Management of liver trauma

The increasing incidence of hepatic trauma has been mirrored by a rise in the expectant management of these injuries. Liver injuries should be managed in a multimodal manner, with discussion with regional specialist units.

The liver is the most commonly injured intra-abdominal organ despite its protected location under the right costal margin (Badger et al, 2009). Liver parenchyma is relatively fragile and is contained within a thin fibrous capsule, which provides little protection; both hepatic tissue and vasculature are therefore susceptible to trauma (Ahmed and Vernick, 2011).

There has been a paradigm shift in the management of hepatic trauma in recent years from early intervention and definitive repair of injuries to conservative management, with damage control surgery as the preferred initial operative strategy (Leppäniemi et al, 2011). It is anticipated that as both experience and confidence grow in the non-operative management of liver trauma the number of patients who can be expectantly managed will increase, making operative intervention for liver injury less common. Patients with hepatic trauma must be discussed with a regional centre for advice regarding management.

This article outlines evidence-based management strategies for patients with liver trauma, particularly informing early management for clinicians outside specialist liver surgery centres.

Incidence

Liver trauma is common, affecting 2.95 per 100 000 of the population annually (Talving et al, 2003). Blunt hepatic trauma is more common in Europe and Australasia, while penetrating trauma from stab wounds and gunshot injury are more prevalent in North America and South Africa (Lucas and Ledgerwood, 2000; Omoshoro-Jones et al, 2005). There is an increasing incidence of trauma admissions worldwide generally, which is accompanied by an increase in the number of liver injuries (Safi et al, 1999). The increasing frequency of hepatic trauma reflects both improvements in car safety (more patients are surviving road traffic collisions) and improved computed tomography imaging (detecting minor, asymptomatic injuries) (Petrowsky et al, 2012).

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Mechanisms of injury

Liver injury may be the result of either blunt trauma, e.g. from falls or road traffic collisions, or penetrating trauma typically caused by knife wounds or gunshots.

Blunt trauma

Blunt trauma typically affects the right lobe of the liver (Becker et al, 1998; Talving et al, 2003). During deceleration injuries the liver continues to move after impact, causing a shearing force at sites of fixation to the diaphragm and abdominal wall (incorporating the fragile and thin-walled hepatic veins and the inferior vena cava) (Velmahos et al, 2003). Direct blunt force to the liver typically produces a central stellate laceration involving segments IV, V and VII, with possible vascular injuries to the hepatic arteries and veins or the portal vein (Badger et al, 2009).

Penetrating injuries

These are commonly stab injuries, typically with a knife or blade, and usually cause bleeding from the hepatic veins, vena cava, portal vein and hepatic arteries (Burch and Moore, 2006). Gunshots are the most common cause of higher energy penetrating liver injury. Injuries can occur as a result of direct penetration as well as the temporary cavitation effect of the missile (Omoshoro-Jones et al, 2005).

Mortality

The mortality associated with liver injuries rose steadily throughout the 20th century until the early 1990s when improving resolution and availability of computed tomography scans allowed injuries to begin to be managed in an expectant manner (Kozar et al, 2006). Mortality rates vary from 10–30% for blunt injuries and 5–10% for penetrating injuries depending on the severity (Safi et al, 1999). Blunt trauma tends to cause both parenchymal disruption and concomitant injuries, so it is associated with a higher mortality than penetrating injuries. Independent risk factors for death include the presence of shock on admission to hospital, ongoing bleeding (blood loss, number of blood transfusions, hypothermia, acidosis and dysrhythmia) (Asensio et al, 2007) and any simultaneous head injuries (Leppäniemi et al, 2011).

Most patients with liver trauma die from concurrent injuries, most notably from cranial trauma or other intra-abdominal catastrophe (Talving et al, 2003). Early (less than 36 hours) mortality from liver trauma is typically related to uncontrollable haemorrhage from vessels within the liver parenchyma (Chen et al, 2000). Late mortality may be related to sepsis because of intra-hepatic abscess formation in areas of devascularized liver parenchyma, from complications arising from disruption of the biliary system, or multi-organ failure. Mortality from severe injuries is lower in specialist hepatopancreatobiliary and trauma centres, because of increased experience in liver mobilization, vascular exposure, liver resection and management of post-injury complications (Safi et al, 1999). Therefore early consultation with a regional hepatopancreatobiliary centre is encouraged, with possible transfer of patients who are physiologically stable enough to withstand this.

Assessment

Overview

The management of liver injuries is primarily guided by the severity of injury which correlates with both higher rates of surgical intervention and poorer prognosis (Gur et al, 2003; Velmahos et al, 2003). Assessment of patients focuses on their cardiovascular stability during resuscitation which dictates whether they are stable enough for computed tomography scanning to identify and classify any injuries or require immediate laparotomy (Petrowsky et al, 2012).

Clinical history

Hepatic injury should be suspected in any patient who presents with abdominal trauma. Blunt injury should be considered following a fall, crush injury or road traffic collision, while penetrating injuries should be considered with stab or missile tracts to the upper abdomen or lower thoracic regions. The force of the injury sustained is likely to correlate with the likelihood of hepatic damage (Pachter et al, 1992; Leppäniemi et al, 2011), but particular note should be made of patients with connective tissue disorders, e.g. Ehlers–Danlos syndrome, as relatively minor trauma may result in a significant injury.

Clinical examination

Assessment and resuscitation should occur simultaneously in patients with suspected hepatic trauma in line with Advanced Trauma Life Support principles (American College of Surgeons, 2010). Key findings include hypovolaemic shock, abdominal distension or tenderness, and wounds or missile entry points to the abdomen and lower chest (Ahmed and Vernick, 2011). High energy injuries may be associated with a liver injury even if the organ is not located between an entrance and exit wound, as projectiles can take eccentric, non-linear tracts within a body cavity (Morrison et al, 2011).

Haematological assessment

A full series of blood tests is essential in the management of any patient with suspected abdominal injury. A significant drop in haemoglobin suggests active bleeding, while altered liver function tests or clotting screens may indicate hepatic injury. Trauma patients should have blood products available for both immediate and intra-operative resuscitation, with correction of any derangement of clotting factors.

Radiological assessment

In the haemodynamically stable patient who is responding to initial resuscitation, multi-slice detection computed tomography scanning provides a rapid assessment of the abdominal cavity to detect any hepatic or concurrent injuries (*Figures 1* and *2*) (Pachter et al, 1992; Becker et al, 1998). Injuries should be classified according to the American Association for the Surgery of Trauma Organ Injury Scale (*Tables 1* and *2*). Computed tomography

Figure 1. a. Transverse and (b) coronal abdominal computed tomography scan of a male patient with a grade III hepatic injury to Couinaud's segments VII and VIII following blunt trauma from a road traffic collision.

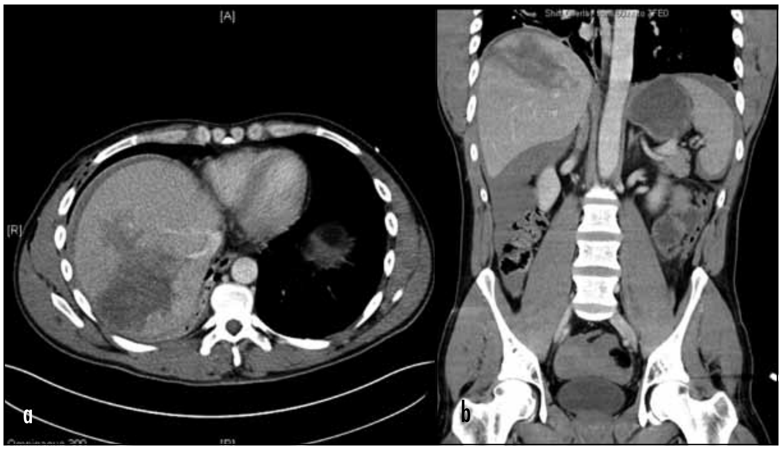
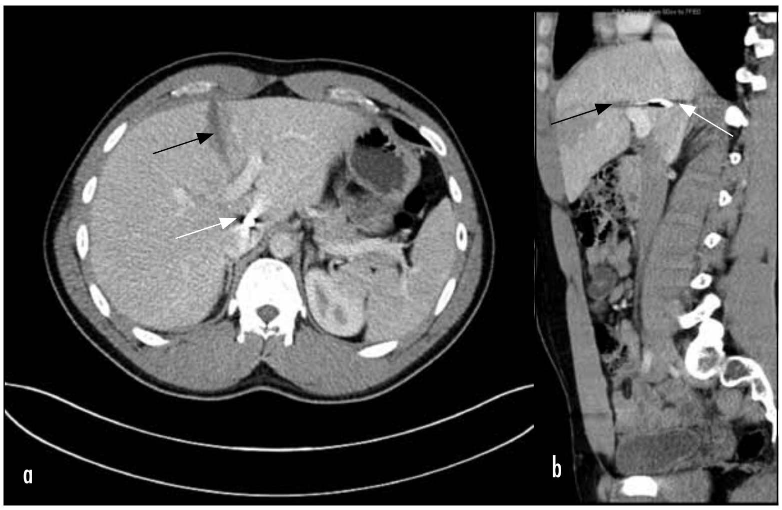


Figure 2. a. Transverse and (b) sagittal abdominal computed tomography scan of a male patient shot at 'point blank' range with an air rifle. Note the air pellet in situ (white arrow), causing slight indentation of the inferior vena cava. Also note missile tract to skin (black arrow).



may reveal whether there is active bleeding, haemoperitoneum, any other vascular injuries or the presence of any devitalized areas (Ahmed and Vernick, 2011).

Previous modalities of assessment, including diagnostic peritoneal lavage and traditional ultrasound, have fallen out of favour in the assessment of abdominal trauma because of the availability of computed tomography imaging. This reflects their level of sensitivity and specificity, the time taken for investigation and the user dependence of that investigation (Petrowsky et al, 2012). Focused Assessment with Sonography for Trauma scans can be useful in detecting free abdominal fluid 'thus dictating the need for an urgent trauma laparotomy in the non-responder' who is deemed too haemodynamically unstable for a computed tomography (Udobi et al, 2001).

Injury scale

Hepatic injuries can be classified via a six-point grading system: minor injuries are graded as I or II, while more severe injuries are graded from III to VI (*Tables 1* and *2*) (Moore et al, 1995). Significant vascular injuries may be associated with a haematoma or parenchymal laceration, but usually only occur with major parenchymal disruption (grades IV and V).

Management of injuries

General principles

The increasing role of selective non-operative management of traumatic liver injuries has been led by both an increased use of computed tomography scanning and improved resolution, leading to a more accurate classification of the injury. An awareness of the liver's significant residual capacity and regenerative properties, combined with increasing experience in the expectant management of liver injuries, has fostered a more conservative approach.

Minor liver injuries in haemodynamically stable patients are managed conservatively (Petrowsky et al, 2012) and there is an increasing tendency to manage severe injuries in this manner (Omoshoro-Jones et al, 2005; Leppäniemi et al, 2011). When operative management cannot be avoided, a policy of damage control surgery should be used, with definitive intervention delayed until the patient's physiology has been optimized, usually at a specialist trauma or hepatopancreatobiliary centre (Badger et al, 2009; Morrison et al, 2011).

Selective non-operative or expectant management strategies

Non-operative management of patients is associated with a decreased length of hospital stay and a reduction in

Table 1. The Hepatic Organ injury Scale for laceration and vascular injury, developed by the American Association for the Surgery of Trauma (AAST) committee

AAST grade	Characteristics of injury	AIS-90 score	Severity
I	Laceration: capsular tear, non-bleeding, <1 cm parenchymal depth	2	Minor
II	Laceration: capsular tear, active bleeding, 1–3 cm parenchymal depth <10 cm in length	2	Minor
III	Laceration: >3 cm parenchymal depth	3	Major
IV	Laceration: Parenchymal disruption involving 25–75% of hepatic lobe or one to three Coinaud's segments in a single lobe	4	Major
V	Laceration: parenchymal disruption involving >75% of hepatic lobe or more than three Coinaud's segments within a single lobe	5	Major
	Vascular: juxtahepative venous injuries (i.e. injuries to retrohepatic vena cava or central major hepatic veins)		
VI	Vascular: hepatic avulsion	5	Major

AIS-90 = Abbreviated injury scale. From Moore et al (1995)

Table 2. The Hepatic Organ injury Scale for subcapsular haematomas, developed by the American Association for the Surgery of Trauma (AAST) committee

AAST grade	Characteristics of injury	AIS-90 score	Severity
I	Haematoma: subcapsular, non-expanding, <10% surface area	2	Minor
II	Haematoma: subcapsular, non-expanding, 10–50% surface area; intraparenchymal non-expanding, <10 cm in diameter	2	Minor
III	Haematoma: subcapsular, >50% surface area, expanding; rupture subcapsular haematoma with active bleeding; intraparenchymal >10 cm or expanding	3	Major
IV	Haematoma: rupture intraparenchymal haematoma with active bleeding	4	Major

AIS-90 = Abbreviated injury scale. From Moore et al (1995) blood transfusion requirement (Badger et al, 2009; Morrison et al, 2011). Both blunt and penetrating injuries can be managed expectantly and success rates range from 83–97% for minor injuries (Omoshoro-Jones et al, 2005; Petrowsky et al, 2012). More severe and complex injuries can also be managed expectantly with a success rate of up to 50% (Leppäniemi et al, 2011). Expectant management depends on the availability of intensive care facilities, the availability of follow-up computed tomography scanning and the presence of experienced surgeons who are able to regularly and repeatedly assess the patient (Gur et al, 2003; Benckert et al, 2010).

Factors that predict a failure of this conservative approach include the presence of concurrent injuries and haemodynamic instability (i.e. persistent hypotension, low haemoglobin and ongoing requirement for blood products) (Kozar et al, 2006; Leppäniemi et al, 2011). Operative intervention is often not related to the liver injury and may reflect co-existing abdominal injuries such as delayed splenic or renal haemorrhage (Burch and Moore, 2006). Failure of selective non-operative management as a result of delayed liver bleeding is rare and tends to be more pronounced in major injuries, where it can affect up to 3.5% of patients (Badger et al, 2009).

Radiological management strategies

Role of computed tomography scanning

Serial imaging of minor injuries is not recommended unless there is a significant change in haemodynamic stability (Badger et al, 2009). In contrast, patients with significant injuries should have interval computed tomography scanning between 3 and 7 days, depending on the extent of injury. Re-imaging can ensure there is no ongoing haemorrhage or septic complication following the initial injury or resuscitative laparotomy (Asensio et al, 2007; Petrowsky et al, 2012).

Role of interventional radiology

Hepatic angio-embolization, either in the acute setting or after a resuscitative laparotomy, is highly effective at controlling arterial bleeding (Asensio et al, 2007). It can be performed selectively to minimize the impact on healthy liver (Misselbeck et al, 2009).

Endoscopic management strategies

Hepatic trauma that results in ductal disruption should be managed with prophylactic endoscopic retrograde cholangiopancreatography and biliary stenting (with or without sphincterotomy). This action decreases the pressure in the biliary system and should encourage bile to flow into the bowel as opposed to through the hepatic injury site (Williamson, 2013).

Operative intervention

Operative assessment

Haemodynamically unstable patients should undergo a resuscitative laparotomy via a long midline incision, which can be extended sub-costally as required. Complete assessment of the right liver necessitates division of the right triangular and coronary ligaments; injury to the lateral wall of the right hepatic vein can occur during division of the superior coronary ligament, while the right adrenal gland and retrohepatic vena cava can be damaged during division of the inferior coronary ligament. Mobilization of the left hemi-liver is usually not required for assessment, but if the posterior diaphragmatic attachments of the left liver are divided, injury to the left hepatic and inferior phrenic veins must be avoided. If an optimal exposure to the junction of the hepatic veins and retrohepatic vena cava is necessary the midline abdominal incision can be extended by means of a median sternotomy (Burch and Moore, 2006).

Damage control surgery

Over the last two decades there has been a move away from immediate definitive surgical management of hepatic injuries to damage control surgery and perihepatic packing (Ahmed and Vernick 2011; Petrowsky et al, 2012). Patients with traumatic injuries die from a triad of coagulopathy, hypothermia and metabolic acidosis and thus damage control surgery aims to achieve physiological stability, prevent metabolic failure and stop uncontrolled bleeding (Asensio et al, 2007; Morrison et al, 2011). Damage control surgery is associated with shorter operating times and improved survival (Badger et al, 2009). Planned relaparotomy with definitive repair can be undertaken, typically after transfer to a specialist unit, following a period of optimization in an intensive therapy unit.

Control of hepatic bleeding

A variety of techniques may be performed to help control liver bleeding: direct manual compression, perihepatic packing and the Pringle manoeuvre. Direct manual compression (*Figure 3*) of the liver with abdominal packs should realign the liver into its anatomical position and control bleeding (Asensio et al, 2007). Perihepatic packing (*Figure 4*) can control haemorrhage in almost all situations, including the retrohepatic vena cava (Feliciano et al, 1986). Fifteen packs should be placed around the site of injury to compress the damaged parenchyma (Morrison et al, 2011). For right-sided injuries packs are placed between the liver and costal margin and anterior chest wall; for left-sided injuries packing is less effective because of the open abdomen, but the liver can be compressed between two hands following division of the left triangular and coronary ligaments. Excessive packing may cause impairment of right hemi-diaphragmatic function and compression of the inferior vena cava which in turn decreases venous return and reduces cardiac output.

Control of the vascular inflow to the liver can be achieved using the Pringle manoeuvre which reduces inflow via the hepatic pedicle (*Figure 5*) (Pringle, 1908).

The technique involves clamping the hepatoduodenal ligament (anterior border of the epiploic foramen of Winslow) which contains the hepatic artery, portal vein and common bile duct (the portal triad). Fingers, atraumatic clamps or vessel loops can be applied to control inflow to the liver. Bleeding from branches of the hepatic artery or portal vein stop when compression is applied, but bleeding from the hepatic veins or retrohepatic vena cava continues (Burch and Moore, 2006). The Pringle manoeuvre can be maintained for at least 30 minutes and up to an hour following ischaemic pre-conditioning (whereby the occlusion is applied for 10 minutes and then released for a further 10 minutes) without any long-term hepatic insult (Clavien et al, 2003).

Figure 3. Intraoperative photograph showing direct manual compression of the liver and finger control of the hepatic pedicle (Pringle manoeuvre). The patient sustained blunt trauma to the liver following a road traffic collision, with associated stellate lacerations.

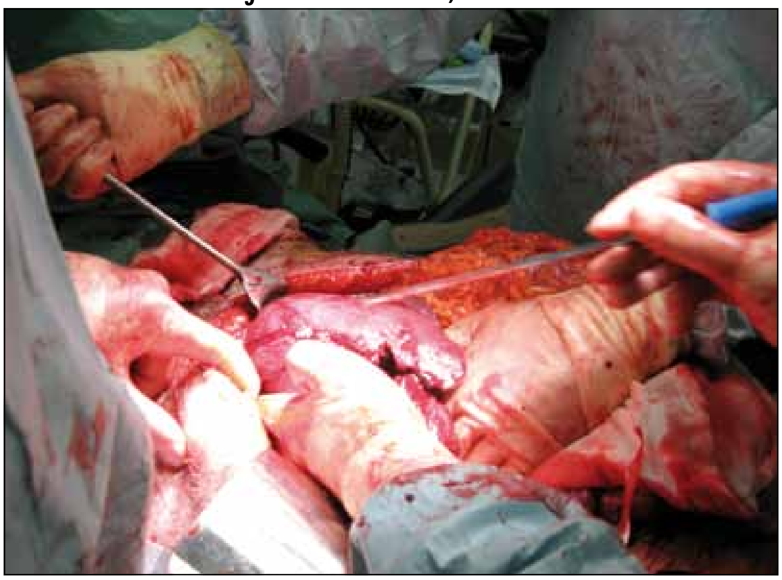
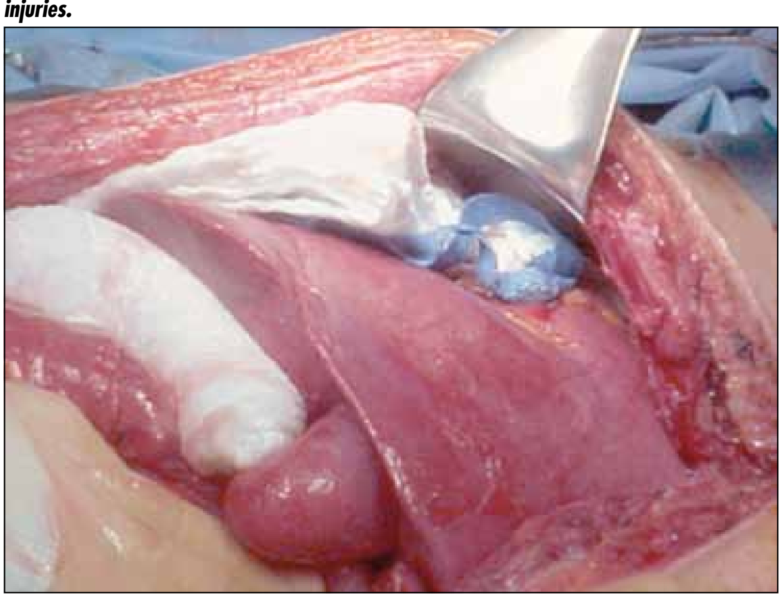


Figure 4. Intraoperative photograph showing perihepatic packs in situ. These align the liver in the correct anatomical position and provide effective tamponade for hepatic injuries.



In a small number of patients, further techniques are required to control haemorrhage: the liver clamp or tourniquet produces direct compression of the liver parenchyma (Murray et al, 1978) and vascular isolation can be performed via arteriocaval shunts and Moore–Pilcher balloons (Mackenzie et al, 2004; Burch and Moore, 2006; Badger et al, 2009; Morrison et al, 2011). These technically demanding procedures are beyond the scope of this article and would typically be performed in a hepatobiliary or specialist trauma centre.

Definitive operative management

Minor injuries (grades I–II): Most minor injuries do not require operative intervention, but they may be discovered during a resuscitative laparotomy for other indications. Hepatic lacerations can be controlled with manual compression or topical haemostatic measures (Levin et al, 1978). Bleeding can be controlled with electrocautery, either from a high-powered diathermy device or argon beam coagulator (Asensio et al, 2007), topical fibrinogenolytic agents, recombinant activated factor VII or tissue glues (Ahmed and Vernick, 2011).

Severe injuries (grades III–VI): Hepatic lacerations should be closed with absorbable sutures; adequate tension is achieved when the haemorrhage ceases or the liver blanches around the suture line – over-tightening can cause hepatic necrosis (Feliciano et al, 1986). Most sources of venous haemorrhage can be controlled with parenchymal suturing (Morrison et al, 2011) and injuries to the retrohepatic vena cava and hepatic veins can be controlled by closing hepatic parenchyma over the bleeding point (Levin et al, 1978). An omental flap may be used to supplement parenchymal suturing by acting as a buttress to provide extra support to prevent a stitch from 'cutting out', especially if Glisson's capsule has been stripped away (Feliciano et al, 1986; Pachter et al, 1992). The omentum can also be used to fill large defects within the liver (Burch and Moore, 2006).

Deep or transhepatic penetrating wounds can be controlled with hepatotomy and selective ligation of bleeding vessels (Ahmed and Vernick, 2011). The site of injury is bluntly extended to identify a bleeding vessel using a cavitron ultrasonic suction aspirator device or 'finger-fracture' technique. Juxtahepatic injuries can also be exposed and repaired via this technique (Burch and Moore, 2006). Viable hepatic tissue is divided during this technique, with resultant blood loss (Morrison et al, 2011).

Hepatic arterial ligation is used less frequently as it cannot control haemorrhage from the portal or hepatic venous systems. If the Pringle manoeuvre results in cessation of haemorrhage, selective clamping of the left and right hepatic artery is performed with subsequent ligation. However, ligation of the proper hepatic artery (distal to the origin of the gastroduodenal artery) is associated with hepatic necrosis (Burch and Moore, 2006).

Resectional non-anatomical debridement removes the damaged hepatic parenchyma, but causes ongoing bleeding before haemostasis (Gur et al, 2003). Compared with deep liver sutures this strategy is associated with a lower mortality, a smaller risk of recurrent bleeding, less blood product requirement and fewer reoperations for hepatic complications (Leppäniemi et al, 2011).

Hepatic resection is a last resort for extensive injuries as mortality exceeds 50% in most trauma series (Donovan et al, 1973; Burch and Moore, 2006). Outcomes may be improved in specialist hepatobiliary centres, reinforcing the important role that timely transfer can play in the management of these patients. For massive bilobar hepatic injuries, total hepatectomy and transplant is an option, but remains uncommon because of its high cost and the limited availability of donors (Burch and Moore, 2006). It is essential that all other injuries are well delineated and the patient must otherwise have an excellent chance of survival for this extraordinary intervention to be considered.

Subcapsular haematoma

Subcapsular haematomas are uncommon and occur when the hepatic parenchyma is disrupted, but Glisson's capsule remains intact (*Table 2*). Grade I and II haematomas can be managed conservatively but, if explored, hepatotomy with selective vascular ligation may be required. Expanding grade III haematomas that are detected intraoperatively are often the result of uncontrolled arterial haemorrhage and selective hepatic arterial ligation may be beneficial. Alternatively, the liver can be packed and subsequent arteriography and arterial embolization of the feeding vessels can be performed (Asensio et al, 2007; Misselbeck et al, 2009). Ruptured grade III and IV haematomas are best treated with exploration and selective ligation supplemented with packing (Burch and Moore, 2006).

Postoperative complications

Postoperative haemorrhage is rare and is usually associated with coagulopathy or a missed vascular injury. Arteriography and embolization is an option, but in most cases reoperation is usually necessary (Asensio et al, 2007).

Perihepatic infections occur in fewer than 5% of patients and are more common in penetrating injuries, presumably as a result of enteric contamination (Burch and Moore, 2006). Computed tomography should be performed in patients with pyrexia or rising inflammatory markers to confirm diagnosis. Infected haematomas and infected necrotic liver tissue may not respond to percutaneous drainage and re-operation may be necessary (Badger et al, 2009).

Major hepatic injuries are associated with fistula formation in 3% of patients; they can communicate with intrathoracic structures (e.g. bronchobiliary or pleurobiliary fistulae) or vascular structures (arterial or venous) (Donovan et al, 1973; Williamson, 2013). Most intrathoracic fistulae close spontaneously, although persistent communications and vascular fistulae may require endoscopic retrograde cholangiopancreatography and sphincterotomy, or hepatic arteriography and embolization respectively to facilitate resolution (Burch and Moore, 2006). BJHM

Conflict of interest: none.

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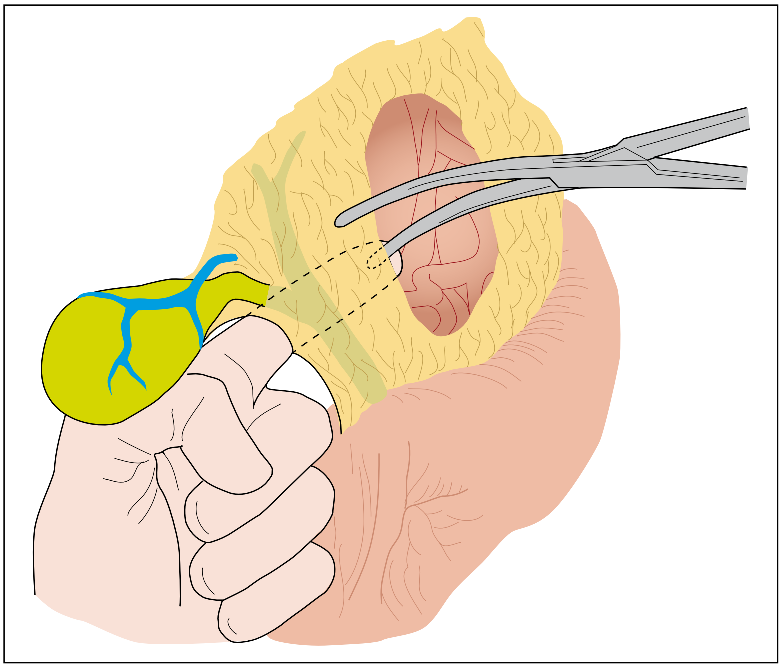
Figure 5. Line drawing illustrating the Pringle manoeuvre: clamping of the hepatoduodenal ligament (containing the portal triad) to control inflow to the liver. The finger is placed through the foramen of Winslow and the omentum opened to allow a clamp to be placed from the lesser sac across the hepatic pedicle.



KEY POINTS

- Hepatic trauma is common and can present to both specialist centres and district general hospitals.
- Management is highly dependent upon the haemodynamic stability of patients: those who are stable enough should have computed tomography assessment to assess the grade of liver injury and exclude other injuries, while unstable patients require resuscitative laparotomy.
- Minor injuries (grades I or II) can be safely managed expectantly, while more severe injuries (grades III–VI) often require operative intervention.
- Where possible, injuries should be managed in a multidisciplinary manner with discussion with a regional trauma or hepatobiliary unit.
- Unstable patients require damage control surgery to achieve physiological stability. Liver bleeding should be controlled with the use of perihepatic packing. Further definitive techniques should be performed at a planned relaparotomy, usually after transfer to a specialist centre.

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