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Emergency laparoscopic and open repair of incarcerated ventral hernias: a multi-institutional comparative analysis with coarsened exact matching

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Abstract

Background The safety of emergent laparoscopic repair of incarcerated ventral hernias is not well established. The objective of this study was to determine if emergent laparoscopic repair of incarcerated ventral hernias is comparable to open repair with respect to short-term clinical outcomes.

Methods Patients undergoing emergency repair of an incarcerated ventral hernia with associated obstruction and/or gangrene were identified using the ACS-NSQIP 2012–2016 dataset. One-to-one coarsened exact matching (CEM) was conducted between patients undergoing laparoscopic and open repair. Matched cohorts were compared with respect to morbidity, mortality, readmission, reoperation, missed enterotomies, and length of stay. Missed enterotomy was defined as any re-operative procedure within 30 days that required resection of large or small bowel segments, based on CPT codes. Multivariate analysis was conducted to determine adjusted predictors of morbidity.

Results A total of 1642 patients were identified after CEM. Laparoscopic compared to open repair was associated with a lower rate of 30-day wound-morbidity (OR 0.35, 95% CI 0.22–0.57, $p < 0.001$). Laparoscopic repair was not associated with lower 30-day non-wound morbidity (OR 0.73, 95% CI 0.51–1.06, $p = 0.094$). Laparoscopic repair was associated with shorter LOS (3.6 days vs. 4.3 days, $p = 0.014$). A higher rate of missed enterotomies was observed in the laparoscopic cohort (0.7% vs. 0.0%, $p = 0.031$). There were no group differences with respect to 30-day readmission, reoperation, or mortality.

Conclusions Emergency laparoscopic repair of incarcerated ventral hernias is associated with lower rates of wound-morbidity and shorter hospital stays compared to open repair. However, laparoscopic repair is associated with a higher rate of missed enterotomies; a rate which is low and comparable to elective non-incarcerated ventral hernia repairs.

Keywords Ventral hernia · Emergency surgery · Laparoscopy · Incisional hernia · Incarceration · Obstruction

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Background

Ventral incisional hernia is a common problem following abdominal surgery with incidence reported to be approximately 11% [1]. It is estimated that approximately $3.4 billion a year is spent in the United States on correcting ventral hernias [2]. Repair of ventral hernias can occur via a laparoscopic or open approach. Meta-analyses and randomized controlled trials have demonstrated equivalence between these two approaches with respect to recurrence rates and decreased wound complications in the laparoscopic approach [3–6]. Furthermore, laparoscopic repairs have been associated with decreased pain scores [7]. What remains unclear is the utility and safety of a laparoscopic repair for incarcerated ventral hernias in the acute setting.

Laparoscopy provides several challenges for repair of incarcerated ventral hernias. Acutely incarcerated hernias are often associated with small fascial defects, adhesions, and distended and gangrenous bowel loops; all of which may increase the risk of complications using laparoscopic instruments. Three recent studies, with small single arm cohorts, have reported early experiences with a laparoscopic approach to incarcerated ventral hernias [8–10]. These retrospective studies argue that laparoscopic repair is feasible, demonstrating low post-operative complication rates and short hospital stays. However, the applicability of this literature is limited by small sample sizes, single arm designs, and non-standardized reporting of outcome metrics. Our group recently demonstrated utilizing the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) dataset that laparoscopic repair of incarcerated ventral and groin hernias with associated obstruction is associated with decreased infectious morbidity and serious complications [11]. Although this work favors the safety of a laparoscopic repair for incarcerated hernias, the generalizability to acutely unwell patients requiring emergency surgery for gangrenous bowel or obstruction remains unknown. Furthermore, the rate and etiology for 30 day readmissions and reoperations, including missed enterotomies, remains unclear. Overall, it is difficult to draw meaningful conclusions regarding the safety of laparoscopy for incarcerated ventral hernias with associated obstruction or gangrene in the emergency setting.

In order to extend the empirical literature on emergent laparoscopic repairs of incarcerated ventral hernias, we sought to conduct a retrospective matched cohort analysis to compare 30 day clinical outcomes between patients undergoing a laparoscopic repair to those undergoing an open repair using the multi-institutional ACS-NSQIP database. The primary objective of this study was to determine if emergency laparoscopic repair for incarcerated ventral hernias with associated obstruction or gangrene is comparable to open repair with respect to 30 day morbidity. The secondary objective was to determine if laparoscopy is comparable to open repair with respect to mortality, readmissions, reoperations, missed enterotomies, and hospital length of stay (LOS).

Methodology

Data source

A multi-institutional retrospective cohort analysis was conducted using the ACS-NSQIP Participant Use File (PUF) between 2012 and 2016. The NSQIP PUF reports on surgical outcomes from 680 participating hospitals across North America. The dataset provides de-identified data on demographic characteristics, peri-operative variables, and post-operative 30 day outcomes for patients undergoing major surgery at participating institutions.

Patient selection

The 2012–2016 NSQIP PUF was utilized to identify all study subjects. The study population consisted of adult patients (≥ 18 years) who underwent emergency repair of an incarcerated or strangulated incisional or ventral hernia with associated obstruction or gangrene. An emergency operation was defined as per the NSQIP definition: an operation performed within a short period of time from diagnosis or onset of symptoms and deemed as an emergency by the operating surgeon or anesthesiologist. Patients undergoing repair of an incarcerated ventral hernia were selected based on the principle operation performed via the following CPT codes: 49561, 49566, 49572, 49587, 49653, 49655, 49657. The study population was then divided into two cohorts: (1) patients that underwent a laparoscopic repair (CPT codes: 49653, 49655, 49657); and (2) patients that underwent an open repair (CPT codes: 49561, 49566, 49572, 49587). Patients that did not have a primary post-operative diagnosis of ventral hernia based on ICD-9 and ICD-10 codes were excluded to reduce heterogeneity. The following ICD-9 and ICD-10 diagnosis codes were utilized to identify patients with associated obstruction or gangrene: 551.1, 551.2, 551.20, 551.29, 552.1, 552.2, 552.20, 552.21, 552.29, K43.6, K43.0, K43.1, K43.7, K43.3, K43.4, K42.0, K42.1. Patients undergoing a concurrent procedure were excluded with the following exceptions: another hernia repair, lysis of adhesions (CPT: 44005, 44180), exploratory laparotomy or laparoscopy (CPT: 49000, 49320), implant of mesh (CPT: 49568), or resection of omentum (CPT: 49255). The final sample prior to matching consisted of 8136 patients (Fig. 1).

Study measures and outcomes

The NSQIP PUF was queried for participant demographic characteristics, co-morbidities, and 30 day surgical outcomes. Co-morbidities were sub-categorized into either absence of co-morbidities, one comorbidity, or two or more co-morbidities. Similarly, American Anesthesiology Association (ASA) scores were sub-categorized into either 1 and 2 or 3 and 4. The primary outcome of the study was 30 day morbidity. 30 day morbidity was sub-classified into wound-related morbidity and non-wound related morbidity. Wound-related morbidity was defined as occurrence of post-operative superficial incisional surgical site infection (SSI), deep incisional SSI, organ/space SSI, or post-operative wound disruption. Non-wound related morbidity was defined as an aggregate endpoint measure consisting of 30 day post-operative pneumonia, unplanned intubation,
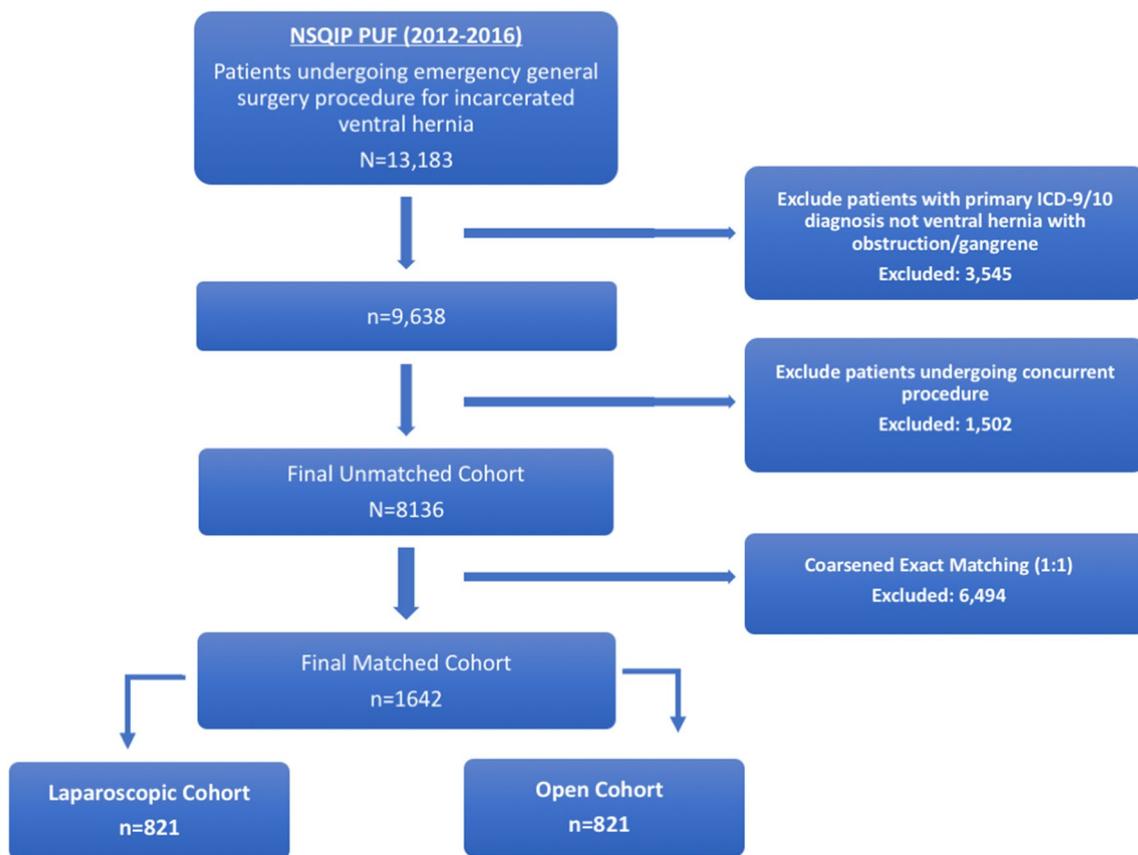
Fig. 1 Patient selection

pulmonary embolism, prolonged ventilation > 48 h, progressive renal insufficiency, acute renal failure, urinary tract infection, stroke, cardiac arrest, myocardial infarction, bleeding requiring transfusion, DVT/thrombophlebitis, sepsis, and septic shock. Secondary study outcomes included 30 day readmission, 30 day reoperation, total hospital LOS, and 30 day mortality. 30 day reoperations were queried for associated CPT codes to determine the incidence of missed enterotomies and other associated complications. A missed enterotomy was defined as any re-operative procedure within 30 days that required resection of large or small bowel segments, based on CPT codes.

Coarsened exact matching

To reduce heterogeneity and the influence of participant demographic characteristic variations between cohorts, a coarsened exact matching (CEM) was conducted. The following patient level variables were selected for matching: age, sex, BMI, ASA classification, presence of pre-operative sepsis, wound classification, and co-morbidities. Prior to matching, age was sub-categorized into the following groups: ≤ 40, 41–60, 61–80, and ≥ 80. Similarly, BMI was

sub-categorized into: ≤ 20, 21–30, 31–40, ≥ 40. A one-to-one CEM was conducted between patients undergoing laparoscopic and open ventral hernia repair. Subsequent to matching a total of 1642 patients were identified, 821 in each cohort.

Statistical analysis

Univariate group comparisons were conducted using the Chi square test or Fischer's exact test as appropriate for categorical variables. Continuous variables were compared using the independent samples t test or Mann–Whitney U test based on data normality. A multivariate analysis was conducted to ascertain the adjusted effect of laparoscopic compared to open repair of emergent incarcerated ventral hernias. A binary logistic regression was conducted to determine predictors of: (1) wound-related morbidity and (2) non-wound related morbidity. The following clinically relevant covariates were included in each of the two models: age, sex, BMI, co-morbidities, ASA class, presence of pre-operative sepsis, wound classification, and operative approach (laparoscopic vs. open). Wound classification was dichotomized into clean vs. contaminated or dirty/infected.

CEM was conducted using STATA V12.0 (College Station, TX: StataCorp LCC). Univariate and multivariate analyses of the matched cohorts were conducted using SPSS V23.0 (Armonk, NY: IBM Corp.). Statistical significance level for all group comparisons was set at a value of $p < 0.05$.

Results

A total of 9638 patients underwent emergency repair of an incarcerated ventral hernia between 2012 and 2016. After applying the study exclusion criteria, 8136 patients were identified, 849 of which underwent laparoscopic repair and 7287 of which underwent open repair. Baseline patient demographics of the unmatched cohorts are demonstrated in Table 1. Of the unmatched cohort, patients who underwent open repair compared to laparoscopic repair were older, of female sex, and had lower BMI ($p < 0.001$). Similarly, patients undergoing open repair compared to laparoscopic repair had a higher comorbidity burden, and higher ASA scores ($p < 0.001$). The open repair cohort compared to the laparoscopic cohort demonstrated higher proportion of patients with pre-operative sepsis and contaminated/dirty wounds ($p < 0.05$). Subsequent to conducting coarsened exact matching, a total of 1642 patients were identified,

821 in each of the open and laparoscopic cohorts (Table 1). There was perfect balance between cohorts with respect to all matched characteristics (L1 statistic = 0).

Clinical outcomes between the matched cohorts are demonstrated in Table 2. Laparoscopic repair was associated with a longer mean operative time (89 min vs. 75 min, $p < 0.001$). Laparoscopic repair was also associated with a shorter mean total hospital LOS (3.6 days vs. 4.3 days, $p = 0.01$), and a lower incidence of aggregate wound complications (3.0% vs. 7.9%, $p < 0.001$) compared to open repair. Sub-group analysis of types of wound complications demonstrated a higher incidence of superficial incisional SSI (3.8% vs. 1.8% respectively, $p = 0.017$), deep incisional SSI (1.9% vs. 0.4%, $p = 0.004$), and wound disruptions (1.6% vs. 0.1%, $p = 0.002$) for open compared to laparoscopic repair. No group differences were demonstrated with respect to organ/space SSI ($p > 0.05$). Laparoscopic repair demonstrated lower incidence of 30-day all morbidity (9.1% vs. 15.1%, $p < 0.001$). However, after excluding wound-related morbidity, there were no group differences with respect to non-wound related 30-day morbidity ($p = 0.105$). There was a trend toward lower 30-day readmission rates with laparoscopic repair, but it did not achieve statistical significance (6.0% vs. 8.4%, $p = 0.056$). There were no group differences with respect to 30-day mortality ($p > 0.05$).

Table 1 Patient demographics and characteristics

	Aggregate cohort			Matched cohort	
	Laparoscopic cohort	Open cohort	p-value	Laparoscopic cohort	Open cohort
N	849	7287		821	821
Mean age (years) [SD]	55.21 (14.78)	57.74 (14.8)	< 0.001	55.75 (15.03)	55.79 (15.10)
Sex			< 0.001		
Male	305 (35.9)	3202 (43.9)		294 (35.8)	294 (35.8)
Female	544 (64.1)	4085 (56.1)		527 (64.2)	527 (64.2)
Mean BMI [SD]	35.32 (13.14)	33.16 (13.98)	< 0.001	35.68 (12.92)	35.74 (13.05)
Co-morbidities			< 0.001		
0	266 (31.3)	1968 (27.0)		256 (31.2)	256 (31.2)
1	296 (34.9)	2368 (32.5)		284 (34.6)	284 (34.6)
≥ 2	287 (33.8)	2951 (40.5)		281 (34.2)	281 (34.2)
ASA			< 0.001		
1–2	358 (42.2)	2468 (34.0)		345 (42.0)	345 (42.0)
3–4	490 (57.8)	4799 (66.0)		476 (58.0)	476 (58.0)
Pre-operative sepsis[a]			< 0.001		
Yes	122 (14.4)	1422 (19.5)		712 (86.7)	712 (86.7)
No	727 (85.6)	5865 (80.5)		109 (13.3)	109 (13.3)
Wound classification			< 0.001		
Clean	649 (76.4)	4858 (66.7)		636 (77.5)	636 (77.5)
Clean/contaminated	156 (18.4)	1429 (19.6)		147 (17.9)	147 (17.9)
Contaminated	37 (4.4)	718 (9.9)		32 (3.9)	32 (3.9)
Dirty/infected	7 (0.8)	282 (3.9)		6 (0.7)	6 (0.7)

[a]Pre-operative sepsis includes SIRS, sepsis, septic shock

Table 2 Clinical outcomes

	Laparoscopic approach	Open approach	*p*-value
Operative outcomes			
Total operative time, mean [sd]	89.54 (63.23)	75.42 (62.70)	< 0.001
Length of stay, mean [sd]	3.65 (5.88)	4.33 (5.21)	0.014
Wound outcomes			
Any wound complication	25 (3.0)	65 (7.9)	< 0.001
Superficial incisional SSI	15 (1.8)	31 (3.8)	0.017
Deep incisional SSI	3 (0.4)	16 (1.9)	0.004
Organ space SSI	8 (1.0)	8 (1.0)	1.0
Wound disruption	1 (0.1)	13 (1.6)	0.002
Morbidity			
All morbidity	75 (9.1)	124 (15.1)	< 0.001
Non-wound morbidity	58 (7.1)	76 (9.3)	0.105
Pneumonia	15 (1.8)	14 (1.7)	0.851
Unplanned intubation	7 (0.9)	7 (0.9)	0.584
Pulmonary embolism	2 (0.2)	4 (0.5)	0.687
Ventilator requirement	7 (0.9)	9 (1.1)	0.803
Progressive renal insufficiency	0 (0.0)	5 (0.6)	0.062
Acute renal failure	6 (0.7)	1 (0.1)	0.124
Urinary tract infection	10 (1.2)	14 (1.7)	0.411
Stroke/CVA	1 (0.1)	0 (0.0)	1.0
Cardiac arrest	3 (0.4)	1 (0.1)	0.625
Myocardial infarction	4 (0.5)	1 (0.1)	0.374
Bleeding requiring transfusion	12 (1.5)	11 (1.3)	0.834
DVT	4 (0.5)	10 (1.2)	0.107
Sepsis	5 (0.6)	17 (2.1)	0.010
Septic shock	6 (0.7)	3 (0.4)	0.507
Other outcomes			
30-day readmission	49 (6.0)	69 (8.4)	0.056
All mortality	11 (1.3)	9 (1.1)	0.653

Table 3 highlights the 30-day reoperation rate and re-operative procedural categorization. There were no group differences with respect to rate of 30-day reoperations (*p* = 0.217). The laparoscopic cohort demonstrated a missed

Table 3 30-day reoperation and missed enterotomies

	Laparoscopic approach	Open approach	*p*-value
30 day reoperation	23 (2.8)	32 (3.9)	0.217
Missed enterotomy[a]	6 (0.7)	0 (0.0)	0.031
Operative classification			
I&D of abscess/seroma/hematoma	6 (0.7)	4 (0.5)	0.753
Surgical debridement/wound revision	0 (0.0)	8 (1.0)	0.008
Removal of infected mesh	0 (0.0)	1 (0.1)	1.0
Other unrelated procedure	4 (0.5)	7 (0.9)	0.547
Repair of recurrent hernia	1 (0.1)	1 (0.1)	1.0
Exploratory laparotomy	3 (0.4)	4 (0.5)	1.0
Bowel obstruction	0 (0.0)	1 (0.1)	1.0
Bowel resection	6 (0.7)	0 (0.0)	0.031
Unknown	3	6	

[a]Missed enterotomy defined as any reoperative procedure requiring a bowel resection

enterotomy rate of 0.7%, compared to 0.0% for the open cohort ($p = 0.03$). Of the six patients with a missed enterotomy, three required a partial colectomy with primary anastomosis, two required small bowel resections with anastomosis, and one patient required small bowel resection with enterostomy. The open cohort had a higher rate of re-operative interventions for either surgical debridement or wound revisions compared to the laparoscopic cohort ($n = 8$ vs. $n = 0$, $p = 0.008$). This consisted of closure of wound dehiscence ($n = 2$), repair of evisceration ($n = 1$), debridement of infected skin ($n = 2$), debridement of subcutaneous tissue ($n = 1$), debridement of muscle/fascia ($n = 1$), and excision of umbilicus ($n = 1$). Of the 23 reoperations in the laparoscopic cohort, three cases were uncategorized. Similarly, of the 32 reoperations in the open cohort, six cases were not categorized.

A multivariate analysis utilizing a binary logistic regression was conducted to determine predictors of wound-morbidity (Table 4). Laparoscopic repair was independently associated with a lower rate of wound-morbidity compared to open repair (OR 0.35, 95% CI 0.22–0.57, $p < 0.001$). Presence of pre-operative sepsis, female sex, and non-clean wounds were also associated with a higher rate of wound-morbidity ($p < 0.001$). No other covariates predicted wound-morbidity. Similarly, another multivariate analysis utilizing a binary logistic regression was conducted to determine covariates associated with 30-day non-wound morbidity. Laparoscopic repair compared to open was not associated with higher non-wound morbidity (OR 0.73, 95% CI 0.51–1.06, $p = 0.094$). Elevated age (OR 1.02, $p = 0.003$), presence of 2 or more co-morbidities (OR = 2.10, $p = 0.011$),

and pre-operative sepsis (OR 2.73, $p < 0.001$) were associated with higher rates of 30-day non-wound morbidity.

Discussion

The role for a laparoscopic approach in the repair of incarcerated ventral hernias with associated obstruction requiring emergency intervention has not been well established. This study, which utilized the risk adjusted ACS-NSQIP dataset, is among the largest study to our knowledge to demonstrate an association with decreased wound-related morbidity and hospital LOS for laparoscopic repair versus open repair of emergent incarcerated ventral hernias. Furthermore, this study demonstrated no significant difference between laparoscopic and open repair with respect to short-term non-wound morbidity, readmission, reoperation, and mortality. However, laparoscopic repair was associated with a higher rate of missed enterotomies compared to open repair, a complication associated with substantial morbidity.

Studies assessing the safety and feasibility of a laparoscopic approach to incarcerated ventral hernias in the acute emergent setting have been limited. Three recent studies have attempted to delineate the role of laparoscopy in this setting. The first study to directly assess the role of laparoscopy in incarcerated ventral hernias was a case series by Landau et al. They reviewed 25 patients undergoing laparoscopic repair of emergency incarcerated hernias and demonstrated a median hospital stay of 3.2 days, and two post-operative complications; thus, arguing that laparoscopic repair with expanded polytetrafluoroethylene (ePTFE) mesh is feasible

Table 4 Multivariate analysis to assess for predictors of clinical outcomes

	Wound complication[a]		Morbidity[b]	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Age	1.01 (0.99–1.02)	0.575	1.02 (1.01–1.04)	0.003
Female sex	2.12 (1.23–3.65)	0.007	1.03 (0.69–1.52)	0.900
BMI	1.00 (0.98–1.02)	0.901	1.01 (0.99–1.02)	0.511
Co-morbidities				
0 (reference)	1		1	
1	1.07 (0.56–2.04)	0.837	0.81 (0.44–1.48)	0.490
≥ 2	1.47 (0.75–2.87)	0.259	2.10 (1.18–3.72)	0.011
ASA ≤ 3	1.30 (0.71–2.38)	0.392	1.39 (0.82–2.38)	0.226
Pre-operative sepsis	3.05 (1.87–4.98)	< 0.001	2.73 (1.79–4.15)	< 0.001
Wound classification				
Clean (reference)	1		1	
Non-clean[c]	2.02 (1.27–3.23)	0.003	1.13 (0.75–1.71)	0.566
Laparoscopic approach	0.35 (0.22–0.57)	< 0.001	0.73 (0.51–1.06)	0.094

[a]Aggregate measure combining superficial SS, deep incisional SSI, Organ/Space SSI, and wound disruption

[b]Excluding wound morbidity

[c]Clean/contaminated, contaminated, dirty/infected

[8]. Subsequently, Shah et al. reviewed their institutional experience between 1998 and 2006 of 112 patients undergoing laparoscopic repair of incarcerated ventral hernias. The authors reported a median hospital stay of 2.8 days, a post-operative complication rate of 20.5%, and a hernia recurrence rate of 2.9% at a median follow-up of 48 months [9]. Most recently Olmi et al. supported the feasibility of laparoscopic ventral hernia repair in the emergency setting after retrospectively reviewing their institutional experience with 48 patients. In this series, they demonstrated an average length of stay of 4 days, eight post-operative seromas, no post-operative complications, and no hernia recurrence at a median follow-up of 38 months [10]. Based on these findings the World Society of Emergency Surgery (WSES) guidelines for emergency repair of complicated abdominal wall hernias has provided grade 2C level of evidence for conduction of laparoscopic repairs in this setting [12]. Furthermore, the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) guidelines for laparoscopic ventral hernia repair support the role of laparoscopy for ventral hernia repair, however, they do caution that incarcerated hernias may increase the difficulty and duration of the procedure with potential increased risk of conversion to an open approach [13].

The aforementioned studies, which support the safety and feasibility of laparoscopic repair of incarcerated ventral hernias, have several inherent limitations. Specifically, these studies are limited by low enrollment (ranging from 48 to 112 patients), single institution designs, lack of a comparative cohort of open repairs, and non-standardized reporting of patient comorbidity and outcome measures. Furthermore, the rate of missed enterotomies has not been well delineated in these studies—a rare but important complication that is compounded with a laparoscopic approach. Analysis of the ACS-NSQIP dataset provides North-American multi-institutional data with standardized outcome measures which allows us to overcome these limitations. A recent NSQIP study by our group evaluated incarcerated abdominal hernias (ventral and groin) between 2005 and 2012 and demonstrated an association with decreased 30 day infectious and serious complications [11]. Although this study favorably supports laparoscopy for incarcerated ventral hernias, there are several limitations that reduce its applicability in the emergency, high acuity setting. First, our previous work assessed outcomes by combining groin and ventral hernias as a common entity. Acute ventral hernias have been associated with higher post-operative morbidity compared to groin hernias due to the potential need for large incisions and soft-tissue flap mobilization. Secondly, our previous work did not distinguish patients undergoing emergency surgery, which classically has been defined by NSQIP as an operation deemed emergent and performed within 12 h of admission. Additionally, our previous work excluded

patients with incarcerated hernias and associated gangrene, a sub-group at risk for complications associated with the use of laparoscopy and laparoscopic instruments. Finally, the 2005–2011 NSQIP dataset is limited by lack of reporting of hospital readmission and reoperation, both of which are important in determining the short-term safety of laparoscopy in the emergency setting. Therefore, this study builds on our previous work by assessing patients with the highest acuity of disease, while also reporting on the clinically relevant readmission, reoperation, and missed enterotomy rates. Furthermore, our study is strengthened by the use of matching between laparoscopic and open cohorts via the CEM technique. CEM allows balancing of cohorts based on clinically relevant characteristics and has been demonstrated to have several advantages over propensity score matching [14]. Overall, this is among the largest studies to our knowledge to have directly assessed the safety and feasibility of laparoscopic incarcerated ventral hernia repair compared to open repair in the emergency setting.

Wound-morbidity is among the most common complications that occur following ventral hernia repair [15]. Acute incarceration is a risk factor for increased wound-morbidity since obstructed and potentially ischemic segments of bowel increase the risk of contamination. This study demonstrates a significantly lower rate of overall wound-morbidity in laparoscopic repairs compared to open repairs after adjusting for confounders. Although no prior studies have directly assessed this outcome in the emergency incarcerated setting, previous literature in the elective non-incarcerated setting has demonstrated this benefit for the laparoscopic approach [16]. A meta-analysis of eight randomized controlled trials comparing open and laparoscopic repair of ventral hernias with mesh demonstrated a relative risk of 0.22 for wound infection in favor of laparoscopy [17]. This is likely a factor of the smaller incision and surface area subjected to the environment in laparoscopy. Although the majority of the wound-morbidity in our study was accounted for by superficial SSIs, we also demonstrated a lower rate of deep incisional SSIs and wound disruption events in the laparoscopic cohort. This is clinically important since deep SSIs may lead to mesh infection and necessitate eventual removal. Our global wound-morbidity rate was low for both open and laparoscopic approaches. This is likely secondary to the fact that patients who underwent a concurrent bowel resection secondary to likely strangulation and bowel compromise were excluded. Additionally, matching reduced the proportion of patients with non-clean wound classification (22.5% with non-clean wound after matching), a factor that we have identified to be associated with wound-morbidity after adjusting for other covariates. Non-clean wounds have been demonstrated by multiple studies to be associated with higher rates of wound infection in hernia repair [18–20]. Overall, these study findings support the idea that

emergency laparoscopic repair of incarcerated ventral hernias are associated with lower wound-morbidity in select patients; caution should be taken for patients with bowel compromise requiring concurrent bowel resection.

This study also adds to our evolving understanding of the impact of emergency laparoscopic repair of incarcerated ventral hernias with respect to non-wound related adverse events. A missed enterotomy is among the most feared complications following hernia repair, and has been reported in 0.2% of elective open repairs and 0.9% of laparoscopic repairs [21]. This fear is heightened in the emergency setting as it is thought that the use of laparoscopic instruments to handle distended bowel may further increase the risk of injury. This study confirms this risk, demonstrating a higher rate of 30 day re-operative surgery for a bowel resection in the laparoscopic group compared to the open cohort. However, our missed enterotomy rate was similar to studies in the elective setting, questioning the concern of compounded risk in the emergency setting with associated obstructed and distended bowel. Furthermore, although our study demonstrates a higher rate of re-operative bowel surgery in laparoscopic repairs, further research is needed to determine the influence of hernia and patient specific factors, such as fascial defect size and adhesions, on the risk of missed enterotomies. Furthermore, this study demonstrated low rates of non-wound related morbidity, with no group differences after adjusting for confounders. This is in concordance to previous small series studies which have demonstrated low complication rates with emergency laparoscopic ventral hernia repair [8–10]. Our study finding of shorter LOS in the laparoscopic cohort is in keeping with literature in the elective non-incarcerated setting, which has favored a shorter LOS in laparoscopic surgery [22–24]. It is postulated that with smaller laparoscopic incisions there is less associated postoperative pain and risk of wound complications, all of which contribute to an enhanced recovery. The average length of stay of 3 days for laparoscopic repair is in line with other studies [8–10]. Overall, assessment of adverse events following repairs of emergent ventral hernias support the safety of the laparoscopic approach, with the caveat of a small but significant risk of a missed enterotomy.

This study must be interpreted in the context of several limitations, the majority of which are inherent to the NSQIP dataset. Firstly, the NSQIP dataset is limited to fixed 30 day outcomes. Therefore, we were not able to report on clinically relevant long-term outcomes including hernia recurrence, quality of life, or mesh infection. Secondly, patient selection was based on CPT and ICD coding. Thus, due to limitation in the dataset, we were not able to report on several important factors, such as: the type of open hernia repair, recurrent versus primary hernia, the utilization of mesh, type of mesh used, location of mesh, utilization of drains, hernia defect size, or conversion rates from laparoscopic to open approach. Third, our study is limited by its retrospective design making it prone to the effects of unmeasured confounders and selection bias. We attempted to minimize this limitation by excluding patients undergoing concurrent procedures and by conducting our analysis by coarsened exact matching, thus allowing for a more homogenous and balanced analysis. Fourth, we defined missed enterotomy as any operation within 30 days resulting in a bowel resection. It is plausible that a bowel resection could have resulted from inadequate assessment of potentially ischemic segments of bowel at time of initial surgery. Finally, although the NSQIP dataset encompasses outcomes from over 600 North-American hospitals, enrollment is voluntary and thus there may be a level of selection bias which may limit the generalizability of our outcomes.

Conclusion

This study confirms that laparoscopic repair of acutely incarcerated ventral hernias with concomitant small bowel obstruction or gangrene is associated with lower wound-related morbidity and shorter hospital LOS. We demonstrate that laparoscopic repair is comparable to open repair with respect to 30 day non-wound morbidity, readmissions, overall reoperations, and mortality. However, laparoscopic repair is associated with a higher rate of missed enterotomies, a complication which can have series consequences and associated morbidity. Further research exploring patient and hernia specific factors associated with missed enterotomies is required to help guide patient selection for laparoscopic repair of incarcerated ventral hernias in the acute setting.

Compliance with ethical standards

References

1. Le Huu Nho R, Mege D, Ouaissi M, Sielezneff I, Sastre B (2012) Incidence and prevention of ventral incisional hernia. J Visc Surg 149(5 Suppl):e3–e14

2. Poulose BK, Beck WC, Phillips SE, Sharp KW, Nealon WH, Holzman MD (2013) The chosen few: disproportionate resource use in ventral hernia repair. Am Surg 79(8):815–818

3. Eker HH, Hansson BM, Buunen M, Janssen IM, Pierik RE, Hop WC et al (2013) Laparoscopic vs. open incisional hernia repair: a randomized clinical trial. JAMA Surg 148(3):259–263

4. Rogmark P, Petersson U, Bringman S, Eklund A, Ezra E, Sevonius D et al (2013) Short-term outcomes for open and laparoscopic midline incisional hernia repair: a randomized multicenter controlled trial: the ProLOVE (prospective randomized trial on open versus laparoscopic operation of ventral eventrations) trial. Ann Surg 258(1):37–45

5. Sauerland S, Walgenbach M, Habermalz B, Seiler CM, Miserez M (2011) Laparoscopic versus open surgical techniques for ventral or incisional hernia repair. Cochrane Database Syst Rev 16(3):CD007781

6. Asencio F, Aguilo J, Peiro S, Carbo J, Ferri R, Caro F et al (2009) Open randomized clinical trial of laparoscopic versus open incisional hernia repair. Surg Endosc 23(7):1441–1448

7. Itani KM, Hur K, Kim LT, Anthony T, Berger DH, Reda D et al (2010) Comparison of laparoscopic and open repair with mesh for the treatment of ventral incisional hernia: a randomized trial. Arch Surg 145(4):322

8. Landau O, Kyzer S (2004) Emergent laparoscopic repair of incarcerated incisional and ventral hernia. Surg Endosc 18(9):1374–1376

9. Shah RH, Sharma A, Khullar R, Soni V, Baijal M, Chowbey PK (2008) Laparoscopic repair of incarcerated ventral abdominal wall hernias. Hernia 12(5):457–463

10. Olmi S, Cesana G, Erba L, Croce E (2009) Emergency laparoscopic treatment of acute incarcerated incisional hernia. Hernia 13(6):605–608

11. Elnahas A, Kim SH, Okrainec A, Quereshy F, Jackson TD (2016 Aug) Is laparoscopic repair of incarcerated abdominal hernias safe? Analysis of short-term outcomes. Surg Endosc 30(8):3262–3266

12. Birindelli A, Sartelli M, Di Saverio S, Coccolini F, Ansaloni L, van Ramshorst GH et al. (2017) 2017 update of the WSES guidelines for emergency repair of complicated abdominal wall hernias. World J Emerg Surg 12(7):37

13. Earle D, Roth JS, Saber A, Haggerty S, Bradley JF 3rd, Fanelli R et al (2016) SAGES guidelines for laparoscopic ventral hernia repair. Surg Endosc 30(8):3163–3183

14. Iacus SM, King G, Porro G (2012) Causal inference without balance checking: coarsened exact matching. Political Anal 20:1

15. Nguyen MT, Berger RL, Hicks SC, Davila JA, Li LT, Kao LS et al (2014) Comparison of outcomes of synthetic mesh vs suture repair of elective primary ventral herniorrhaphy: a systematic review and meta-analysis. JAMA Surg 149(5):415–421

16. McCormack K, Scott NW, Go PM, Ross S, Grant AM, EU Hernia Trialists Collaboration (2003) Laparoscopic techniques versus open techniques for inguinal hernia repair. Cochrane Database Syst Rev 1:CD001785

17. Forbes SS, Eskicioglu C, McLeod RS, Okrainec A (2009) Meta-analysis of randomized controlled trials comparing open and laparoscopic ventral and incisional hernia repair with mesh. Br J Surg 96(8):851–858

18. Choi JJ, Palaniappa NC, Dallas KB, Rudich TB, Colon MJ, Divino CM (2012) Use of mesh during ventral hernia repair in clean-contaminated and contaminated cases: outcomes of 33,832 cases. Ann Surg 255(1):176–180

19. Kelly ME, Behrman SW (2002) The safety and efficacy of prosthetic hernia repair in clean-contaminated and contaminated wounds. Am Surg 68(6):524; discussion 528–529

20. Carbonell AM, Criss CN, Cobb WS, Novitsky YW, Rosen MJ (2013) Outcomes of synthetic mesh in contaminated ventral hernia repairs. J Am Coll Surg 217(6):991–998

21. LeBlanc KA, Elieson MJ, Corder (2007 Oct-Dec) JM,3rd. Enterotomy and mortality rates of laparoscopic incisional and ventral hernia repair: a review of the literature. JSLS 11(4):408–414

22. Barbaros U, Asoglu O, Seven R, Erbil Y, Dinccag A, Deveci U et al (2007) The comparison of laparoscopic and open ventral hernia repairs: a prospective randomized study. Hernia 11(1):51–56

23. Carbajo MA, Martin del Olmo JC, Blanco JI, de la Cuesta C, Toledano M, Martin F et al (1999) Laparoscopic treatment vs open surgery in the solution of major incisional and abdominal wall hernias with mesh. Surg Endosc 13(3):250–252

24. Misra MC, Bansal VK, Kulkarni MP, Pawar DK (2006) Comparison of laparoscopic and open repair of incisional and primary ventral hernia: results of a prospective randomized study. Surg Endosc 20(12):1839–1845