Trauma laparotomy and damage control surgery

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Abstract

Abdominal trauma can result in multiple different injuries affecting a number of organs. Early recognition and management of these injuries will improve patient survival and morbidity. Appropriate intervention involves the use of either definitive or damage control surgery for both haemorrhage and peritonitis. This article discusses the different mechanisms of injury, early assessment and investigations. It goes on to highlight the features of a trauma laparotomy, its preparation, management and the systematic approach for damage control surgery. The main abdominal organs are outlined in more detail to describe the individual approach to them in trauma.

Keywords Abdominal trauma; damage control surgery; haemorrhage; laparotomy; pelvic trauma; peritonitis; trauma; trauma laparotomy

Background

Trauma laparotomy (TL)

The TL is frequently used for patients presenting with severe abdominopelvic injuries. It involves a series of methodical steps that can enable a surgeon to gain access to these injuries internally, identify them and address them. Each TL is unique as the steps become priority-driven according to the different injuries found, the precedence of each injury and the overall stability of the patient.

This article provides an overview of TL – it is not possible to describe every possible aspect to equip you to become a fully-fledged trauma surgeon. There is clearly no substitute to experiencing the real-life situation, but the theory described should work as a useful adjunct to the practical experience in your training. There is no one way of doing things during a TL, and this article merely offers a guide to what we deem the most suitable to maintain adhering to the universally accepted key principles.

We describe a logical sequence of steps for efficient preparation and access to equipment as well as the stages to safely enter and assess the patient's abdomen. The TL is described with specific manoeuvres to identify and treat injuries that are otherwise missed. We outline the individual organs with their common patterns of injury and management.

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Alternative interventions

As techniques evolve, it is also important to consider alternatives to laparotomy with the ever-expanding availability and successful application of interventional radiology. Laparoscopy is also increasingly popular in trauma for the stable patient and carries valuable diagnostic power and, at times, therapeutic options. It can reduce the sequelae associated with a 'negative' TL, but it must be used cautiously in select individuals.[1] One should have acute awareness of its limitations and associated risks for a trauma patient and be willing to convert to a laparotomy if indicated.

Decision for TL should be made in a multidisciplinary fashion and this is particularly important in the patient with polytrauma. This chapter focuses on abdominal and pelvic trauma, but clearly, there must be consideration to the other major compartments. Indeed, the need for surgery outside the abdomen for other injuries such as a combined thoracotomy or fixation of fractures need judicious coordination and the communication with other specialists is paramount. There is no point spending time repairing bowel, while ignoring significant life-threatening injuries outside the abdomen.

Damage control surgery

The abdomen provides particular challenges in trauma because surgery is also indicated for peritonitis. The primary objective in every TL is to achieve haemostasis. In an abdomen with multiple injuries it is possible to lose focus of this and be distracted by other less important issues.

The secondary objectives are to focus on reconstructing anatomy and ensuring the abdomen is decontaminated. Achieving this may involve temporary measures and techniques rather than definitive surgery. This chapter maintains a running theme regarding the concept of damage control surgery (DCS), which is widely used and accepts that the patient will need at least one further operation at a later stage. It contributes to reducing the primary operating time, prevention of any irreversible physiological insult and facilitates recovery in the intensive care unit. It is also used when a planned relook laparotomy is required when there is uncertainty of an organ's viability. The definitive surgical procedure may need to be performed by an expert in the field or at another centre.

The surgeon

Once the decision for a laparotomy is made, the actions of the surgeon take a dynamic pathway governed by the ever-changing physiological status of the patient and the injuries encountered. The book *Top Knife*[2] describes the surgeon as requiring a three-dimensional set of skills to tackle the adversities faced in theatre. The first is employing experienced tactics to perform individual tasks such as identifying and stopping bleeding. The second is to pay attention to the 'big picture' and control the strategic dimension of the operation by considering targeted goals, the means to achieve those goals and possible alternatives. The third is the team dimension that requires good leadership and clear communication. This is mainly between the scrub team and anaesthetists in the theatre that will enable coordination and

focus on the same goals. Poor communication and leadership are perhaps the biggest threats to a successful TL.

Mechanisms of injury

Truncal trauma is broadly categorized into two sections: penetrating and blunt. There can be significant overlap, such as in blast injuries. It is important to know the different patterns of injuries that are seen from both mechanisms to understand how the different organs are affected.

Penetrating

Penetrating trauma is further categorized in to three types: high, medium and low energy. High- and medium-energy penetrating traumas are typically from gunshot wounds. High-energy injuries tend to be caused by rifles and medium tend to be from handguns. These injuries will result in tissue injuries away from the tract as the deceleration force on the bullet will dissipate the energy into the surrounding tissues causing damage. In the United Kingdom, low-energy trauma is dramatically on the rise with the increasing prevalence of knife crime. In low-energy penetrating trauma, the surrounding tissues are not damaged, but significant bleeding can occur from the blood vessels that are directly injured, or penetration of the viscus from the sharp injury will lead to leak and peritonitis. As the surrounding tissues of the tract are not always damaged, the direction and depth may not always be apparent. This can potentially lead to missed injuries of deeper organs in the retroperitoneum such as the duodenum or pancreas, which have a far worse outcome in delayed diagnosis. At laparotomy, attempts should be made to determine the pathway of the penetrating sharp object through the peritoneal cavity and one can then consider mobilizing and investigating the retroperitoneal organs as appropriate. These manoeuvres are discussed later on.

Blunt

Blunt injuries are common and are most typically seen in road traffic accidents from the seatbelt. The damage is either from a crushing force or there is shearing to tissues. Organs in the abdominal cavity have different levels of mobility and damage can occur between areas that are fixed and mobile such as the pedicles of organs. If haemostasis from the bleeding has been achieved, the organs supplied by the damaged vessels may have been devascularized. Secondary ischaemic injury may occur, such as in an injury to the mesenteric edge of the small bowel that will give it a bucket handle tear appearance.

Assessment, investigations and resuscitation

As with a critical ill patient, a sequenced ABCDE approach should be employed via Advanced Trauma Life Support® (ATLS) principles.[3] A penetrating truncal injury or trauma involving significant forces (such as a road traffic accident or a fall from a significant height) mandates a trauma call to involve all appropriate specialties. An initially stable patient does not signify a lack of potentially life-threatening injuries and a high index of suspicion should be maintained with regular monitoring and serial examinations. Bleeding should be considered from all major sources including the chest, abdomen, pelvis and long bones of the body.

Imaging has now become essential in the early decision making in trauma. There is a wide range of options including plain radiographs, focused assessment with sonography in trauma (FAST), magnetic resonance imaging (MRI) and computed tomography (CT).

FAST is useful at the bedside, avoids transfer to the radiological department and can be employed as a serial investigation. However, it will not necessarily say where the bleeding is coming from and is user dependent. The sensitivity has been reported up to 100% for detecting haemoperitoneum, but some studies report this to be significantly lower.[4] One should also be aware of the existence of diagnostic peritoneal lavage (DPL), but that is seldom used in modern hospitals and is all but taken over by CT.

CT is universally recognized as the best initial imaging modality for major trauma, offering a wide range of information regarding bleeding status and visceral injury. The higher resolution, quicker scanning times and rapid availability allows its use in not only stable patients, but also some potentially unstable patients.[4] A trauma surgeon should become familiar with interpreting CTs and consult directly with the radiologist.

The haemodynamically unstable patient requires simultaneous resuscitation during assessment. A trauma patient that is shocked is deemed to be from reduced circulating volume (haemorrhagic shock) until proven otherwise. After initial crystalloid infusion, further fluid should be given as packed red cells and plasma in a 1:1 ratio as per the current NICE guidance.[5] One should understand the classes of haemorrhagic shock that are shown in Table 1 as described in the ATLS course manual.[3] An easy way to remember it is using a tennis score in terms of percentage of circulating volume lost: Love: 15%: 30%: 40%.

Classes of shock[3]

	Class I	Class II	Class III	Class IV
Blood loss (ml)	Up to 750	750–1500	1500–2000	>2000
Blood loss (%blood vol)	Up to 15	15–30	30–40	>40
Pulse rate	<100	100–120	120–140	>140
Blood pressure	Normal	Normal	Decreased	Decreased
Pulse pressure	Normal or increased	Decreased	Decreased	Decreased
Respiratory rate	14–20	20–30	30–40	>35
Urine output (ml/hr)	>30	20–30	5–15	Negligible
Mental status	Slightly anxious	Mildly anxious	Anxious/confused	Confused/lethargic

Table 1

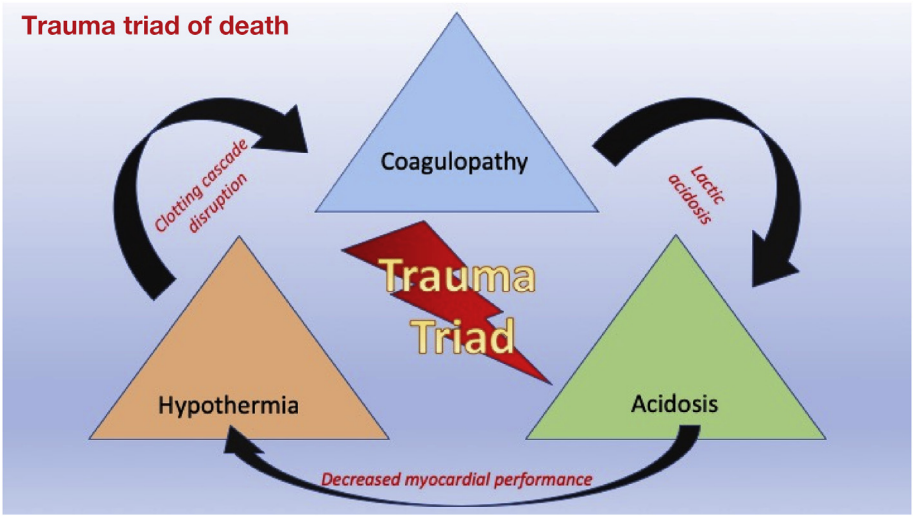

Figure 1

It is not only this, but also the response to the initial fluid resuscitation that needs to be measured, which will help guide further management. This is further categorized into three types: rapid response, transient response and minimal or no response. Someone with no response needs to go to theatre urgently.

The trauma triad of death (Figure 1) has been implicated in perpetuating bleeding and significantly increasing patient mortality.[6] The three parameters are hypothermia, coagulopathy and acidosis.

Early recognition and intervention to prevent the positive feedback loop of the triad is a priority. Ultimately, if a patient continues to bleed intra-abdominally, then a laparotomy may be the only intervention to break the cycle. If this loop is well underway during laparotomy then, unfortunately, further surgical intervention is often futile. Intraoperative 'bail out' options need to be sought well before the cycle is initiated as the physiological insult is too massive, hence the advocation of DCS.

Undertaking the trauma laparotomy

Preparation

As the surgeon, it is your responsibility to help coordinate the team to ensure the patient is transferred to theatre quickly and efficiently. If a TL is looking likely, the emergency scrub team need to be notified early to create theatre space, prepare equipment and bring in more staff as required. The anaesthetic team should also be informed early if not already involved in the trauma call. A team briefing needs to take place as part of the WHO checklist. It ensures that there is an understanding of available equipment and members of the team have specific roles according to their ability. Discuss the injury burden, the timeframe of getting knife to skin and agree on definitive versus DCS goals.

Likely equipment requirements should be requested at this stage. It is far better to have the items at the beginning of the operation than lose theatre staff during the procedure looking for specific tools. Some of the recommended items beyond the standard laparotomy set include:

- an open vascular set with vascular clamps
- multiple large abdominal swabs
- bowel staplers
- an Omni-Tract or other self-retainer if the patient is obese
- long needle holders with desired sutures
- cell saver suction device
- polyethylene sheets and vacuum device for possible laparostomy
- an energy device such as a Harmonic scalpel or LigaSure™.

It is also important to ensure that the intensive care team is aware, and a bed is made available when the operation is finished. There is little point performing DCS if there is nowhere for the patient to recover.

Once the patient is anaesthetized and if stable, it is best advised to stay at the operating table and lead in the adequate positioning of the patient. The patient should be placed in the supine position with both arms fully abducted to the body on supports in the crucifix position (Figure 2). This allows for the

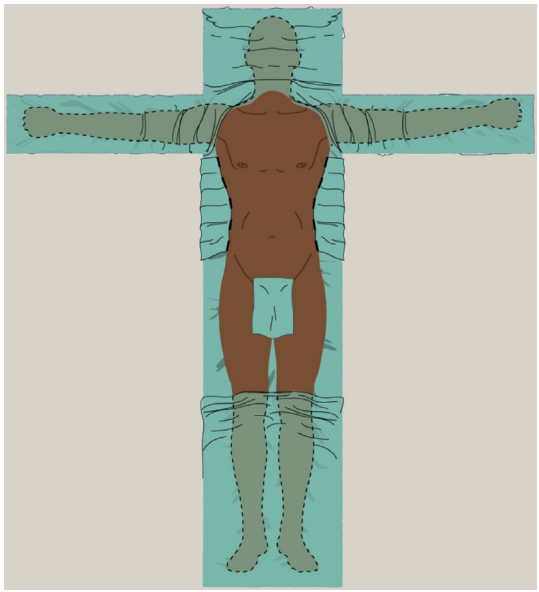

Figure 2 Patient preparation and exposure on operating table

anaesthetic team to access the upper limbs for peripheral access and gains adequate space at the sides for the surgeon, assistant and scrub nurse. However, under anaesthetic, there is a period of time when worsening decompensation may occur. If the patient is unstable, there may be little time to help set up or spend much time scrubbing.

Prepping and draping the patient should be to prepare for worst case scenario in the event of an unplanned thoracotomy or required access to the groins. The patient should therefore be draped from chin to above knee and between the posterior axillary lines. One must bear in mind that such exposure will perpetuate the hypothermia of the patient. Once the laparotomy is started, this will only get worse through evaporation and convection. One can consider a warming mattress on the operating table, Bair Hugger™ over the extremities, and warmed intravenous infusions should be used. Unfortunately for all the theatre team, it is recommended that the temperature of the theatre be adapted for the patient rather than the staff. As a scrubbed surgeon, this will feel uncomfortably hot, but is better for the patient if it can be tolerated.

Abdominal access

In order to gain access, make a bold midline incision from xiphisternum to pubis using the knife. Time should not be wasted coagulating the small bleeding skin vessels with diathermy at this stage, there are far more pressing issues ahead within the abdomen that need attention. Make a sharp incision down to the fascia and again, with sharp dissection, divide the linea alba. Once you encounter the preperitoneal fat, you can breech the peritoneum with a finger into the abdomen just above the umbilicus, which is where it is usually at its thinnest. Perform a circumferential sweep with the finger to confirm entry then complete the incision with Mayo scissors. The non-dominant hand is used to keep the bowel and other organs out of the way. If necessary, divide the falciform ligament between clamps to complete the full access.

Entry into the abdomen can be far more complicated in patients that have had previous surgery and unfortunately, iatrogenic injury is far more likely from adhesions. For those that have had a previous laparotomy, it is advised to try and enter above or below the previous scar in virgin territory. If there are major concerns about access from previous operations then it has been advocated to do a bilateral subcostal incision, which is far more time consuming, but may be more beneficial in the long run.[2]

Once safely into the abdomen you may be greeted by a sea of blood from a major haemorrhage, but at this stage, you are unlikely to be clear where it has come from. The next step is to deliver the small bowel in two large abdominal packs to the patient's right. This will generate more space to work inside the abdomen.

Packing the abdomen

Once satisfactory access is achieved, and if there is haemorrhage, then temporary control can be achieved with good packing. This priority at the beginning of the laparotomy will buy time, allowing for a pause in theatre for the anaesthetic team to 'catch up'. The main principle of adequate packing is to create a haemostatic pressure effect that approximates the tissue planes and will provide temporary haemostasis. Blindly shoving packs into the abdomen achieves nothing other than soaking up the blood and is unlikely to stop haemorrhage. Perform systematic empirical packing using large abdominal packs unless there is an obvious bleeding point that has revealed itself and needs attention first.

Start with the liver by placing your left hand over the dome and place swabs above your hand, perform the same under the liver and this will create the sandwich effect to achieve approximation of any ruptured surfaces. The mistake here is to just pack swabs up into the inferior surface of the liver, which does not result in the required compression to stop bleeding. Pack swabs into the right paracolic gutter and then move across to the spleen where the same technique of placing your non-dominant hand over the lateral aspect of the spleen to facilitate lateral packing and the compression is made by further swabs medially. Pack more swabs into the left paracolic gutter and then accurately pack the pelvis between the organs.

Move on to inspect the small bowel that you have retracted to ensure there is nothing exsanguinating from the mesentery that can be dealt with. If there is an obvious presenting vessel then this can be dealt with by manual compression or clamps for temporary control.

Aortic control

If the general picture is of overwhelming bleeding and there is simply no means of getting other temporary control or immediate access to the specific bleeding, then we advocate aortic control. It is generally bad news if this is required. The targeted part of the aorta is in the supracoeliac region, which is technically the lowermost part of the thoracic aorta that can be accessed via the abdomen. The clamp should not be applied blindly, and you need to perform dissection to directly expose it. If the left lobe of the liver is obscuring, then divide the left triangular ligament to retract it back on itself to the right. Bluntly open the lesser omentum to the right of the lesser curve of the stomach. A Deaver retractor is helpful to retract the stomach to the left and reveal the posterior peritoneum. Open the posterior peritoneum either bluntly or with Mayo scissors and then separate the two limbs of the right crus of the diaphragm to reveal the lower thoracic aorta. Sliding two fingers around each side of the aorta here will develop a space to place the clamp across it. Another option is to simply manually compress the aorta up against the vertebral body of the spine and have your assistant hold it to free both your hands.

Aortic control does not offer definitive haemostasis and prolonged ischaemic time to the major organs is damaging. It should be seen as a last-ditch attempt to allow 'catch up' from the anaesthetic team and buy some time. For major vessel bleeding, distal control is also required. Repairing the major vessels requires significant experience and techniques that we will not discuss in this chapter.

Exploration of the abdomen

Once you have successful temporary haemostasis then the panic and mayhem should start to calm down. Communicate clearly with the anaesthetist and once they are satisfied that they have an improved physiological status, then start exploring the abdomen. This should be in a methodical and thorough manner.

The transverse colon is a useful structure to separate the superior and inferior aspects of the abdomen.

There is no fixed sequence to the exploration unless there is an obvious bleeding target organ. We follow the chapter *Trauma Laparotomy: Principles and Techniques* from the book *Trauma.*[7] Start in the right upper quadrant. Systematically remove packs around the liver, inspect the gallbladder and biliary tree and lookout for any bile that may be a clue to injury. Palpate the right kidney below and then move to the left upper quadrant. Again, by carefully removing packs, inspect the spleen and left kidney. Visually inspect both hemidiaphragms for injury and ensure they are convex rather than bulging downwards. Palpate the gastro-oesophageal junction and feel around the exposed areas of the stomach to the second part of the duodenum. Open the lesser sac through the omentum above the left side of the transverse colon, this will expose the posterior wall of the stomach and the body and tail of the pancreas. If duodenal injury is suspected, then you must Kocherise it to mobilize and view segments II, III and IV in full as well as the head of the pancreas. Blood or contaminant in the lesser sac means you should perform this manoeuvre. You should also inspect the duodenum if there is clinical indication following the trajectory of injury from penetrating trauma in that direction. Missing such an injury is very difficult to manage if diagnosis is not established at first laparotomy.

Below the transverse colon, start at the ligament of Treitz and run the bowel from the proximal jejunum all the way to the rectum. Carefully inspect both sides of the bowel with its mesentery. Any haematoma around the ascending or descending colon could represent injury underneath indicating it needs mobilizing to be certain.

Commonly missed points of injury from penetrating trauma are:

- oesophageal junction
- proximal jejunum
- mesenteric border of small bowel
- posterior wall of transverse colon
- retroperitoneal duodenum (segments II, III and IV)
- ureters
- extraperitoneal rectum and bladder.

Manoeuvres

If there is suspicion of retroperitoneal injury, then a left or right medial visceral rotation can be performed to expose that side. A right-sided rotation (or Cattell-Braasch manoeuvre — Figure 3) is achieved by continuing the Kocherisation of the duodenum laterally and dividing the lateral attachments of the right colon (down the white line of Toldt). Once at the caecal pole and with the small bowel still eviscerated to the right, the division turns medially and superiorly towards of the ligament of Treitz. Separating the avascular attachment of the small bowel from the posterior peritoneum will enable the right colon and small bowel to be placed on the patient's chest. This exposes the entire inframesocolic retroperitoneum and visualization of key retroperitoneal structures.

In the case of retroperitoneal supramesocolic bleeding, then the left-sided medial rotation is indicated.[2] This is achieved by dividing the equivalent white line of Toldt of the left colon from the lowermost part of the descending colon upwards to the splenic flexure. We advocate performing Mattox's description of the manoeuvre (Figure 4), which is to head posterior to the left kidney and include that in the rotation (unlike the Cattell-Braasch, where the left kidney is left in place). If there has been significant haemorrhage, then the bleed may have already helped dissect this plane. The reason for going behind the kidney is to avoid the anterior renal fascia and the left renal vein that can block access to the aorta.

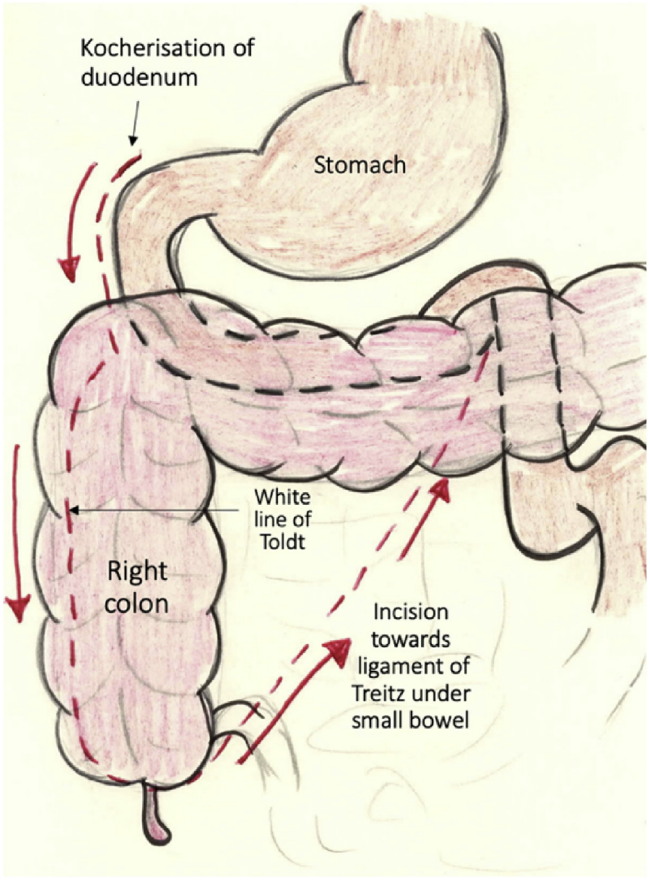

Figure 3 Cattell-Braasch manoeuvre

Such manoeuvres provide excellent access and are often key to success in the otherwise difficult to control bleeding retroperitoneum. However, they carry risk of iatrogenic injury and should only be performed when necessary. The Cattell-Braasch manoeuvre jeopardizes the superior mesenteric vein where the middle colic drains into it and is prone to avulsion. The Mattox manoeuvre is even more risky and may result in splenic injury, avulsion of the descending lumbar vein and injury to the left ureter.

Closure

If definitive surgery has been performed and the patient is stable, then it may be appropriate to close the abdomen. This should be done as a mass closure technique as with a standard laparotomy. It is easy to switch off at the end of the operation and as with any closure, one should take extreme care in this part of the operation. A mistake can increase the chance of a troublesome hernia or even worse you may cause an iatrogenic injury that goes unnoticed for a time and then requires a further operation in an already physiologically insulted patient.

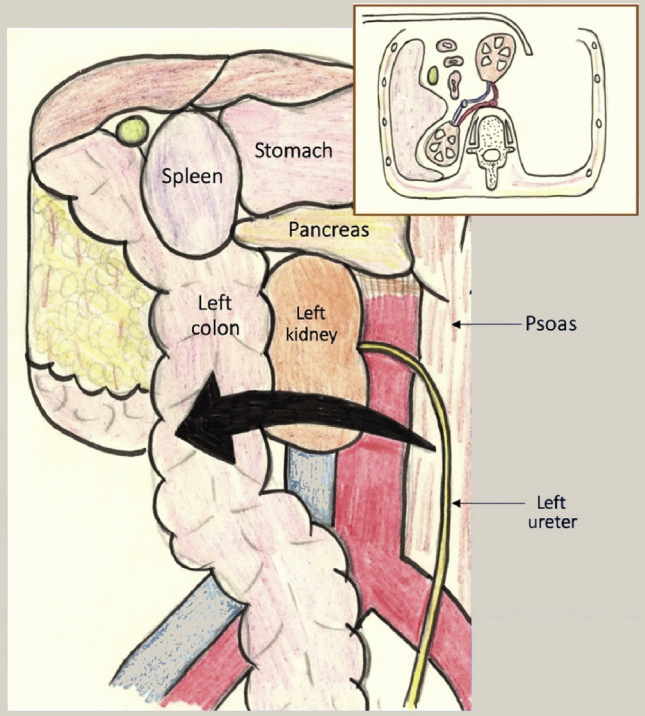

Figure 4 Mattox manoeuvre

Grade of liver laceration according to American Association of Surgery for Trauma (10)

Grade	Type	Description
I	Haematoma	Subcapsular, <10% surface area
	Laceration	Capsular tear, <1 cm parenchymal depth
II	Haematoma	Subcapsular, 10–50% surface area;
	Laceration	intraparenchymal, <10 cm in diameter
		1–3 cm parenchymal depth, <10 cm in length
III	Haematoma	Subcapsular, >50% surface area or
	Laceration	expanding; ruptured subcapsular or parenchymal haematoma
		>3 cm parenchymal depth
IV	Laceration	Parenchymal disruption involving 25–75% of hepatic lobe or 1–3 Couinaud's segments within a single lobe
V	Laceration	Parenchymal disruption involving >75% of
	Vascular	hepatic lobe or >3 Couinaud's segments within a single lobe
		Juxtahepatic venous injuries; i.e. retrohepatic vena cava/central major hepatic veins
VI	Vascular	Hepatic avulsion

Table 2

If DCS has been performed or there is an indication for a relook then a temporary closure in the form of a laparostomy should be performed. This allows for protection of the swelling abdominal organs in the postoperative period, particularly when ileus is inevitable. It also allows drainage of intrabdominal fluid, preservation of muscle wall and skin and a means for easier repeat access. We recommend the use of the vacuum pack technique described by Brock et al.[8] This technique is a sutureless containment that is rapid and reduces adhesions to the lateral abdominal wall. This can improve the eventual definitive closure due to the preservation of mobility. A polyethylene sheet is wrapped around the viscera and the edges are placed down to the paracolic gutters. Abdominal towels or vacuum sponge is placed on top and suction drains are placed into this and out via the lower or upper part of the abdominal wound. Finally, a large polyester adhesive drape is sealed over the abdomen to allow for the suction.

Principles of the key organs

Here we talk about the individual organs in more detail to describe some of the more common injuries and how to approach them.

The liver

The liver is the largest solid organ in the abdomen and injuries are graded I – VI (Table 2). Most of it sits anteriorly and the delicate parenchyma is prone to damage by the disruption of Glisson's capsule. This makes it the most common organ to be injured in abdominal trauma.[9]

CT angiography has a sensitivity and specificity to liver injuries of 92–97% and 98.7%, respectively. Rather than the grade of injury, it is active bleeding, shown by extravasation of contrast, that determines the need for intervention, which is more frequently now performed by interventional radiology. This should be employed for the stable patient or moderately unstable with immediate availability. If the patient is severely unstable or there are multiple other injuries, then surgical approach is indicated. A stable haematoma around the liver without a blush of contrast can be monitored with serial examinations and CT scans. Also be aware that fluid adjacent to the liver could be bile representing a biliary injury rather than blood.

Intraoperatively, there are various techniques to control haemorrhage after packing. Pringle's manoeuvre will reduce haemorrhage while attempting repair (Figure 5). Compression is applied to the hepatoduodenal ligament, which is on the free

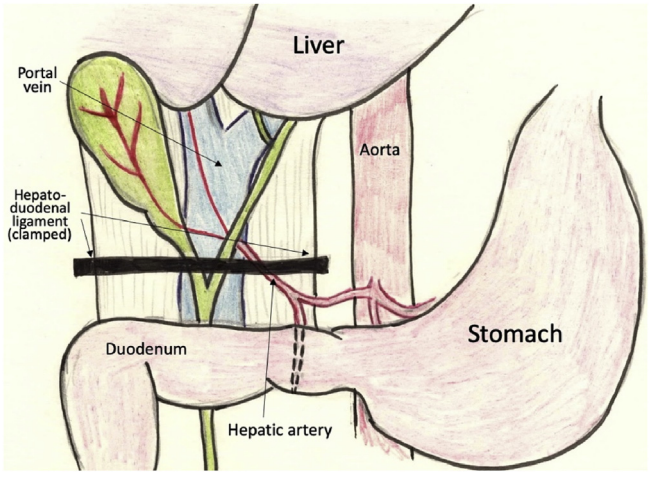

Figure 5 Pringle's manoeuvre

edge of the lesser omentum and contains the hepatic artery, portal vein and bile duct. You can use either manual compression, a tourniquet or a large atraumatic vascular clamp. In the case of clamping these vessels, be aware of prolonged ischaemic time to the liver and aim to have the clamp removed after 30–45 minutes. Small hepatic lacerations may be controlled with manual compression, diathermy on a high setting of spray, direct suturing or haemostatic products. For a larger laceration, we recommend the use of an omental patch to plug the defect and provide the required compression. A tongue of omentum is created by dividing vertically up the avascular plane of the greater omentum and usually the right side can then by rotated up into the liver defect and secured with loose interrupted stitches.

In the case of persistent bleeding, despite Pringle's manoeuvre, then more definitive control is required. Supra-coeliac clamping is the quicker option, but it may be possible to get supra- and infra-hepatic cross-clamping of the inferior vena cava. To gain access, division of the various hepatic ligaments will provide mobilization to deliver the desired lobe to the midline. The falciform should be divided between clamps and released all the way up to the diaphragm. The left and right triangular ligaments and anterior and posterior coronary ligaments should be very cautiously divided under vision to avoid collateral injury to adjacent vessels.

Dark blood welling up from behind the liver can represent injury to the retrohepatic veins, which is very difficult to manage. Gently pushing the liver posteriorly and to the left may buy some time to consider options. Mobilizing the liver in this situation can cause complete avulsion and uncontrolled haemorrhage. You should be aware of the atriocaval shunt, but this rarely works in reality.[2] Instead, continue with manual compression and do not explore any already contained haematomas as you are likely to make things worse.

If bile is found, then carefully inspect the biliary tree for injury. For a gallbladder injury, you can perform a cholecystectomy or simply close it with sutures and leave a drain or a cholecystostomy. If there is injury to the bile duct, then this can either be managed with endoscopic stenting or T-tube placement. A full transection of the biliary tree will require a hepaticojejunostomy.

The spleen

Splenic injuries are also graded with scores ranging from I–V. Grade I is described as a subcapsular haematoma, <10% surface area and V is either a laceration that has completely shattered the spleen or a hilar vascular injury that devascularizes the spleen.[10] The grading is useful for descriptive measures, but does not necessarily dictate management or likely outcome. The principles of monitoring an injured spleen vs radiological intervention vs surgical are similar to the liver.

At a TL the spleen is a resectable organ and attempts to repair should be determined by overall trauma burden, patient age, severity of the injury and surgeon ability. The mobility of the spleen varies from patient to patient. If attempted packing control measures have failed, surgery to the spleen can only be achieved once mobilized to the midline. Place your hand over the anterior surface and with your fingertips resting around the lateral aspect and you will be able to feel the membrane of the lienorenal ligament posteriorly. Gently pulling to the midline will then expose this ligament for division. There may be adhesions to the abdominal wall, which need to be divided first and this can be done with sharp dissection. If there is a short lienorenal ligament, you may need to help release this by dividing it with scissors over the tips of your fingers. When pulling the spleen medially be careful not to go posterior to the left kidney, accidently delivering this too. Be aware that the distal pancreas will also be coming across risking iatrogenic injury.

To divide the spleen from its blood supply, use serial clamping across and close to the hilum. Be careful not to catch the distal pancreas in the clamps and the greater curve of the stomach when coming across the short gastric arteries. Secure the vessels with transfixion sutures under the clamps.

The pancreas

The distal pancreas is visualized by entering the lesser sac. Divide the gastrocolic ligament horizontally above the colon to get a full view if injury is suspected. Distal pancreatectomy is indicated if there is a ductal injury or suspicion of one, otherwise you can perform manual compression for haemostasis and a drain must be left to control a pancreatic leak. If there is a severe injury, but it is not clear whether the duct has been injured, then perform the distal pancreatectomy and splenectomy. The division is generally achieved across the pancreas incorporating the splenic artery with a large stapler.

A head of pancreas injury invariably requires a safe damage control option, which is to ensure haemostasis and adequate drainage until the patient is stable enough for definitive repair at a specialist centre. Pancreatic anastomosis should not generally be attempted at an initial TL.

Diaphragm

Diaphragmatic injuries occur in both penetrating and blunt trauma. They are important not to miss as potential herniation can occur with a high risk of strangulation and associated mortality. CT is only 61–87% sensitive for rupture,[11] so it is essential to maintain a high level of suspicion and carefully inspect the diaphragm. Good retraction and performing an adequate incision initially will aid this. In a stable patient and no other indication for laparotomy, but with diaphragmatic injury suspected, it may be suitable to investigate laparoscopically for the better view of the upper abdomen. One should be prepared with a chest drain as the pneumoperitoneum can quickly create a tension pneumothorax. Hollow viscus perforation is commonly associated with a diaphragmatic injury, so if injury is found, vigilantly view the other organs and convert to laparotomy if needed.

To repair a defect, you should use strong non-absorbable sutures with big bites. Long Allis clips are useful to evert the edges towards you and leave the sutures long when cutting to be able to keep the tension. It may be preferable to use mattress sutures or even a double layered repair.

In blunt trauma, the diaphragm may be avulsed laterally and will have retracted making it difficult to reattach to its original rib, in which case, it can be attached 1–2 ribs above. If you cannot reattach because the defect is too big then a mesh is required. It is important to realize that repair at reoperation will be more difficult due to further retraction. A temporary absorbable mesh as a barrier may make a large amount of difference if it

can be fitted quickly. If there is pleural contamination of gastric contents, then adequate wash must be achieved either by initially enlarging the defect or even a thoracotomy and a chest drain should be left.

Bowel

For bowel injuries, the first priority is to ensure haemostasis. The mesenteric vessels are difficult to control as they retract into the fat and create a haematoma. Do not blindly clamp these vessels and be particularly vigilant on areas close to the blood supply origins in order not to cause major ischaemia by avulsion or damage. Use manual compression proximal to the bleeding points and carefully open the serosa to identify the individual bleeding vessel to obtain control. Contamination of a perforated viscus should be controlled with soft bowel clamps. If a defect in the bowel is encountered, the opposite wall of the viscus may be hiding a further injury.

Where the bowel is injured or transected, formal reconstruction to continuity is desired, but not essential. Spending time over an anastomosis, in an unstable patient, is detrimental to the patient's overall physiological status. Stomas should be avoided as they often retract and make abdominal wall closure more difficult.

Stomach and duodenum: The stomach can be repaired with sutures or a stapler. Exposure is key to assess all of the stomach including the lesser curve and posterior wall. A commonly missed area is the oesophagogastric junction. To view this, ensure the patient is head up, divide the left triangular ligament and the posterior peritoneum will contain the distal oesophagus. This can be repaired with primary closure and can be protected by folding and securing the fundus over the repair and a drain. If not possible then suction drainage into the open oesophagus and a staple across the distal stomach is a potential solution. If multiple stomach injuries or no possible means for reconstruction, then a stapled partial gastrectomy is required with reconstruction at a later stage.

The duodenum poses a particular problem at the level of D2 around the pancreatic head. A more straightforward enterotomy can be closed primarily with sutures making sure there is no tension and no stricturing by orientating the sutures transversely. For a full transection, then perform an end-to-end anastomosis if possible. All repairs should be protected with an external drain and the bail out option is to suture a larger defect around one to create a controlled fistula. Roux-en-Y reconstruction is time consuming but may be the only definitive option in the larger injuries for a more stable patient. Injuries necessitating a trauma Whipple's are rarely survivable.

Small bowel: The small bowel may have multiple areas of injury with either enterotomies or ischaemic points from bucket handle tears. In DCS, contamination can be controlled with sequential stapling and resection without anastomosis or occluding the bowel with tape. If decision is to repair, then make sure the edges of the injury has healthy tissue and has a good blood supply and a sutured repair or anastomosis is recommended in the fashion you are most comfortable with. Again, avoid a repair that narrows the lumen by orientating stitches over an enterotomy in a transverse fashion. For proximal jejunal injury, you may need to mobilize the ligament of Treitz for access.

Colon: Colonic injuries are easy to miss and if there is suspicion either from tracing the trajectory of penetration or evidence of even a small bruise on the anterior side, then that segment of colon should be mobilized to investigate the posterior wall. If there is a simple colonic enterotomy, then perform primary closure as per the small bowel. If resection is required, then one should perform a right hemicolectomy for a right-sided or transverse colon injury. Left-sided colonic injuries carry more debate due to the higher leak rate of a colo-colostomy. This anastomosis should only be performed in a stable patient. The alternative is to perform an extended right hemicolectomy, which is time consuming or a Hartmann's procedure, which is to staple the distal end and bring out the proximal colon as an end colostomy.

Rectum: If rectal injury is suspected, then legs should go in stirrups at set up to allow the lithotomy position for access. A rectal injury can be diagnosed with rigid sigmoidoscopy and proctoscopy. If easily accessible and small, then primary repair is appropriate. If endoanal approach does not allow immediate repair, then proximal diversion with a loop sigmoid colostomy should be performed.

Genitourinary system

All urological injuries should involve a urology specialist. Blood at the urethral meatus may mean a urethral injury, for which a catheter must not be inserted. A retrograde cystogram or direct visualization will confirm diagnosis.

If a bladder injury is discovered at laparotomy then it can be repaired with a running stitch. If DCS is required, then a severely damaged bladder can be packed for haemostasis and ureteric intubation will be required. A transected ureter can be tied off for later nephrostomy or a paediatric feeding tube can be fed into the proximal ureter and exteriorised if there is time. Do not mobilise the ureter as this devascularises it.

The kidneys are resectable and the principles are similar to the spleen. Access is achieved by a left or right rotation depending on side to expose the retroperitoneum and Gerota's fascia. Incising the fascia from the lateral aspect allows the kidney to be delivered and manual compression of the hilum can be achieved. As with the spleen, there are some repair options, which is pertinent if both kidneys have been injured, as you do not want to leave your patient anephric. Again, specialist urological support should be sought.

Trauma to the female pelvic organs and pregnant patients necessitates involvement of the gynaecologists and obstetricians.

Pelvis

An unstable fracture is unpredictable in potentially causing major life-threatening haemorrhage at any time. A pelvic binder will reduce this risk along with early external fixation. Angiographic embolization is the preferred option for early haemostasis. If there is a pelvic haematoma found at laparotomy, the advice is to not enter it and arrange urgent angiography. However, if a main iliac vessel is injured then this will need surgical repair. Left or right mobilization is required for the identification

for proximal and distal clamping. Then walk the clamps closer together until the injury is identified. Unless the injury is easily secured with a couple of sutures, a temporary shunt may be the safest option.

Conclusions

There is no one way of doing things during a TL and each individual case will always be different. As a surgeon, one should always be willing to adapt to an ever-changing situation for their patient. Communication is vital to recognizing these changes and the importance of teamwork can never be underestimated.

The key technical skills are in the basic principles of haemostasis and ensuring contamination control. DCS is often the bravest, yet most appropriate management for your patient and will improve their chances of survival.

Techniques and evidence are always evolving. There is no substitute for experiencing real-life trauma surgery as an assistant before attempting parts of the TL under supervision first. ◆

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