]	0.690
Ileus	10 (4.7%)	988 (5.8%)	0.80 [0.42, 1.53]	0.496	0.81 [0.42, 1.55]	0.529
Wound	0 (0.0%)	100 (0.6%)	1.00 [N/A]	N/A	1.00 [N/A]	N/A
Infectious	2 (0.9%)	99 (0.6%)	1.62 [0.38, 6.80]	0.511	1.55 [0.35, 6.78]	0.563
Genitourinary	19 (8.9%)	1674 (9.9%)	0.90 [0.55, 1.45]	0.657	0.97 [0.59, 1.58]	0.897
Systemic	1 (0.5%)	118 (0.7%)	0.67 [0.09, 5.05]	0.701	0.72 [0.10, 5.44]	0.751

All *n* are analytic sample; all % and means (SD) are survey-weighted to reflect national estimates

OR odds ratio

[a]Adjusted age, race, BMI class, insurance status, residential income quartile, Elixhauser comorbidities score, type of hernia, bowel resection, BMI, hospital location, and hospital teaching status

Table 3 Adjusted cost and length of stay differences, Nationwide Inpatient Sample 2015–2019

n (sample size) *N* (weighted population estimate)	Payer type					
	Laparoscopic *n* = 213 *N* = 1065	Open *n* = 16,992 N = 84,960	Unadjusted difference	*p* value	Adjusted difference[a]	*p* value
Length of stay, mean (SD), days	4.41 (4.24)	4.49 (5.51)	− 0.09 [− 0.67, 0.50]	0.774	− 0.02 [− 0.56, 0.52]	0.934
Cost, mean (SD), USD	19,295.67 (23,619.16)	16,321.65 (20,449.95)	2794.01 [− 254.47, 6202.48]	0.071	3028.29 [− 110.94, 6167.53]	0.059

SD standard deviation

[a]Adjusted age, race, BMI class, insurance status, residential income quartile, Elixhauser comorbidities score, type of hernia, bowel resection, mesh use, BMI, hospital location, and hospital teaching status

mean total admission cost was $19,295.67 (± $23,619.16) USD for LIHR and $16,321.65 (± $20,449.95) USD for OIHR (Table 3). Within the multivariate analysis, no difference was observed between groups (MD: $3,028.29, 95% CI [$− 110.94, $6167.53], $p = 0.06$).

Discussion

Our nationwide study is the first of its kind to compare perioperative outcomes and healthcare utilization in laparoscopic versus open inguinal hernia repair in an emergency setting. We demonstrated no significant differences between in-hospital complications, mortality, or ICU admissions in both groups. In addition, length of stay and total admission cost were similar between both groups.

The laparoscopic approach for elective inguinal hernia repairs has been well documented in the literature and widely accepted as safe and effective, with reports of reduced post-operative pain and faster return to activity compared to the open approach [3, 5, 21–27]. However, the use of laparoscopy in the management of incarcerated or strangulated hernias is still up for debate. Previous studies have attempted to clarify the role of laparoscopic techniques in cases of emergent hernia repair. A recent systematic review concluded that laparoscopic management of incarcerated and strangulated inguinal hernias was safe and feasible [10]. The review determined that rates of complications and length of hospital stay were comparable between both laparoscopic and open groups, which is in concordance with our results. In addition, Matsuda et al. found no difference in mortality or morbidity between LIHR and OIHR in their series of 33 patients, which is also in agreement with our findings [28]. Other studies have found that morbidity was actually lower in patients undergoing emergent LIHR repair compared to OIHR [11, 29, 30]. Furthermore, several case series studies have demonstrated the safety and feasibility of LIHR in incarcerated and strangulated hernias when surgical expertise is available, though these studies did not directly compare LIHR to OIHR [12, 31–35]. Moreover, although we found no significant difference in length of stay, previous studies have demonstrated that LIHR is associated with shorter hospitalization in cases of incarcerated or strangulated inguinal hernia repair [11, 13, 29, 30]. These studies found increased post-operative complications and morbidity in the open surgical approach, which may contribute to lengthier hospitalizations. Finally, to the best of our knowledge, no previous studies have compared post-operative ICU admissions after LIHR or OIHR for incarcerated or strangulated inguinal hernias, for which we found no difference between groups.

In addition to potentially reducing post-operative morbidity, the laparoscopic approach may offer several other benefits [11, 12, 29, 30, 36]. Laparoscopy allows for the exploration of bowel viability, therefore, potentially avoiding unneeded laparotomy [8, 9, 11, 36, 37]. Additionally, the time required for hernia reconstruction allows ample time for the incarcerated organs to recover, potentially preventing unnecessary bowel resection [12, 38]. Laparoscopy also offers the benefit of allowing for a thorough contralateral examination, thus permitting the detection of any unsuspected bilateral hernias [11, 13, 36, 37]. In cases where bowel resection is necessary and a larger incision is required for extraction of the specimen, laparoscopy can be used to take down surrounding adhesions and may allow surgeons to minimize the size of the skin incision [36]. Despite these advantages, we found a considerable discrepancy between the numbers of laparoscopic hernia repairs compared to the conventional open approach. The low numbers of LIHR may reflect the lack of training and expertise with the procedure. However, it is encouraging that the utilization of LIHR and its associated outcomes are trending in a positive direction. A recent report demonstrates that minimally invasive hernia repair, such as laparoscopic and robotic-assisted approaches, are being increasingly used over the last decade with considerable improvements in perioperative metrics, including operative time and complication rate [39]. Therefore, though OIHR still occupies the vast majority of inguinal hernia repair cases, there is an optimistic trend towards increased utilisation and improved outcomes with the minimally invasive approach. Nonetheless, laparoscopic repair for acutely strangulated hernias does not come without its challenges. The procedure itself is technically challenging and is associated with a steep learning curve, which is closely related to perioperative outcomes [40–42]. Dilated and edematous bowel may compromise the operative space, and extreme caution must be taken to avoid iatrogenic injury [11]. Moreover, some studies have shown lengthier operative times in laparoscopic repair of incarcerated or strangulated inguinal hernia [28–30]. Potential explanations include varying experience and expertise amongst surgeons as well as the identification and remediation of compromised bowels or contralateral hernias [11, 13]. Though our study found no significant differences in total admission costs between the LIHR and OIHR, previous studies have reported increased costs associated with laparoscopy [43, 44]. The authors of these studies attributed the cost differentials to the high cost of laparoscopic instruments, increased operative time, and higher level of operating room care and equipment requirements [43, 45, 46]. However, it is argued that the lower rates of post-operative complications, analgesia consumption, quicker return to work, fewer outpatient visits, and lower rates of chronic pain may ultimately reduce global expenses [9].

Our study has several implications for existing guidelines and future research. Currently, there is no international consensus regarding laparoscopic surgery for emergency repair of inguinal hernias. To date, there is a paucity of literature directly comparing LIHR versus OIHR in cases of incarcerated or strangulated inguinal hernias. Given the lack of evidence supporting an optimal surgical approach, guidelines recommend a tailored approach based on factors such as patient condition and surgeon skill [7]. As our study found no notable short-term difference between the approaches, current guidelines and recommendations can build on and incorporate our results. For instance, LIHR may be justified in emergency settings if the expertise is available, especially when considering the promising long-term data demonstrating reduced rates of chronic pain, faster return to activity, and similar rates of recurrence associated with the laparoscopic technique [3, 5, 21–27]. Moreover, our study can provide the foundation for future prospective investigations looking at long-term outcomes in this patient population.

The present study should be interpreted with the understanding of several important limitations related to the nature of the NIS database. The data contained in the NIS do not allow us to collect specific details of the laparoscopic (e.g., transabdominal pre-peritoneal approach, totally extraperitoneal approach, etc.) or open (e.g., Lichtenstein, McVay, etc.) inguinal hernia repair techniques. The database also does not provide any information on wound type, so the degree of contamination could not be controlled for. Next, though we controlled for mesh use, we could not collect data on the type of mesh (e.g., biological versus synthetic), which may influence overall costs [47, 48]. Furthermore, we obtained data on BMI using ICD-10 codes for obesity, though we recognize that not all physicians will code this as a diagnosis, thereby possibly affecting our demographic data and observed outcomes. Another limitation is that we could not collect data on conversion from laparoscopic to open, however, previous reports have found low conversion rates in LIHR in the emergency setting [10–13, 35, 38]. Moreover, utilization of the recent years of the NIS database does not allow us to collect information on hospital volumes of specific procedures. Finally, the NIS contains data for in-patient admissions only and therefore does not report follow-up data or long-term outcomes relevant to hernia repair occurring outside of the hospital such as recurrence, chronic pain, or re-admissions. Longitudinal studies evaluating these outcomes after emergent LIHR are thus warranted. Despite these limitations, our study reports nationwide data, producing the largest investigation of in-hospital surgical outcomes in emergent laparoscopic versus open inguinal hernia repair. The use of such a large sample size makes our findings widely generalizable across hospitals in North America.

Conclusion

The present study demonstrates that laparoscopic repair of incarcerated or strangulated inguinal hernias is comparable to the conventional open approach with respect to low rates of in-patient morbidity and mortality in both groups, as well as no significant difference in healthcare resource utilization. As with most surgical emergencies, open approach in surgery cannot be completely replaced, and surgeons should be familiar with both open and minimally invasive techniques. However, when the expertise is available, a select group of patients may be potential candidates for laparoscopic repair. Areas of future research include the direct comparison between different laparoscopic techniques as well as the evaluation of long-term outcomes.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10029-023-02742-x.

Data availability statement Data will be made available upon request.

Declarations

Conflict of interest Nothing to disclose.

Ethical approval This retrospective chart review study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Approval was given by the Hamilton Integrated Research Ethics Board (HiREB).

Human and animal rights This research was based on data derived from medical records and thus included human participants. As such, it complied to all ethical standards.

Informed consent statement The data used in this study was taken from the National Inpatient Sample database. As this repository only supplies deindentified data, informed consent could not be obtained.

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