Laparoscopy in Abdominal Trauma

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Abstract

Purpose of Review Exploratory laparotomy is the traditional therapeutic approach in patients with abdominal trauma. However, due to potential associated morbidity and mortality, avoiding unnecessary laparotomies is an important issue.

Recent Findings While selective nonoperative management has shown good results, certain clinical situations in hemodynamically stable patients, where the need for surgery could be in doubt, call for proactive diagnosis. In these cases, laparoscopy can be used to exclude or diagnose potential injuries requiring surgery. When the surgeon has the necessary expertise, some of these injuries can be treated laparoscopically.

Summary Over the last decades, diagnostic and therapeutic applications of laparoscopy have increased, with reported reduction in nontherapeutic laparotomies. Furthermore, shorter

duration of hospital stay, faster recovery, and reduced costs have been reported. However, as seen in other minimally access interventions, safe implementation of laparoscopy in trauma care requires adequate surgical training and skills as well as appropriate staffing and equipment.

Keywords Abdominal trauma · Penetrating abdominal injury · Blunt abdominal injury · Negative laparotomy · Diagnostic laparoscopy · Therapeutic Laparoscopy

Introduction

Trauma is the leading cause of mortality in patients under 35 years worldwide [1] and poses a major challenge to health care providers. Although geographical variations exist, blunt trauma accounts for 78.9 to 95.6 % of injuries around the globe [2–5]. Between 9 and 14.9 % of all trauma cases involve the abdomen [2, 4]. Laparotomy is the standard approach for abdominal trauma but is associated with morbidity ranging from 20 to 22 % [6, 7] to 41.3 % [8], particularly when explorative laparotomy is negative.

With increasing conservative, nonoperative management (NOM) policies [9, 10], technical developments in imaging, and advances in surgical techniques, the rate of negative and therefore unnecessary laparotomy has been reduced. Laparoscopy in trauma can potentially further decrease the negative laparotomy rate [11]. Proposed as early as 1925 [12], the initial experiences with laparoscopy in abdominal disorders and trauma date from the 1960s [13, 14] and laparoscopy then made its way into clinical practice. Since, a steadily rising amount of data and experience has been generated, showing the adequacy of laparoscopy in selected patient groups, primarily as a diagnostic tool but also as a therapeutic measure.

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The aim of this article is to review and highlight the current use and indications of laparoscopy in abdominal trauma.

Management of Abdominal Trauma

The management of abdominal trauma has evolved over the last decades, mainly driven by the goal of reducing additional iatrogenic aggression to the initial trauma. Several guidelines and recommendations for the management of abdominal trauma have been published over the last years: these include evidence-based approaches combining clinical examination, diagnostic tools, and operative measures both in blunt and penetrating abdominal trauma [15•, 16–18].

Initial assessment of abdominal trauma consists in proper anamnesis including trauma mechanism and clinical examination, aiming for quick identification of possible injuries. However, physical examination may be unreliable. Concomitant head trauma, changes in consciousness due to substance abuse, accompanying spinal trauma and absence of clinical signs, notably in retroperitoneal injuries, are confounding factors. After clinical examination, additional diagnostic tests may be required to determine injury characteristics and immediate need for surgery or not.

In penetrating trauma, local wound exploration (LWE) can be used for exclusion of peritoneal penetration. This is essential for further diagnostic and interventional steps, as patients without penetration of the peritoneal cavity may be discharged safely [15•, 19]. However, LWE has to be performed meticulously, as simple probing may lead to false-negative results [20]. Especially in obese patients, diagnostic laparoscopy may provide more reliable results in determining peritoneal penetration [21, 22].

Diagnostic peritoneal lavage (DPL) has been described as cost-effective and easy to perform. In a systematic review, Catre reported a mean sensitivity of 98 % (range from 90 to 100 %) with a specificity of 92 % (range from 73 to 100 %) [23] for DPL. DPL usually is considered positive when the red blood cell (RBC) count is greater than $5000/\text{mm}^3$ in the lavage fluid [15•], although one article suggested a higher threshold of $10,000/\text{mm}^3$ to reduce nontherapeutic interventions [24]. In fact, according to Wood and colleagues, the high sensitivity and relatively low specificity might contribute to unnecessary exploratory operations in about 15 to 20 % of patients [25].

Abdominal and thoracic X-rays can be used to screen for free abdominal air and diaphragmatic injuries, as well as determination of the trajectory in gunshot wounds (GSWs) by marking the entrance and exit wounds with radiopaque material [15•].

Focused assessment with sonography for trauma (FAST) is a relatively simple bedside screening tool for detection of abdominal free fluid and pericardial effusion both in penetrating and blunt trauma. However, apart from being—as is sonography in general—operator dependent, sensitivity is significantly lower

than in DPL. Reported sensitivity rates range from 21 to 83.3 %, whereas specificity is reported to be 94 to 99.7 % [26–28]. In their study on anterior abdominal stab wounds (SWs), Biffl et al. reported that 19 % of their patients had to undergo a therapeutic laparotomy after initial negative FAST [19]. Therefore, a positive FAST can be seen as a strong predictor for abdominal injury, whereas negative results should be followed by further clinical or radiological assessment [28].

Computed tomography (CT) has high overall sensitivity and specificity [29, 30] in detecting abdominal abnormalities. Holmes et al. described a 0.3 % missed intra-abdominal injury rate after blunt trauma [31]. In abdominal GSW, sensitivity and specificity were reported to be 90.5 and 96 %, respectively [32]. However, drawbacks have been described in diagnosing several specific conditions following trauma. Lin et al. reported a false-negative rate of 46.2 to 54.5 % in hollow viscus perforation [33]. Similar results have been observed by Bhagvan et al., who described a sensitivity and specificity of 55.3 and 92.1 %, respectively [34•]. In diaphragmatic injuries, 82.1 % sensitivity and 99.7 % specificity have been reported [35]. Nevertheless, in their paper on traumatic diaphragmatic rupture, Mihos et al. achieved a correct preoperative diagnosis in only 26 % of all patients, 74 % being diagnosed intra-operatively [36].

Of note, with improvements in imaging techniques over the last decade, especially with CT, conservative treatment has become more common in patients with blunt and penetrating trauma. While selective NOM has been considered the standard of care in blunt abdominal solid organ injuries [37, 38], its implementation in penetrating abdominal trauma has been considerably slower [10, 32, 39, 40].

In their 2001 report, Velmahos et al. [9] reported a 38 % success rate for selective NOM of all patients admitted for penetrating trauma at a level 1 trauma center over 8 years. Negative laparotomy was performed in 9 % of cases (as compared to 47 % if treated by standard laparotomy). Delayed laparotomy was recorded in 4 % and 0.3 % had complications potentially related to the delay in laparotomy. Furthermore, these authors reported an estimated 3650-day reduction in hospital stay and overall \$9,555,752 savings in hospital charges compared with routine laparotomy. Of note, however, this study was performed at a high-volume center with a dedicated trauma team.

Similarly, in their analysis of 25,773 patients sustaining penetrating abdominal trauma between 2002 and 2008 in the USA, Zafar and colleagues [40] found an increasing use of NOM, resulting in a significant reduction in nontherapeutic laparotomy. An overall 20.2 % rate of abdominal GSW and 33.9 % of SW were treated conservatively. NOM failure occurred in 20.8 % (GSW) and 15.2 % (SW) respectively, leading to an increased mortality risk (4.48- and 9.83-fold increase, respectively; adjusted for demographics, injury severity, and clinical variables).

Despite the advances in noninvasive diagnostics and the negative impact on outcome in case of failure, a substantial number of patients neither qualify for NOM nor present formal indications for urgent laparotomy: this group of patients might constitute an excellent indication for laparoscopic exploration.

Several surgical societies [16, 41–43] have recommended the use of laparoscopy for selected patients with blunt and penetrating abdominal trauma, either for screening, or as a diagnostic and therapeutic tool.

Apart from the reduction of additional surgical trauma, Taner et al. also described possible economic benefits, as non-therapeutic laparotomy was associated with a 1.78-fold increase in cost compared to exploration by laparoscopy [44].

Prerequisites for Laparoscopy

Prerequisites for laparoscopy are hemodynamic stability, absence of indications for urgent laparotomy, or intracranial trauma. Although one study [45] reported use of laparoscopy in hemodynamically unstable patients, hemodynamic instability and shock are generally considered as contraindications for laparoscopy [19, 46–48]. Other contraindications include diffuse peritonitis, evisceration, and penetrating anal or vaginal injuries [19, 46–48]. If intracranial injuries are suspected, pneumoperitoneum should only be established after careful evaluation, as abdominal carbon dioxide insufflation and increased intra-abdominal pressure can lead to elevated intracranial pressure (ICP) [49–51]. Multiple organ injuries have also been considered as limiting factors [48]. Sufficient training and experience of both the surgeon and trauma team, as well as infrastructural and economic measures, pose another challenge for routine use of trauma laparoscopy [47•, 52].

Indications for Laparoscopy

As stated before, laparoscopy in trauma can be used for diagnosis and therapy in several indications, both in blunt and penetrating trauma:

1. Suspected hollow viscus injury (HVI) [22, 46, 53•, 54, 55•]—HVI occurs in about 0.9 to 2.5 % of all trauma patients, predominantly involving the small bowel [2, 5, 55•] (Fig. 1). In their retrospective analysis of more than 275,000 trauma admissions, Watts et al. [5] observed full thickness perforation in 41.5 % of all patients with HVI. They also described a 27.6 % morbidity and statistically significantly elevated mortality (19.8 % with compared to 12.2 % without HVI). In their 2003 report, Omori and colleagues [56] reported promising results in their therapeutic laparoscopic approach to isolated bowel rupture after blunt trauma. Despite nonstatistically significantly

Fig. 1 Stab injury to the small bowel detected through diagnostic laparoscopy

- longer operative times in laparoscopy as compared to laparotomy (132 ± 58.7 vs. 143.6 ± 27.3 , $p = .296$), they described a statistically significant reduction in blood loss (266.8 ± 277.8 mL in laparotomy vs. 57.6 ± 57.1 mL in laparoscopy, $p < .05$), no conversions and a similar duration of hospital stay.
2. Suspected diaphragmatic injury [21, 54]—Diaphragmatic injuries can be seen after penetrating thoraco-abdominal as well as blunt abdominal trauma. The importance of diaphragmatic repair has been underlined by Degiannis et al. [57], reporting a mortality rate of 25 % after complications of delayed diagnosis as compared to 3 % after early diaphragm repair. As radiological findings for diaphragmatic injuries may be equivocal, laparoscopic evaluation can clarify suspected injuries [58]. In their 10-year experience, Johnson et al. [53•] avoided a laparotomy in 89.3 % of patients with laparoscopic evaluation and therapy in suspected diaphragmatic injury. Laparoscopic repair of diaphragmatic laceration was the most common procedure observed by Zafar et al. [47•] in their 2015 systematic review, accounting for 19.2 % of all operations.
3. Free fluid of unknown source/suspected mesenteric laceration—Management strategies for the presence of free fluid without specific diagnosis of solid organ injury on CT [33, 59] include observation, DPL, diagnostic laparoscopy, and exploratory laparotomy [53•]. However, if a mesenteric injury is suspected, conservative management might be risky and it is important to check the perfusion of the respective bowel segment [53•] (Fig. 2). Mesenteric injuries in blunt trauma are relatively rare and occur mostly due to seatbelt restraint [54, 60•]. Delay in recognition of mesenteric injuries and possible consecutive bowel damage (by ischemia) can lead to devastating outcomes. As reported, CT sensitivity of 75 to 81 % [29, 61] leaves a certain degree of uncertainty. Laparoscopic exploration offers a sensitivity of 92 to 97.1 % with a specificity of 100 % [62, 63].
4. “Unclear abdomen”—In case of significant discrepancy between clinical examination and imaging studies, as well

Fig. 2 Blunt abdominal trauma with mesenteric tear suspected on CT scan. Definitive diagnosis was made laparoscopically followed by laparoscopic suture repair once vascular integrity was checked

as diffuse and unspecific symptoms, exploratory laparoscopy can be used to identify possible causes (i.e., adhesions, internal hernia secondary to mesenteric laceration, volvulus) [22, 46, 54].

5. In penetrating trauma with hemodynamic stability, the most common indications for laparoscopy are evaluation for diaphragmatic and intra-abdominal injury (e.g., free fluid of unknown source as discussed above) as well as screening for peritoneal violation in tangential stab and GSW [21, 42, 53•, 54].

As far as splenic injuries are concerned, the literature only mentions case reports of laparoscopic splenectomy and mesh splenorrhaphy; therefore, these operations are not supported by sound data [64–67]. From our point of view, splenic injuries are not an indication for laparoscopy for the following reasons: (I) stable patients with a splenic injury should undergo NOM and do not require surgery. (II) Unstable patients who remain so in spite of resuscitation require a trauma laparotomy; in these cases, laparoscopy is contraindicated. (III) Laparoscopic procedures on the spleen are usually undertaken with the patient in the right semilateral recumbent position, with the left arm fixed over the head. In trauma cases, however, this position can be counterproductive if more extensive surgeries become necessary.

The only exceptions for laparoscopy in splenic injury can be the fortuitous discovery of a minor splenic injury during laparoscopic exploration to exclude a diaphragmatic rupture or injury to the intestine or mesentery. In such cases, the concomitant splenic injury can be treated with fibrin adhesive or hemostyptic fleece. It must be emphasized that in this setting, the primary aim is not to treat the splenic injury but the other organ injuries; the splenic injury is sealed as a prophylactic measure to prevent further bleeding.

Therapeutic laparoscopy

Laparoscopy features a high therapeutic potential as several studies have reported successful interventions in blunt and penetrating trauma, thus further reducing the need for laparotomy [11] (Fig. 3a–d).

After implementation of exploratory laparoscopy for penetrating injuries, Kawahara et al. [63] reported a 73.3 % reduction in laparotomy with definitive laparoscopic repair in 22.7 % of cases. These authors proposed a standardized examination system, leading to no missed injuries with an accuracy of 98.7, 97.6 % sensitivity, and 100 % specificity. Chol et al. reported an 83 % therapeutic rate with a 3.8 % postoperative complication rate and no missed injuries [18]. In their systematic review of 51 studies on laparoscopy in penetrating injuries, O'Malley and colleagues [52] reported an overall therapeutic rate of 13.8 % (ranging from 6.7 to 100 %) with a 3.2 % missed injury rate. Diaphragmatic injuries accounted for 53.4 % of all therapeutic laparoscopies. More recently, Zafar et al. [47•] found similar results in their analysis of the US National Trauma Data Bank data on 4755 patients undergoing diagnostic laparoscopy. Interventions were therapeutic in 19.3 % of all patients and most often performed for diaphragmatic lacerations (19.2 %), gastrostomy (14.4 %), bowel repair (15.6 %) or resection (11.8 %), and splenectomy (5.2 %).

Promising results have also been reported in pediatric abdominal trauma. Marwan et al. [68] achieved a 90.5 % successful diagnostic laparoscopy rate including 23.8 % of patients undergoing to therapeutic laparoscopy. The 9.5 % missed injury rate was due to delayed intervention several days after initial presentation. Li and colleagues [69•] conducted a meta-analysis of 64 studies (5 RCTs, 16 cohort studies, 43 case series) comparing laparoscopy to laparotomy; 76 % of all included patient were successfully treated with laparoscopy. There was a significantly lower risk for postoperative complications (RR 0.37, 95 % CI 0.29–0.46; $p < 0.001$) and a reduction in perioperative mortality (RR 0.64, 95 % CI 0.52–0.80; $p < 0.001$) in patients undergoing laparoscopy. Of note, however, only five studies were randomized; therefore, a selection bias in favor of laparoscopy cannot be excluded.

Conversion rates seem to depend strongly on the policies adopted in the respective hospitals, as some centers indicate routine laparotomy while others proceed to laparoscopy in comparable patients [33, 62]. Reported rates lie between 2.1 and 45 % in penetrating [62, 70, 71] and 8.5 to 50 % in blunt trauma [33, 62]. Two recent systematic reviews [47•, 53•] reported overall conversion rates of 10.7 and 20.2 %, respectively.

Another relevant topic routinely discussed in all laparoscopic procedures is the impact on duration of hospital stay. Several studies have reported statistically significant reductions as compared to open surgery. Lin et al. [33] observed a mean hospital stay of 11.0 days in laparoscopy

Fig. 3 **a** Stab wound to the right upper quadrant; **b** view on abdomen: diagnostic laparoscopy confirmed the peritoneal penetration; **c** superficial hepatic laceration next to the gall bladder; **d** laparoscopic closure of the laceration

as compared to 17.6 days ($p < .001$) after repair for blunt HVI and mesenteric trauma. Similar results (11 vs. 21 days; $p < 0.001$) have been reported by Lee and colleagues [72]. A statistically significant reduction has also been reported in penetrating trauma (5.0 vs. 9.9 days; $p < 0.001$) [6, 70]. In their systematic review of 64 studies on blunt and penetrating trauma, Li et al. [69•] found a mean reduction in duration of hospital stay of 5.15 days (95 % CI –6.80 to 3.50; $p < 0.001$); however, adjustment for injury severity score was not performed, and hospital stays vary from country to country, according to hospital policies and cultural differences, leaving room for a potential selection bias.

Complications of Trauma Laparoscopy

Apart from the general risks related to laparoscopy (such as iatrogenic vascular and intestinal injuries), additional complications may be proper to trauma laparoscopy. First and foremost, missed injuries pose a serious risk, as delayed treatment can lead to increased morbidity and mortality. Early experiences have reported missed injury rates up to 77 % in diagnostic laparoscopy [73]. These high rates, however, have been challenged by more recent data showing that missed injury rates are currently low, ranging between 0 and 3.2 % [18, 33, 47•, 52, 53•, 63, 74].

Development of (tension-) pneumothorax in patients with diaphragmatic injury has been described [74, 75]. Although rare, a high index of suspicion should lead to correct diagnosis, if patient status deteriorates during laparoscopy for trauma without any other obvious reason. Venous gas embolism is another reported complication of laparoscopy in general [76]. Although to the best of our knowledge there have not been any reports of this complication in trauma laparoscopy, gas embolism could possibly occur especially when venous injury is present. Due to trans-peritoneal absorption of carbon dioxide elevated ICP (see above) and acidosis may occur [18, 51, 77], the latter being one proponent of the infamous “trauma triad of death” [78].

Technique

Patients should be prepared and positioned in the same way as for trauma laparotomy, allowing rapid conversion to open surgery and access to the whole trunk, whenever necessary. Surgical instruments for open surgery should be readily at hand. Furthermore, patients should be securely fixed to the operating table, as intra-operative tilting to shift the intra-abdominal organs might be necessary [18].

To minimize the risk of missed injuries, a systematic approach for evaluation of the abdomen should be used [79]. As described previously [22, 46], one possible approach for diagnostic and therapeutic laparoscopy

Fig. 4 Trocar sites for diagnostic laparoscopy. Staggering the flank trocars slightly cranial and caudal of the umbilicus enables better exploration with less instrument collision

could be the following: the initial trocar (5/10/11 mm) is inserted at the umbilicus via the open method [80•]. Pneumoperitoneum is established slowly and cautiously. After initial inspection of the abdominal cavity, two more working trocars (5–10 mm) are placed (Fig. 4).

The abdomen is evaluated for possible additional injuries, starting from the right upper quadrant, systematically in a clockwise manner. The liver, spleen, and diaphragm are evaluated with the patient in the reverse Trendelenburg position; the surgeon then inspects the splenic flexure, descending and sigmoid colons toward the pelvis, runs over to the right lower quadrant and then the cecum and ascending colon. Then, patients are positioned in the Trendelenburg position to examine the rectum, Douglas' space, bladder, and pelvic organs. The position of the omentum is shifted cranially to enable evaluation of the small bowel. Starting in the ileocecal region, the intestines are examined in the oral direction to the Treitz ligament with the assistance of two atraumatic forceps. The lesser sac may be opened to evaluate the duodenum, posterior gastric wall, and pancreas. However, this procedure is performed only when injury of these organs is suspected.

Laparoscopic treatment depends on surgeon skills and the availability of equipment. Simple lacerations may be sutured using 3/0 monofilament material. However, resection is required when larger injuries of the hollow organs are present. Continuity can be restored rapidly and safely with stapled anastomoses. Diaphragmatic injuries may be repaired depending on their size, by sutures or appropriate prosthetic materials. Hemostasis can be achieved by using coagulation, hemoclips, or sutures. Large wound surfaces and lacerations of the solid organs may be treated rapidly and effectively using

tamponade with gauze sponges and fibrin glue or with new hemostatic agents alone (e.g., Floseal®, Hemopatch®). If severe bleeding is present or adequate visualization is not possible, conversion to an open approach should not be delayed.

Conclusion

Management of abdominal trauma remains a challenging field for the trauma personnel. The ambitious goal of minimizing aggressive procedures and related morbidities has to be weighed against the potential consequences of delayed treatment of missed injuries. As a complement to NOM, laparoscopy can play an important role in diagnosis and treatment of blunt and penetrating trauma in hemodynamically stable patients. Low missed injury rates, reduced duration of hospital stay, faster recovery, and reduced cost make it an attractive and safe alternative to classical trauma laparotomy. However, as stated by Zafer et al. [47•] surgeon experience and skill as well as sufficient staffing and equipment are key factors for successful implementation of laparoscopy in routine trauma management.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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