Background:

Trauma surgeons must know which patients require an exploratory laparotomy, when one must be performed urgently, and the key principles of the procedure itself.

The indications for an exploratory laparotomy vary slightly depending on whether the patient presents after a blunt or penetrating mechanism. Hemodynamic instability in the setting of a positive focused assessment sonography of trauma (FAST) exam is a common indication. A positive FAST exam often indicates the presence of blood, enteral contents, or urine in the peritoneal cavity, all of which require surgical exploration. If the patient is hemodynamically stable and undergoes a computed tomography (CT) scan where free fluid is identified, a clinical assessment must be made to determine its source. Patients with a concomitant solid organ injury who remain hemodynamically stable can be observed, as the fluid is likely to be blood. The suspicion for either a hollow viscus or bladder injury arises when there is no concomitant solid organ injury, in which case the patient will require intervention. These patients may also exhibit peritonitis on physical examination, which is another indication for surgical exploration.

The classic indications for an exploratory penetrating laparotomy in trauma include hemodynamic instability, transabdominal а trajectory, peritonitis, and/or evisceration of intestinal contents.^{1,2} A CT scan can be obtained if there is uncertainty about the trajectory. Gunshot wounds can be managed nonoperatively if confined to the liver, the patient remains hemodynamically stable, and there is no evidence on CT of another potential intraabdominal injury. Similarly, patients with anterior abdominal stab wounds with peritoneal violation can be observed with routine physical examinations if they remain hemodynamically stable and do not exhibit peritonitis. However, the abdominal examination can be difficult to interpret if the patient is altered or intubated and if performed by different individuals, which may lower the threshold for surgical exploration. See Approach to Penetrating Abdominal Trauma.

Diagnostic laparoscopy may be considered in select individuals. It is a helpful adjunct when there is a question of peritoneal violation, to assess for a hollow viscus and/or mesenteric injury, or to examine the diaphragm after penetrating trauma. The patient must be hemodynamically stable, as they are unlikely to tolerate hemodynamic changes with peritoneal insufflation.

Once the decision has been made to proceed with surgical exploration, the operating room must be notified promptly to make arrangements. This is especially imperative if the patient is in hemorrhagic shock, as delays in hemorrhage control can result in further morbidity and mortality. Blood products should be readily available, and activation of the massive transfusion protocol should be considered.

Since time is of the essence, equipment should be gathered while the patient is being transported to the operating room. In addition to the exploratory laparotomy tray, the trauma surgeon should request a self-retaining retractor, a vascular instrument set, 3-0 silk sutures, 0 and 2-0 silk ties, and an electrocautery. An electrothermal vessel sealing system device may be considered, along with a cell saver, if available. The cell saver is an autologous blood recovery system that recycles blood from the patient, filters to remove debris, and centrifuges the blood to be transfused back into the patient.

The surgeon must also be aware of the principles of damage control surgery and when to apply them. Damage control surgery is an operation abbreviated aimed at controlling optimize hemorrhage and contamination to resuscitation efforts and correct any ongoing coagulopathy, hypothermia, and metabolic disturbances, including metabolic acidosis.³ A damage control approach should be considered if the patient remains coagulopathic after surgical hemorrhage control has been achieved and bowel contamination has been addressed, or if the patient is hypothermic or acidotic. Patients with injuries requiring complex reconstruction may also be left open. Understanding which patients are appropriate candidates for damage control surgery is imperative,



as inappropriate use of damage control surgery can result in difficult abdominal closures, hernias, fistulas, and long-term morbidity.

We will now describe the fundamental steps of a trauma laparotomy, which include:

- Entering the peritoneal cavity through a midline incision
- Packing for hemorrhage control if the patient is hypotensive
- Systematically evaluating injuries while controlling contamination
- Considering leaving the abdomen open if damage control surgery is appropriate

Steps:

- 1. Ensure that the room is warm and that the proper equipment is available.
- 2. Discuss resuscitation strategies with the anesthesia team, including balanced transfusions, limiting crystalloids, and recognizing and correcting coagulation and metabolic derangements. See <u>Airway Management in Trauma</u>.
- 3. If a urinary Foley catheter has not already been inserted, it should be placed in addition to an orogastric or nasogastric tube.
- 4. The patient is placed in <u>supine position</u> with both arms extended and abducted at 90 degrees. The side rails of the operating room table should be cleared and exposed so that posts for a selfretaining retractor can be easily placed.
- 5. The patient can be placed in a modified lithotomy position if there is a concern for a rectal injury so that a rigid proctoscopy can be performed to further characterize the injury.
- 6. The skin should be prepared from the chin to the knees, including the chest, as there may be a concomitant thoracic injury that requires operative intervention or a severe intraabdominal injury that necessitates entry into the chest for repair or cross-clamping of the descending thoracic aorta. The lower extremities are included, as the saphenous vein may need to be harvested if a vascular injury is identified. The

Foley catheter can be prepped in the field if there is a concern for a bladder injury.

7. A <u>midline laparotomy incision</u> is created using a #10 blade starting from the xiphoid process. The incision is classically extended toward the pubic symphysis. It may terminate half-way between the umbilicus and the symphysis pubis if preperitoneal pelvic packing placement through a separate incision is needed. See <u>Preperitoneal Packing for Pelvic Trauma Hemorrhage</u>.



Upper extent of midline laparotomy. To gain an extra 2cm of access, extend your fascial incision to one side of the xiphoid process (Black arrow).

- 8. The dissection is carried through the skin, subcutaneous tissue, and linea alba. The peritoneum is then entered carefully to avoid damage to the underlying bowel.
- 9. If the patient is in hemorrhagic shock, quickly pack the abdomen in all four quadrants and pelvis.
- 10. After hemorrhage control has been temporarily achieved, allow the anesthesia team to "catch up" with resuscitation.
- 11. The falciform ligament should be divided and tied off with 0 silk ties. This is done because any additional retraction of the falciform ligament could result in an iatrogenic liver injury.
- 12. A self-retaining retractor can be placed to improve visualization.

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- 13. The abdomen should be quickly surveyed to identify any obvious sources of bleeding. Bleeding from the mesentery can be controlled promptly with silk sutures. Inspect and palpate both the liver and the spleen. Bleeding from the liver and/or spleen can be temporarily controlled with packing.
- 14. If the patient continues to exsanguinate and the aorta has not already been occluded, the gastrohepatic ligament can be incised, the stomach and esophagus can be retracted laterally, and the left diaphragmatic crus can be divided to expose and clamp the aorta. Alternatively, a sponge stick can be placed on the aorta at this location or a left anterolateral thoracotomy is performed to cross-clamp the abdominal aorta. If available, Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) is an alternative if femoral access can be achieved.



Relationship between the aorta at the diaphragmatic hiatus, the lesser curvature of the stomach, and the left and caudate lobes of the liver. The aorta can be quickly accessed, for clamping or pressure, by incising the gastrohepatic ligament, retracting the proximal stomach to the left, and retracting the liver to the right.



The gastrohepatic ligament is incised, and the stomach and esophagus are displaced to the left to expose the diaphragmatic hiatus.

- 15. The small bowel is eviscerated through the incision. To encapsulate the small bowel contents, a warm, soaked towel can help.
- 16. Proceed with a systematic assessment of the retroperitoneum and note any hematomas. All hematomas in penetrating trauma should be explored. The decision to explore retroperitoneal hematomas in blunt trauma is nuanced. All Zone I hematomas (central-retroperitoneal hematomas) must be explored in blunt trauma, as a major vascular injury is likely present. Zone II hematomas (in the peri-nephric area bilaterally) should only be explored if there is pulsatile bleeding or an expanding hematoma during the operation. A stable Zone III hematoma (pelvic region) in the presence of a pelvic fracture should be observed and addressed post-operatively by angiography and possible embolization if an arterial bleeding is identified. Expanding or ruptured hematomas in hemodynamically unstable patients in the setting of blunt trauma may require operative intervention, particularly in the absence of a pelvic fracture. In the presence of a pelvic fracture, preperitoneal pelvic packing through a separate midline or lower abdominal transverse incision may provide temporary control of bleeding.





The retroperitoneum is conceptually divided into three zones: Zone 1, Central, further subdivided into "Supramesocolic" and "Inframesocolic" sections, contains the aorta, vena cava, and mesenteric vessels. Zone 2, lateral, contains the kidneys. Zone 3 includes the pelvis. Source: https://doi.org/10.1016/j.tcr.2021.100561

17. Zone I hematomas and a left-sided Zone II hematoma are explored after performing a left medial visceral rotation, the "Mattox maneuver." The splenorenal ligament is divided, and the lateral retroperitoneal attachments of the descending colon ("White Line of Toldt") are taken down from the splenic flexure to the sigmoid colon. If the surgeon is in the correct plane, they will encounter an avascular space between the colon and the underlying structures. The left colon, spleen, and pancreas are mobilized to the midline. Mobilization of the kidney is optional and depends on the location of the injury. This exposure allows the surgeon to assess the aorta, celiac axis, superior mesenteric vessels, left kidney, iliac vessels, and the left ureter.



Left medial visceral rotation, the Mattox Maneuver. Incise the lateral peritoneal attachments of the descending colon and bluntly dissect the avascular plane here, allowing you to mobilize the colon and mesentery the spleen and pancreas off of the retroperitoneum. The kidney can be left in place or rotated medially as well, depending on which part of the aorta you need to access.

Source: <u>https://doi.org/10.5090/kjtcs.2015.48.5.371</u>



The Mattox maneuver requires mobilization of the colon, spleen, and the tail of pancreas. With this maneuver, the surgeon can visualize the aorta and its branches. Here, the aorta is seen surrounded by dense connective tissue after a medial visceral rotation has been performed. The patient's head is to the right of this photo.

18. If the decision is made to explore a right-sided Zone II hematoma, perform a right medial

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visceral rotation, the "Cattell-Braasch maneuver." The first step is to take down the lateral retroperitoneal attachments of the right colon ("White Line of Toldt") from the hepatic flexure of the colon down to the cecum and distal ileum. The colon and small bowel are mobilized to the left of the abdomen and eventually exteriorized through the midline incision. The Cattell-Braasch maneuver allows exposure of the inferior vena cava, right kidney, ureter, and right iliac vessels. Mobilizing the hepatic flexure and performing a Kocher maneuver exposes the duodenum, the head of the pancreas, and the juxta-renal portion of the inferior vena cava.



Right medial visceral rotation, the Cattell-Braasch maneuver. The peritoneum is incised from the second portion of the duodenum to the lateral border of the ascending colon, and then along the base of the small bowel mesentery from the cecum to the retroperitoneal attachment of the proximal jejunum. All of the small bowel and ascending colon can then be lifted towards the patient's head, exposing the right retroperitoneum and its structures.

Source: <u>https://doi.org/10.1186/s12893-021-01338-5</u>



The ureter, which is displaced medially, and a part of the inferior vena cava are visualized after a Cattell-Braasch maneuver. The patient's head is to the left of this photo.



Medial reflection of the duodenum and head of pancreas ("Kocher maneuver") provides better visualization of these structures.

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- 19. Next, the surgeon should systematically assess the remaining contents of the peritoneal cavity. First, the anterior aspect of the stomach is examined.
- 20. Next, the posterior aspect of the stomach and the pancreas are visualized by entering the lesser sac, which is done by dividing the gastrocolic ligament.



Pull the stomach cranially and the transverse colon caudally, and divide the tissue that separates them, the gastrocolic ligament, as shown by the Black dotted line. Several vessels cross this incision transversely, they should be ligated unless the patient is in extremis, in which case their bleeding is of little consequence. Source: Dr. Johannes Sobotta, Public domain, via Wikimedia Commons



Division of the gastrocolic ligament and lifting the stomach allows entry into the lesser sac and visualization of the pancreas.

21. The transverse colon is lifted cephalad, and the ligament of Treitz and proximal jejunum are identified. The surgeon and the assistant then proceed to identify any small bowel or mesenteric injuries. A Babcock clamp can be used to contain any bowel contamination before definitive repair or resection is performed. Hematomas in the small bowel should be explored as there may be an underlying full-thickness injury.





The transverse colon is lifted cephalad to expose the ligament of Treitz and the proximal jejunum.

- 22. The large bowel is examined from the ileocecal valve to the rectum. Hematomas in the large bowel are similarly explored. A rigid proctoscopy can be performed if there is a concern for an extraperitoneal rectal injury.
- 23. The remaining solid organs, including the liver, spleen, and both kidneys, are palpated and inspected. The bladder and diaphragm should also be assessed in a similar fashion.
- 24. The surgeon must now decide whether the identified injuries should be repaired definitively or whether a damage control approach is more appropriate.
- 25. If the surgeon chooses to leave the abdomen open, a commercially available negative pressure device can be placed. First, place the fenestrated visceral protective layer over the abdominal viscera. Next, tuck the edges of this layer circumferentially between the abdominal wall and the abdominal contents. The foam dressing is

then cut to size and placed above the fenestrated layer at the subcutaneous tissue level. The surgeon can secure the foam dressing to the skin using a stapler. An overlying adhesive layer is applied, and a defect is created through the adhesive layer so the tubing can be attached. The machine is typically set to a pressure of -125 mmHg, but this is at the surgeon's discretion.



The ABTheraTM negative pressure system is a commercially available device for temporary abdominal closure. Source: <u>https://doi.org/10.1186/1745-6215-14-141</u>

- 26. A surgeon may fashion a temporary abdominal closure if a commercial device is not readily available. Please see <u>Temporary Abdominal</u> <u>Closure</u> for further details.
- 27. If the surgeon elects to close the abdomen instead, a few measures should be taken before proceeding. Drains can be placed at this time, and the orogastric tube can be switched to a nasogastric tube if prolonged gastric decompression is required. A postpyloric feeding tube can be placed and confirmed with palpation if it is determined that the patient needs distal feeding access.
- 28. Next, the fascia is closed primarily with an absorbable suture, such as a #1 PDS. Figure-of-eight internal retention sutures, supplementing the running closure every 3-5cm, should be strongly considered in patients with a history of laparotomy, as these patients may be at risk for fascial dehiscence.

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29. The skin can be approximated with staples. One may consider leaving the skin open if there is significant bowel contamination,⁴ however, newer evidence suggests this may be unnecessary.⁵

Pitfalls

- Not prepping widely enough: A surgeon may need to enter the thoracic cavity or harvest a saphenous vein. The trauma surgeon does not have the luxury of knowing the type of injuries they will encounter before starting the operation!
- Poor communication with the anesthesia team: Intraoperative decision-making is often guided by the patient's hemodynamics. Additionally, what happens above the curtain is just as important as what happens below the curtain.
- Not making the incision large enough: inexperienced surgeons often struggle with obtaining the appropriate exposure. Extending the incision to allow for better visualization goes a long way.
- Liberal application of damage control surgery: It can be difficult to close an abdomen that has remained open due to loss of abdominal domain, particularly after aggressive resuscitation. These patients are more likely to develop hernias and fistulas and are more likely to dehisce in the event that fascial closure has been achieved. An experienced surgeon will often recognize a situation that calls for damage control even before surgery begins, and notify the team appropriately.

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