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Original Article

Laparoscopy for stable penetrating abdominal trauma

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ABSTRACT

Introduction. Trauma laparotomy remains the gold standard for treating penetrating abdominal trauma, but it carries a higher risk of complications and longer hospital stays than other approaches. We explored whether laparoscopy could serve as a valuable alternative in the trauma setting. This study analysed the management of haemodynamically stable patients with penetrating abdominal trauma to assess the applicability of laparoscopy and its potential to reduce non-therapeutic laparotomies.

Methods. We conducted a retrospective study of haemodynamically stable patients with penetrating abdominal trauma who underwent surgery. Data were collected over a five-year period (January 2018-December 2022), including demographics, radiological procedures, surgical findings and interventions, and post-operative outcomes: mortality, complications (including reoperation and missed injury) and length of stay.

Results. A total of 127 patients were included and divided into three groups: laparoscopy, laparoscopy converted to laparotomy and laparotomy. Extended focused assessment with sonography in trauma E-FAST and computed tomography were significantly more often positive in the laparotomy group than in the other groups. Commonly injured organs included the liver, diaphragm, stomach, small bowel, colon, retroperitoneum and spleen. Frequent interventions were liver haemostasis and diaphragm repair. In total, 29 patients (28%) underwent non-therapeutic laparotomy.

CONCLUSIONS. We found a high rate of non-therapeutic laparotomies. Given the injuries and procedures, laparoscopy appears feasible in experienced hands. Prospective studies are urgently needed to assess its safety and efficacy in abdominal trauma.

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Trial registration. Not relevant.

Trauma remains a major cause of mortality, accounting for 8% of deaths worldwide [1]. In Denmark, around 2,600 trauma patients are admitted annually [2]. Both penetrating and blunt trauma may require surgical evaluation. Exploratory laparotomy has been the gold standard in suspected intra-abdominal injury or peritoneal breach. However, studies have reported negative laparotomy rates up to 61%. Moreover, in penetrating trauma, up to 45% of negative laparotomies may be avoidable using laparoscopy [3-5].

Laparotomy carries an increased risk of complications and longer hospital stays [3, 6]. Whereas laparoscopy is widely used in elective and emergency surgery, its role in trauma remains limited. Early studies reported high

rates of missed injuries, particularly small-bowel lesions [7-9]. More recent research shows that diagnostic laparoscopy can be performed safely [3, 6, 10, 11, 12]. Laparoscopy can be exploratory (peritoneal integrity), diagnostic (injury evaluation) or therapeutic (repair of injuries) [3, 11].

This study assessed the management of haemodynamically stable penetrating abdominal trauma and explored the potential of laparoscopy to reduce negative and non-therapeutic laparotomies.

Methods

We conducted a retrospective study of haemodynamically stable patients with penetrating abdominal trauma from January 2018 to December 2022, admitted to the Trauma Centre at Rigshospitalet, which serves 2.6 million people in Eastern Denmark. The study followed the STROBE guidelines, and ethical approval for data access was obtained.

Patient selection

We included all haemodynamically stable patients (pulse ≤ 100, systolic blood pressure ≥ 100) admitted with penetrating anterior abdominal and/or flank trauma planned for surgery. Data were retrieved from the Trauma Registry and the EPIC electronic health record system.

Study variables

Data collected included demographics (sex, age), injury mechanism, Injury Severity Score (ISS), American Society of Anesthesiologists (ASA) score, Abbreviated Injury Score (AIS) and Charlson Comorbidity Index (CCI). In-hospital data covered vitals, radiological findings, surgical indication, approach (laparoscopy or laparotomy), operative findings and procedures. Post-operative data included mortality, reoperations, complications (Clavien-Dindo score), missed injuries and length of stay (LOS). Primary outcomes were non-therapeutic laparotomies and missed injuries. Secondary outcomes included mortality, procedure time, LOS, complications and reoperations. Follow-up was performed at 30 days and in the long term.

Data and statistical analysis

Statistical analyses were performed using IBM SPSS Statistics (v29.0.1.0). Categorical data are presented as percentages; continuous data as means ± SD or medians with IQR. The χ^2 test assessed proportions and trends. Data were tested for normal distribution using the Shapiro-Wilk test. The one-way analysis of variance (ANOVA) test was applied to compare unpaired normally distributed continuous data. Univariate analyses identified statistical differences. Two-tailed p values < 0.05 were considered significant.

Data registry

All data were entered into the REDCap system (Vanderbilt University, USA).

Trial registration: not relevant.

Results

We identified 252 patients presenting with penetrating abdominal injury within the five-year study period. Among these, 125 were excluded due to haemodynamic instability (n = 40), no relevant abdominal trauma (e.g. dorsal torso stabs or gunshots) (n = 40), no abdominal surgery performed (n = 24) or dead at or soon after arrival (n = 21). A total of 127 patients were included in the study; 112 with stab wounds, ten with gunshots and five patients with a trauma mechanism after falling over a penetrating object. This included one patient falling onto the bicycle handlebars and four patients who hit a penetrating object during a fall from heights.

We separated the patients into three groups. Group one consisted of patients undergoing only laparoscopy (n = 25), group two included patients initially planned for laparoscopy but converted to laparotomy (n = 19), and group three comprised patients who had undergone direct laparotomy (n = 83). All conversions from laparoscopy to laparotomy were due to breach of the peritoneum. There was no statistical difference between groups regarding sex, age, CCI, type of admission, pulse and systolic blood pressure (**Table 1**). The laparotomy group had a significantly higher AIS and ISS than the other groups. Furthermore, extended focused assessment with sonography in trauma (E-FAST) was more often positive in the laparotomy group. There was one positive E-FAST in the laparoscopy group, which was due to pneumothorax and not an indication for abdominal injury. The CT more often showed positive findings, indicating intra-abdominal injuries in the laparotomy group. CT findings were the primary determinant for proceeding with laparotomy. The predominant indication for laparoscopy was the need for surgical evaluation due to the trauma mechanism and uncertainty regarding peritoneal penetration.

TABLE 1 Baseline patient characteristics.

	Laparoscopy (N_{scopy} = 25 (20%))	Laparoscopy converted (N_{conv} = 19 (15%))	Laparotomy (N_{tomy} = 83 (65%))	p value
Sex, n (%)				0.67
Male	23 (92)	17 (90)	71 (86)	
Female	2 (8)	2 (10)	12 (14)	
Age, median (IQR), yrs	25.4 (21.1-42.5)	38.7 (26.9-54.9)	26 (20.4-44)	0.16
CCI, mean (± SD)	0.2 (± 0.5)	0.8 (± 1.1)	0.6 (± 1.6)	0.31
Trauma mechanism, n (%)				0.30
Stab	23 (92)	19 (100)	70 (84)	
Gunshot	1 (4)	0	9 (11)	
Falls over a penetrating object	1 (4)	0	4 (5)	
Type of admission, n (%)				0.28
Primary	22 (88)	19 (100)	73 (88)	
Secondary	3 (12)	0	10 (12)	
Haemodynamics, mean (± SD)				
Pulse, beats/min.	93 (± 19.7)	99 (± 20.6)	95 (± 21.2)	0.63
sBP, mmHg	129 (± 25.1)	141 (± 17.1)	131 (± 24.9)	0.20
Shock index: pulse/sBP	0.77 (± 0.37)	0.72 (± 0.20)	0.76 (± 0.24)	0.80
AIS, abdomen, mean (± SD)	0.6 (± 0.58)	1.7 (± 1.03)	2.3 (± 0.96)	< 0.001
ISS, mean (± SD)	3.1 (± 3.01)	5.6 (± 4.3)	10.4 (± 7.1)	< 0.001
E-FAST, n (%)				
Positive	1 (4)	0	19 (23)	0.005
Negative	22 (88)	18 (95)	52 (63)	0.005
Not performed	2 (8)	1 (5)	12 (14)	0.45
CT findings, n (%)				
Positive	3 (12)	8 (42)	61 (73)	< 0.001
Negative	17 (68)	8 (42)	3 (4)	< 0.001
Suspicion of peritoneal perforation without intra-abdominal lesion	2 (8)	2 (11)	6 (7)	0.89
Inconclusive	2 (8)	0	0	0.27
Not performed	1 (4)	1 (5)	13 (16)	0.18
Indications, initiation, n (%)				
CT findings	5 (20)	8 (42)	68 (82)	< 0.001
Objective signs of peritoneal penetration	0	0	6 (7)	0.3
Trauma mechanism	20 (80)	11 (58)	4 (5)	< 0.001
Other[a]	0	0	5 (6)	0.51

AIS = Abbreviated Injury Score; CCI = Charlson Comorbidity Index; E-FAST = extended focused assessment with sonography in trauma; ISS = Injury Severity Score; sBP = systolic blood pressure.
a) Positive E-FAST and haemodynamic instability after arrival.

Frequent injuries included damage to the liver (20%), diaphragm (13%), stomach (10%), small and large bowel

(13% and 12%), retroperitoneal haematoma (12%) and spleen (8%) (**Table 2**). Injuries to the duodenum and pancreas were rare (below 10%). Two patients in the laparoscopic group had a peritoneal breach. One patient had a liver injury but did not require intervention. In the other patient, no intra-abdominal injuries were noted. The laparotomy group included seven patients without breach of the peritoneum. One of those seven patients had a retroperitoneal haematoma and did not require an intervention. In total, 20 laparotomies (20%) were performed without any intra-abdominal findings. Among these 20 patients, seven were in the conversion group, and all had peritoneal breach. The remaining 13 patients were in the laparotomy group. Among those, seven were without breach of the peritoneum, and six were with breach of peritoneum but had no intra-abdominal injuries.

TABLE 2 Intraoperative findings and interventions.

	Laparoscopy (N_{scopy} = 25 (20%))	Laparoscopy converted (N_{conv} = 19 (15%))	Laparotomy (N_{tomy} = 83 (65%))	p value
Findings, n (%)				
Intact peritoneum	23 (92)	0	7 (8)	< 0.001
Peritoneal perforation	2 (8)	19 (100)	76 (92)	< 0.001
Intra-abdominal injuries:				
None	24 (96)	7 (36)	13 (16)	< 0.001
Single	1 (4)	6 (32)	32 (38)	0.005
Multiple	0	6 (32)	38 (46)	< 0.001
Organ injuries, n (%)				
Liver	1 (4)	3 (16)	22 (26)	0.04
Gallbladder	0	0	4 (5)	0.78
Spleen	0	0	10 (12)	0.06
Small bowel:				
Serosal	0	1 (5)	5 (6)	0.46
Perforation	0	0	10 (12)	0.06
Large bowel:				
Serosal	0	2 (10)	4 (5)	0.26
Perforation	0	3 (16)	6 (7)	0.13
Appendix	0	0	1 (1)	0.77
Diaphragm	0	1 (5)	15 (18)	0.03
Stomach:				
Serosal	0	0	6 (7)	0.19
Perforation	0	1 (5)	6 (7)	0.38
Duodenum	0	0	1 (1)	0.77
Pancreas	0	0	4 (5)	0.78
Bladder	0	0	1 (1)	0.77
Vessels	0	1 (5)	3 (4)	0.60
Omentum	0	4 (21)	2 (2)	0.006
Mesentery	0	2 (10)	8 (10)	0.30
Retroperitoneal haematoma	0	1 (5)	14 (17)	0.04
Therapy, n (%)				
None	25 (100)	9 (47)	20 (24)	< 0.001
Suture of the stomach:				
Serosal	-	0	5 (6)	0.51
Perforation	-	1 (5)	6 (7)	0.39
Suture of small bowel:				
Serosal	-	1 (5)	5(6)	0.48
Perforation	-	0	4(5)	0.78
Suture of the large bowel:				
Serosal	-	2 (10)	4 (5)	0.30
Perforation	-	3 (16)	6 (7)	0.13
Suture of the duodenum	-	0	1 (1)	1
Small bowel, resection	-	0	6 (7)	0.30
Large bowel, resection	-	0	0	NA
Haemostatic procedure:				
On liver	-	2 (10)	14 (17)	0.06
On kidney	-	0	4 (5)	0.78
On pancreas	-	0	2 (2)	1
On spleen	-	0	6 (7)	0.21

Continues >

TABLE 2 (CONTINUED) Intraoperative findings and interventions.

	Laparoscopy (N_{scopy} = 25 (20%))	Laparoscopy converted (N_{conv} = 19 (15%))	Laparotomy (N_{tomy} = 83 (65%))	p value
Splenectomy	-	0	5 (6)	0.27
Suture of diaphragm	-	1 (5)	15 (18)	0.04
Cholecystectomy	-	0	4 (5)	0.78
Ligature of bleeding/vessel	-	1 (5)	3 (4)	0.60
Procedure on the greater omentum	-	4 (21)	2 (2)	0.006
Procedure at the retroperitoneum	-	0	1 (1)	1
Appendectomy	-	0	1 (1)	1
Suture of the urinary bladder	-	0	1 (1)	1
JJ ureteral stent	-	0	1 (1)	1
ERCP	-	0	2 (2)	1
Procedures for review, n (%)				
None	25 (100)	3 (16)	12 (14)	< 0.001
Access to the lesser sac	-	14 (74)	60 (72)	< 0.001
Kocher manoeuvre	-	6 (32)	41 (49)	< 0.001
Cattell-Braasch manoeuvre	-	0	4 (5)	0.78
Preparation for Pringle manoeuvre	-	0	2 (2)	1
Mobilisation of colon	-	1 (5)	20 (24)	0.007

ERCP = endoscopic retrograde cholangiopancreatography.

The most frequent surgical interventions were haemostatic procedures on the liver (16%) and suture of the diaphragm (16%). The most frequently performed procedures to review the abdomen were obtaining access to the lesser sac (omental bursa) (73%) and the Kocher manoeuvre (46%). Fifteen laparotomies (15%) involved no further procedures to examine the abdominal cavity. Non-expanding retroperitoneal haematoma (8%) and non-bleeding liver lesions (6%) were the most common intraoperative findings, for which no further therapy was needed.

In the study group, 29 (28%) non-therapeutic laparotomies were performed (**Table 3**). One patient died due to respiratory and cardiac failure after laparotomy. This patient was a 70-year-old female with a stab wound injury to the serosa of the stomach (which was sutured) and a non-bleeding lesion to the mesentery of the small bowel. Most complications were graded less than Clavien-Dindo IIIb, not requiring general anaesthesia. The most common complications were renal failure, pain, pneumonia and wound dehiscence. Ten patients underwent an unplanned reoperation within the first 30 days, of whom three had fascial dehiscence, one paralytic ileus, one gastrointestinal bleeding requiring gastroscopy, one with wound infection, one with hernia in the injury wound containing small bowel, one with the need for a Double-J stent due to a retroperitoneal haematoma compromising the ureter, and two patients due to missed injuries in the laparotomy group. One of the two missed injuries was a patient with additional stomach perforations from multiple stab wounds, and the other was a patient with damage to the pancreas and a bile duct with bile leakage. No patients in the laparoscopy group had missed injuries. Procedure time and LOS were statistically significantly longer for laparotomies than for laparoscopy. In the follow-up period, five reoperations were performed in the laparotomy group. Three of those were due to hernias, and two were due to adhesive small bowel obstruction.

TABLE 3 Primary and secondary outcomes.

	Laparoscopy (N_{scopy} = 25 (20%))	Laparoscopy converted (N_{conv} = 19 (15%))	Laparotomy (N_{tomy} = 83 (65%))	p value
Negative laparotomies[a], n (%)	-	9 (47)	20 (24)	0.04
Missed injuries, n (%)	0	0	2 (2)	0.58
Procedure time, mean (± SD), min.	28.84 (± 15.5)	85.2 (± 31.5)	91.8 (± 43.7)	< 0.001
LOS, mean (± SD), days	1 (± 1.02)	4.1 (± 1.8)	6.8 (± 6.3)	< 0.001
Reoperation in the first 30 days, n (%)	0	3 (16)	7 (8)	0.15
Long-term reoperation, n (%)	0	1 (5)	4 (5)	0.51
Clavien Dindo Score, n (%)	-	0	1 (1)	
Grade 0	24 (96)	8 (42)	44 (53)	< 0.001
Grade I	0	5 (26)	9 (11)	0.02
Grade II	1 (4)	1 (5)	11 (13)	0.30
Grade IIIa	0	0	6 (7)	0.19
Grade IIIb	0	5 (14)	10 (12)	0.03
Grade IVa	0	0	2 (2)	0.58
Grade IVb	0	0	0	-
Grade V	0	0	1 (1)	0.77
Mortality, n (%)	0	0	1 (1)	0.77

LOS = length of stay.
a) Laparotomies with no injuries or injuries without the need for therapy.

Discussion

The current standard for penetrating abdominal trauma involves performing a full trauma laparotomy, with a midline incision from the xiphoid to the pubic symphysis. Abdominal assessment includes inspection of hollow and solid organs, the Kocher manoeuvre to expose the duodenum and access to the lesser sac to inspect the posterior stomach and pancreas. The Pringle manoeuvre, Cattell-Braasch and colon mobilisation are performed as indicated. Laparoscopy offers a minimally invasive overview and initial diagnosis to guide further steps.

We observed a 28% rate of non-therapeutic laparotomies in stable patients with penetrating abdominal trauma; 20% showed no pathological intra-abdominal findings. International studies, including studies encompassing high-volume centres, report negative laparotomy rates ranging from 4% to 61% [3-5, 10, 13, 14]. Rates of non-therapeutic laparotomies appear higher in stable penetrating trauma, where laparoscopy may help reduce unnecessary laparotomies. In stable cases, there is time to perform a thorough diagnostic laparoscopy. Laparotomy was primarily based on suspected peritoneal penetration on CT, though seven patients had intact peritoneum. In all cases, CT showed equivocal findings, e.g. small amounts of free air near the entry site. Stab wounds may introduce air along the wound tract. If the injury stops short of the peritoneum, it can be difficult to distinguish intra-abdominal air from air between the fascia and the peritoneum. In the laparoscopy group, another seven patients were converted to laparotomy without additional findings. These seven patients all had a negative E-FAST and CT before surgery. Overall, we have to interpret CT findings more cautiously. Moreover, since patients are haemodynamically stable, they can benefit from an initial explorative and diagnostic laparoscopy and likely avoid a laparotomy. FAST and CT scans are valid diagnostic tools for this patient group and may help select the right patients for diagnostic laparoscopy.

Until now, the worldwide consensus has been that conversion is indicated when the peritoneal breach is found, but this is likely to change. The latest guidelines from the World Society of Emergency Surgery (WSES) regarding a laparoscopic approach for general surgery emergencies and abdominal trauma suggest that laparoscopy should be the first approach for stable patients undergoing emergency abdominal surgery and abdominal trauma, and they introduce the laparoscopic therapeutic approach [15]. The WSES stated that, e.g., bowel

injuries, bladder repair, splenectomy, distal pancreatectomy, diaphragm repair and haemostasis can be handled laparoscopically, depending on the surgeon's experience and skills.

The most commonly injured organs – stomach, liver, diaphragm, small bowel and colon - account for 68% of all injuries. These can typically be visualised laparoscopically, making laparoscopy sufficient in many cases. In our study, 31% of patients had only one injury requiring surgery, often manageable laparoscopically, e.g. liver haemostasis or gastric/diaphragmatic suturing. If laparotomy is needed (e.g. for bowel resection), a targeted incision can be made, avoiding full trauma laparotomy. Most surgeons trained in laparoscopy will manage to create access to the lesser sac, but the Kocher manoeuvre may be more challenging and may increase the risk of iatrogenic damage to the duodenum. If it is necessary to examine the abdomen using more advanced procedures, there is a substantial probability that the injuries are so severe that addressing them laparoscopically may not be beneficial. Under any circumstances, it is relevant to consider the trauma mechanism and location in greater detail and to develop a personalised approach for the individual patient. For instance, a single stab wound on the anterior part of the abdomen that has caused no damage to the nearest organs in front is unlikely to have caused damage to the posteriorly located organs. Therefore, if there are no visible injuries at the anterior wall of the organ, it should not be indicated to look in the lesser sac or perform a Kocher manoeuvre.

It would be interesting to determine whether the trauma mechanism itself may influence the decision to initiate laparoscopy or laparotomy. But since stab wounds are the predominant trauma mechanism in our study, we could not make any meaningful subgroup analysis. A South African study included all trauma patients managed with laparoscopy over four years and showed that the most common mechanism of injury in the conversion group was a gunshot wound [16]. Moreover, they concluded that laparoscopy appears to be a safe approach for all stable trauma patients.

Selective conservative management in the treatment of stable penetrating abdominal trauma has been suggested, but the evidence is sparse, and more research is required before a recommendation can be made [17].

Laparoscopy appears to be an obvious way of identifying intra-abdominal injuries after penetrating trauma in the haemodynamically stable patient and may lead to a decreased number of non-therapeutic laparotomies. More research is needed to clarify whether diagnostic laparoscopy is safe in the trauma setting. Moreover, a clear definition of what constitutes a sufficient diagnostic laparoscopy in trauma is required.

Limitations

The retrospective design of this study is a limitation, and data were derived from a single centre. Due to the limited number of patients and laparoscopies, we cannot draw firm conclusions on the safety of laparoscopy in trauma. This limitation is further accentuated by the fact that laparoscopy was performed in an exploratory manner rather than as a diagnostic or therapeutic intervention.

Conclusions

In this exploratory study to investigate the role of laparoscopy in penetrating haemodynamically stable trauma patients, we identified a 28% rate of non-therapeutic laparotomies. The detected organ injuries and the performed surgical interventions are considered to be laparoscopically treatable. Therefore, laparoscopy may play an important role in trauma surgery, though a well-designed randomised trial is necessary to demonstrate its safety and efficacy in trauma patients.

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