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SURGICAL SYMPOSIUM CONTRIBUTION

Laparoscopy in Penetrating Abdominal Trauma

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Abstract If morbidity and mortality are to be reduced in patients with penetrating abdominal trauma, first priority goes to prompt and accurate determination of peritoneal penetration and identification of the need for surgery. In this setting, laparoscopy may have an important impact on the rate of negative or non-therapeutic laparotomies. We analyzed indications and patient selection criteria for laparoscopy in penetrating trauma along with outcomes. The analysis focused on identification of peritoneal penetration and injuries to the diaphragm, small intestine, and mesentery. Results from the early phase of laparoscopy were compared with those from recent decades with more advanced laparoscopic equipment and instruments and more experienced surgeons. A systematic review of the role of laparoscopy in penetrating abdominal trauma shows a sensitivity ranging from 66.7 to 100 %, specificity from 33.3 to 100 % and accuracy from 50 to 100 %. Publications from the 1990s found trauma laparoscopy to be inadequate for detecting intestinal injuries and so to lead to missed injuries. Twenty-three of the 50 studies including the most recent ones report sensitivity, specificity, and accuracy of 100 %. Laparoscopy is more cost effective than negative laparotomy. Laparoscopy can be performed safely and effectively on stable patients with penetrating abdominal trauma. The most important advantages are reduction of morbidity, accuracy in detecting diaphragmatic and intestinal injuries, and elimination of prolonged hospitalization for observation, so reducing the length of stay and increasing cost effectiveness.

Introduction

Although several diagnostic methods are available for evaluation of trauma patients, prompt recognition of intraabdominal injury still poses a significant clinical challenge, particularly in patients with diaphragmatic, mesenteric, and/or small bowel injury. The presence of free fluid in the abdomen without evidence of any organ injury also must be clarified [1, 2]. An exploratory laparotomy will often be needed in this setting; however, if performed routinely for every suspected diaphragmatic and/or small bowel injury, up to 45 % of exploratory laparotomies will be non-therapeutic [3, 4]. Non-therapeutic operations or negative laparotomies for penetrating trauma carry a significant complication rate [3, 5–7], with mortality of up to 5 % and morbidity as great as 20 % [8]. The rationale for diagnostic and therapeutic laparoscopy in trauma has evolved since it was initially proposed in the early 1970s [9, 10]. Basically, the goal of laparoscopy as a diagnostic tool is to determine the need for further surgery [11, 12]. In addition to this primary task, laparoscopy has therapeutic potential. Unfortunately, in the initial phase, when the technique was still in the developmental phase and surgeons' experience in advanced laparoscopy was low, laparoscopy came to be

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seen as unsuitable for small intestinal and retroperitoneal injuries [13, 14]. These results from the 1990s, however, are out of line with more recent experience [12, 15, 16] and now, diagnostic and therapeutic laparoscopy for blunt and penetrating abdominal injuries could reduce the rate of non-therapeutic laparotomy to 1.8 % [17]. Therapeutic laparoscopy was successful in 13.8 % of patients with abdominal injury found upon diagnostic laparoscopy [12]. The purpose of this paper is to update and evaluate the role of laparoscopy in penetrating trauma today.

Diagnosis with penetrating abdominal trauma

Following clinical examination and determination of the mechanism of injury, radio-diagnostic tests will be ordered for rapid and accurate identification of injuries and any indication for surgery. Ultrasound and computed tomography are the imaging modalities of choice in penetrating trauma [18].

Ultrasound can be performed in the emergency room with hand-held scanners, usually by general or trauma surgeons. The Focused Assessment for the Sonographic Examination of the Trauma Patient (FAST) protocol is intended to determine the presence of free fluid in the abdominal cavity and assess its quantity and location [19]. With portable equipment, ultrasound can be also performed on hypotensive patients simultaneously with ongoing resuscitation and can be done at the bedside without moving the patient. Rozycki et al. achieved a sensitivity of 83.3 % and specificity of 99.7 % in 1,540 patients with blunt and penetrating injuries [20].

CT is non-invasive and operator independent; in hemodynamically stable patients, it can provide valuable supplemental information on the size, number, and extent of pathological changes. The findings can be determined precisely and reproducibly as opposed to ultrasound, which require interpretation by an experienced sonographer. CT has 97 % sensitivity, 98 % specificity, and 98 % accuracy for peritoneal violation [21]. In detecting bowel injury, CT has an overall sensitivity of 94, and 96 % in detecting mesenteric injury [22].

Both ultrasound and CT have limitations for diagnosing injuries to the diaphragm: Mihos et al. [23] achieved a correct preoperative diagnosis in only 26 % of 65 patients with a diaphragmatic injury, and for the remaining 74 %, the diagnosis was made during the operation.

Laparoscopy

Although ultrasound and computed tomography provide high quality information, there is still a degree of diagnostic uncertainty, especially when the diaphragm, gastrointestinal tract and pancreas are involved. The considerable number of unnecessary exploratory laparotomies increases morbidity rates.

The literature shows that a variety of laparoscopic techniques can produce good results with abdominal trauma. In a review by Villavicencio and Ancar [24], in nine prospective series, screening laparoscopy for penetrating trauma showed sensitivity of 85–100 %, specificity of 73–100 %, and accuracy of 80–100 % with only two procedure-related complications among 543 patients. Diagnostic laparoscopy for penetrating trauma had a sensitivity of 80–100 %, specificity 38–86 %, and accuracy of 54–89 % [24]. The rate of missed injuries at laparoscopy was 0.4 % (6 of 1,708 patients). The rate of laparoscopy-related complications was 1.3 % (22 of 1,672 patients). Laparoscopy may avoid laparotomy in 63 % of patients presenting with a variety of injuries [24]. The laparoscopic approach decreased non-therapeutic laparotomies in abdominal stab wounds from 57.9 to 0 %, and the accuracy of diagnostic laparoscopy was 100 % [11]. In the same study, laparoscopy was successfully performed in 94.1 % of patients with significant intraabdominal injuries [11]. A systematic review on the role of laparoscopy in penetrating abdominal trauma showed sensitivity ranging from 66.7 to 100 %, specificity from 33.3 to 100 % and accuracy from 50 to 100 %. Twenty-three of the 50 studies including the most recent ones reported sensitivity, specificity, and accuracy of 100 % [12]. The various diagnostic options and their value are summarized in Table 1 [25]. Laparoscopy is cost effective when compared with negative laparotomy [13]. Thanks to laparoscopy, laparotomy was avoided in 13 of 21 (62 %) pediatric patients with abdominal trauma and in the 10 of them with penetrating trauma (100 %, $p = 0.02$) [26].

Selection of patients

Patients should only undergo laparoscopy when an urgent trauma laparotomy is not indicated and findings are unclear. Patients with penetrating trauma who are potential candidates for laparoscopy must be hemodynamically stable. Those who become stable relatively quickly during the resuscitation process and remain so can also qualify for laparoscopy.

Laparoscopy candidates frequently first have a CT with the aim of increasing accuracy, reducing the rate of missed injuries, and preventing unnecessary surgeries. If any diagnostic and therapeutic uncertainty still remains, then laparoscopy is an alternative to exploratory laparotomy.

Table 1 Options for evaluation in penetrating abdominal trauma [25]

	PE	LWE	DPL	FAST	CT scan	Laparoscopy	Laparotomy
Sensitivity (%) (for therapeutic intervention)	95–97	71	87–100	46–85	97	50–100	–
Specificity (%)	100	77	52–89	48–95	98	74–90	–
NPV (%)	92	79	78–100	60–98	98	100	–
Requires awake, cooperative patient	+	–	–	–	–	–	–
Invasive	–	+	+	–	–	+	++
Requires admission	+	+/–	–	–	–	+	+
Evaluates retroperitoneum	+/–	–	–	–	+	–	+
High clinical workload	+	–	–	–	–	+/–	+/–
Complication rate	–	+	+/–	–	–	+	++

PE physical exam, *LWE* local wound exploration, *DPL* diagnostic peritoneal lavage

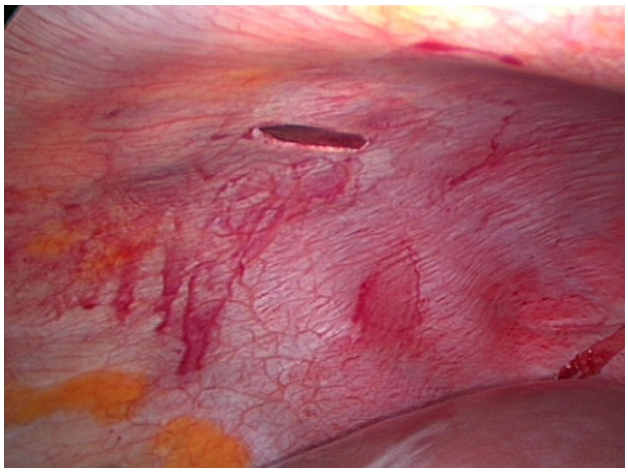

Fig. 1 Laparoscopic view of a stab wound with significant bleeding from the abdominal wall

Indications for laparoscopy

In penetrating trauma, laparoscopy can be used for screening, diagnosis, and treatment. The main emphasis is on diagnosis of peritoneal penetration and injuries to the diaphragm, hollow viscus and mesentery. There is considerable therapeutic potential with certain subgroups, assuming a surgeon with expertise in advanced laparoscopy [12]. The most common indications for laparoscopy in penetrating abdominal trauma may be summarized as follows:

Stab wound: stable patient, CT with intraabdominal free fluid from unclear source

Patients who have free fluid in the peritoneal cavity after penetrating abdominal trauma, but in whom the source of bleeding cannot be determined, should undergo a diagnostic intervention, preferably laparoscopy. When nonoperative management has been chosen but the amount of free fluid increases or abdominal symptoms become more pronounced, an exploratory laparoscopy or laparotomy may be indicated. In these cases, the source of bleeding might be the abdominal wall (Fig. 1), though it could also be a mesenteric laceration or an injury to the GI tract that a CT scan can often miss. This selected case shows a hole in the anterior gastric wall with injury to the vessels of the lesser curvature not diagnosed by CT (Fig. 2a, b).

Stab wound: stable patient, CT with a small amount of free fluid and suspected intestinal injury

When an intestinal laceration is suspected with penetrating abdominal trauma, laparoscopy can provide a secure diagnosis with the therapeutic potential to oversew the laceration or resect injured tissue (Fig. 3a, b).

Stab injury to a solid organ: stable patient, CT with a significant amount of free fluid, unclear bleeding status—ongoing or stopped spontaneously?

When CT has shown one or more hepatic or splenic lacerations, but it is unclear whether the bleeding is ongoing, laparoscopy can visualize the injury and explore for other organ injuries, so that appropriate surgical measures can be taken (Fig. 4a, b).

Unclear abdomen after trauma

The term "unclear abdomen" indicates a discrepancy between the findings of imaging studies and clinical examination. Laparoscopy can quickly clarify such situations and may also provide a therapeutic option.

Penetrating trauma: stable patient, CT is suspicious for diaphragmatic laceration

There is an increased advantage with diagonal thoracoabdominal stab or gunshot wounds in the flank as a CT

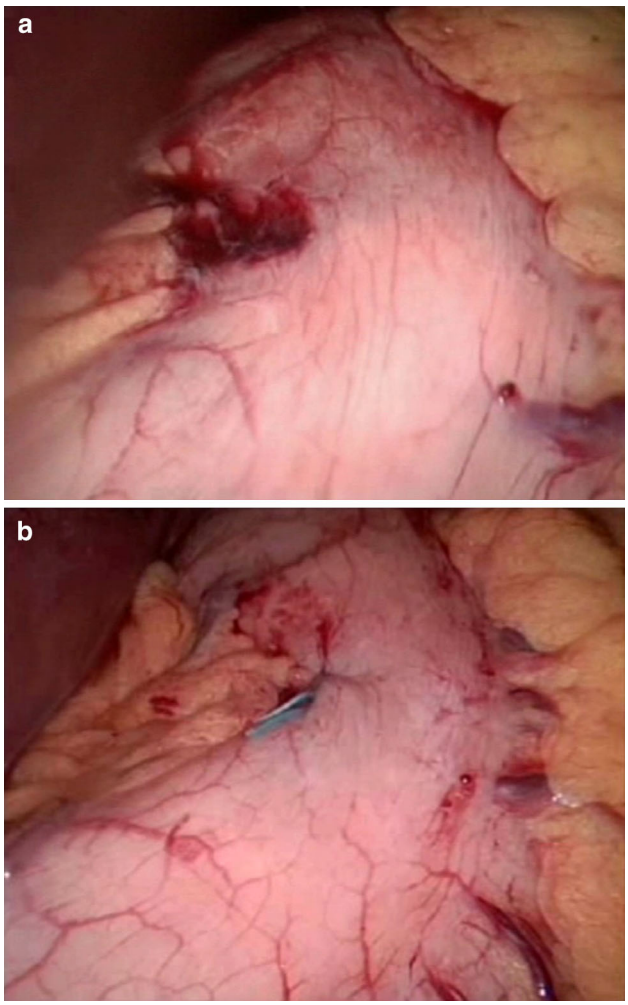

Fig. 2 **a** Stab wound of the gastric wall not detected with CT. **b** Laparoscopic closure of the hole shown in **a**

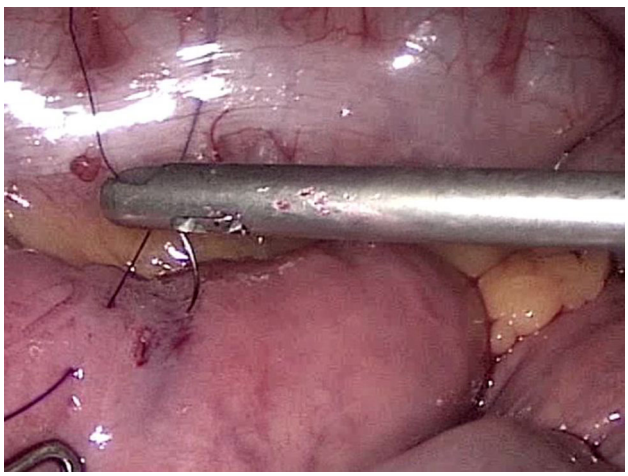

Fig. 3 Laparoscopic closure of a stab injury of the small bowel not detected with CT

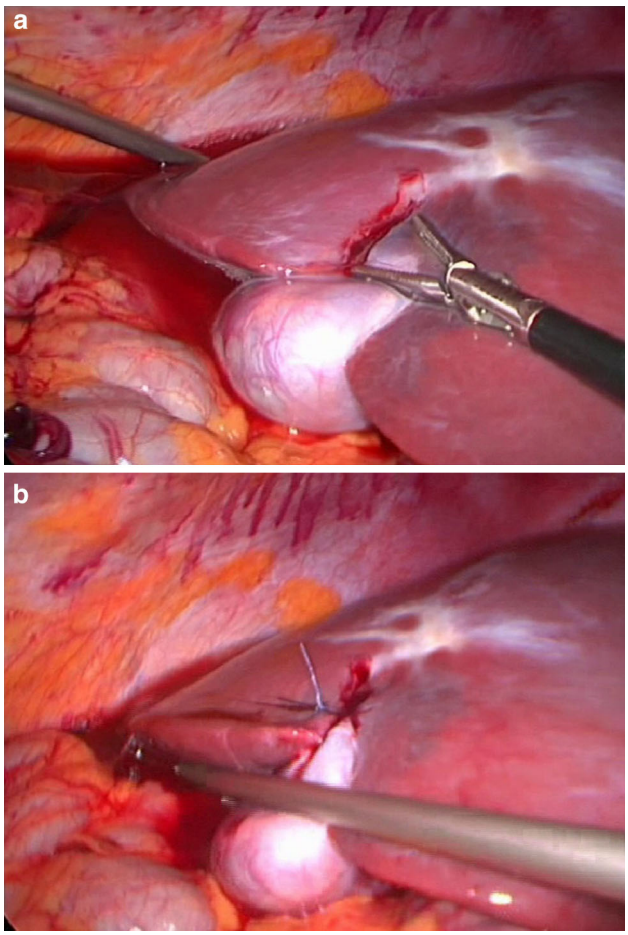

Fig. 4 **a** Laparoscopic presentation of a stab injury of the liver with ongoing bleeding. **b** Suturing the liver injury to stop the bleeding

diagnosis may miss an injury to the diaphragm. In these cases, the wound can be explored laparoscopically or thoracoscopically to determine whether laparotomy, thoracotomy, or a minimal access procedure is indicated (Fig. 5a, b).

How to perform laparoscopy in trauma

The positioning and preparation of the patient for trauma laparoscopy are essentially the same as for a trauma laparotomy. Conversion should be possible without delay or additional preparation. The patient should be securely fixed on all sides so that the operating table can be turned to shift the abdominal organs in whatever directions are needed. The first trocar is 10/11 mm and will usually be inserted with open technique at the navel (Fig. 6).

After a preliminary inspection of the abdominal cavity, two more trocars are introduced on both flanks (Fig. 7).

The abdomen is explored systematically, beginning with the right upper quadrant and proceeding clockwise. A Cell Saver® helps to reduce transfusions. While the liver and

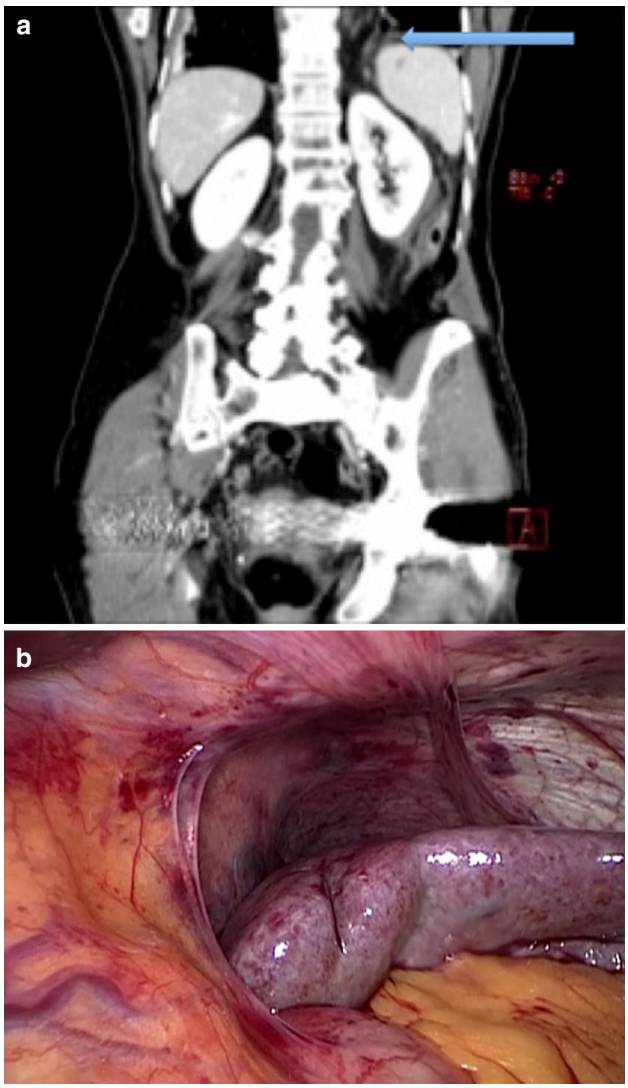

Fig. 5 **a** CT suspicious for left-sided diaphragmatic injury and a small lesion of the splenic pole. **b** Laparoscopic view of the diaphragm excluding a diaphragmatic rupture but confirming the splenic injury that was treated with fibrin glue and collagen fleece

spleen are being examined in reverse Trendelenburg position, even the most remote parts of the diaphragm can be seen much better laparoscopically than with open technique (Fig. 5b).

After the upper abdominal organs have been examined, the left flank with the left flexure, descending colon, and sigmoid are checked for injuries down to the left lower quadrant. The patient is placed in the Trendelenburg position for examination of the rectum, Douglas' space, urinary bladder, and, in women, the internal genital organs. The examination is continued in the right lower quadrant with the cecum and right hemicolon. The omentum is shifted cranially so that the small intestine can be examined. Two atraumatic grasping forceps are used to follow the small intestine from the ileocecal region in the oral

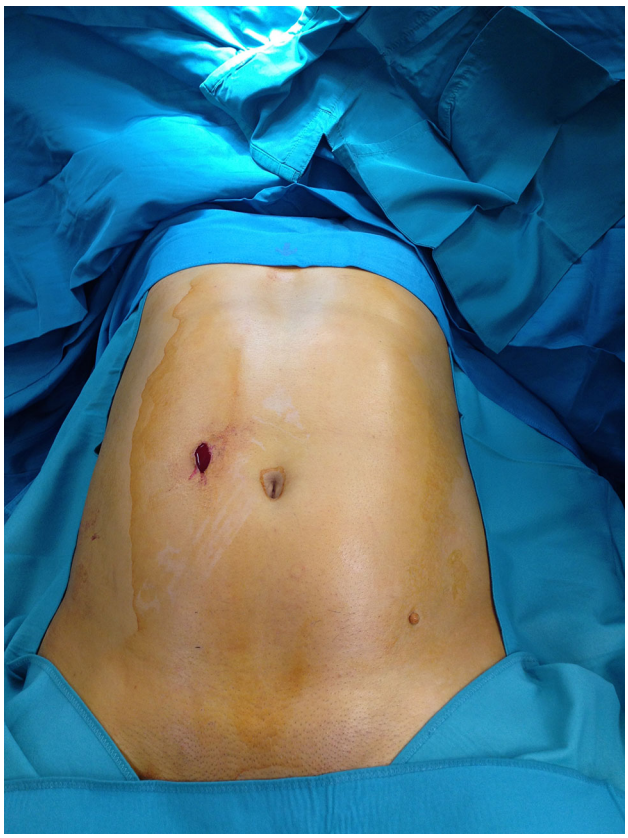

Fig. 6 Stab wounded patient's position on the operating table for trauma laparoscopy suitable for conversion anytime

direction to the duodenal-jejunal flexure. The lesser sac may be opened to explore the duodenum, posterior gastric wall, and pancreas, but this is only indicated when injury to these organs is suspected.

Treatment will depend on the equipment available and the surgeon's expertise. Simple lacerations can be sutured with monofilament 3/0 stitches but larger injuries to the hollow viscus should be resected. Continuity can be established quickly and safely with a stapled anastomosis. Injuries to the diaphragm can be dealt with laparoscopically with sutures or suitable polytetrafluoroethylene (PTFE) prosthetic material. In stable patients, sources of bleeding, small vessels and vessels that have ceased bleeding can be coagulated or sutured. Large wound surfaces and lacerations of solid organs can be quickly and effectively sealed laparoscopically with fibrin glue and tamponaded in combination with a fleece or with a new hemostatic agent (Floseal®, Hemopatch) alone (Fig. 8). Laparoscopy is not indicated with profuse bleeding.

Trauma laparoscopy can be complicated by extensive adhesions. In such cases, adhesiolysis should be limited on the basis of CT findings to the suspicious area. Extensive laparoscopic adhesiolysis can take more time than with the open technique and entail higher morbidity.

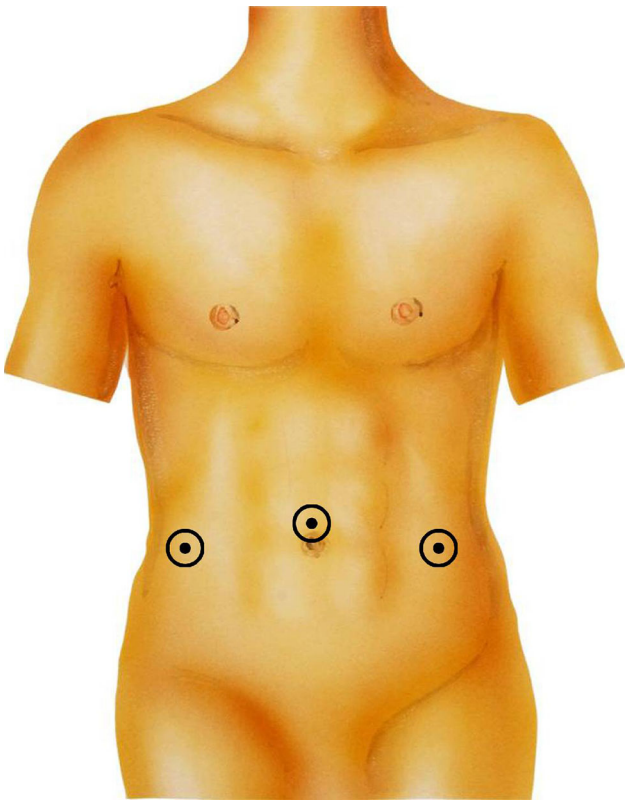

Fig. 7 Trocar positions for explorative laparoscopy

The risks of laparoscopy in trauma

Laparoscopy in penetrating abdominal trauma entails two risks, which, in order of their frequency and importance, are as follows:

(1) missed injuries
(2) laparoscopy-related complications

A recent systematic review showed that missed injuries with 3.2 % (83 in 2,563 patients) are the most common problem and probably pose the most serious risk [12]. Trauma surgeons experienced in advanced laparoscopy rarely have procedure-related complications and the reported rate lies between 0 and 2.8 % [12, 27].

Discussion

There is as yet no consensus as to the optimal procedure with penetrating abdominal trauma. Exploratory laparotomy was long standard in these cases, but routine laparotomy is unnecessary in nearly half of hemodynamically stable patients [3, 4] and is associated with significant morbidity [7]. Hemodynamic instability, physical signs of acute peritonitis or diffuse abdominal tenderness, however, require an immediate laparotomy, irrespective of the extent

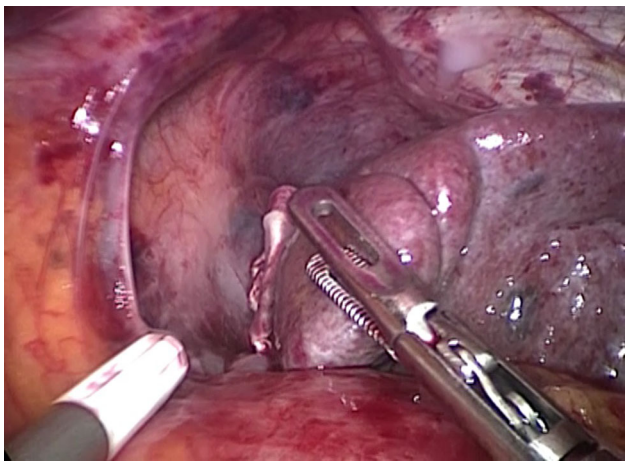

Fig. 8 Laparoscopic treatment of a splenic lesion using fibrin glue and collagen fleece

and location of the penetrating wound. With stable patients with anterior abdominal stab wounds (AASW), however, Biffl et al. propose a selective procedure for non-operative management [28]. In a prospective study with 222 patients, 160 of whom were stable and asymptomatic, 81 (51 %) were treated according to the study protocol and of these patients 20 (25 %) could be discharged after routine wound exploration. According to the Western Trauma Association algorithm, serial clinical assessments can avoid the added expense of CT, DPL, or laparoscopy [4]. Based on these and similar results from other, mostly in high volume centers, the rate of selective, non-operative management (SNOM) for penetrating abdominal injuries is increasing, but when SNOM fails, it might be associated with higher mortality. Careful patient selection and adherence to protocols designed to decrease the failure rate of SNOM are recommended [29]. In contrast, most European trauma centers have fewer penetrating injuries and exploratory laparoscopy will frequently be preferred to local wound exploration, especially when the radiological assessment shows free fluid in the abdominal cavity, and the patient is stable [16]. The main advantage of immediate laparoscopy is that even very small injuries can be identified and treated promptly. This proactive approach avoids the time lapse inherit with serial clinical assessments, where serious deterioration may have occurred by the time it becomes clinically evident.

With penetrating trauma, one of the strengths of laparoscopy is that it allows assessment of peritoneal penetration. This is particularly advantageous with lower chest injuries, tangential upper abdominal and flank stab wounds and tangential entry and exit gunshot wounds without diffuse peritoneal signs or hemodynamic instability [27, 30, 31]. Imaging techniques are reliable for diagnosing intraabdominal injuries, but not for peritoneal penetration,

and they are too vague with injuries to the diaphragm, GI tract and mesentery. As with CT one important limitation or basic prerequisite for laparoscopy is hemodynamic stability.

Although some authors find that laparoscopy is inadequate for detecting intestinal injuries [14, 32], other newer publications, including ours, do not report any missed injuries [11, 15, 26, 27, 30, 31, 33]. Although it is theoretically possible, gas embolism has not yet been reported in trauma patients with intraabdominal venous injuries.

Laparoscopy also offers therapeutic possibilities: wounds to the diaphragm can be sutured, stapled, or covered with prosthetic mesh laparoscopically [17, 30]. Further potential applications are exploration of the intestinal track by running of the whole bowel [30], and closure of gastrointestinal perforations as well as securing hemostasis of low grade liver and splenic lacerations, either by simple sutures, tamponade or with sealants [15, 16, 30].

Identifying the benefits and risks of laparoscopy in the trauma setting will help to define indications for it. Since laparoscopy offers more precise diagnosis of peritoneal penetration and is as good as open surgery for exploring the abdominal cavity, its main advantage is reduction of the rate of non-therapeutic, negative laparotomies and, as a consequence, shorter hospital stay. The major risk of using laparoscopy in trauma care is the potential delay in definitive treatment. Laparoscopy also entails a potential risk of missed injuries and, of course, procedure-related complications.

A variety of diagnostic methods allow the surgeon to make the right decision at the right time. That decision depends on a number of factors, including the surgeon's competence, the infrastructure available, the experience of the entire surgical team, the trauma patient load at the time, and personnel reserves. The question is also whether advanced laparoscopy is routinely used and how many such procedures are performed by the members of the trauma team in an elective setting. In the best case, all the members of the team will have a minimum of competence in laparoscopic procedures so that the treatment algorithm can be followed with the same effectiveness regardless of the composition of the team.

In summary, laparoscopy can be performed safely and effectively in stable patients with penetrating abdominal trauma. The most important advantages are avoidance of both missed injuries and negative and non-therapeutic laparotomies, as well as reduction of morbidity and the observation period, both of which shorten the hospital stay and increase cost effectiveness.

Future new developments in laparoscopy equipment and increased competence in advanced laparoscopic techniques can be expected to have a decisive influence on the treatment of trauma patients.

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