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# Hepatic Trauma

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Additional information is available at the end of the chapter

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## 1. Introduction

The word liver was derived from the old English word “life” [1]. Survival without the liver is impossible for more than a few hours except in very unusual circumstances. The liver is the largest intra-abdominal solid organ; with its friable parenchyma, its thin capsule, and its relatively fixed position in relation to the spine, makes it particularly prone to injury. As a result of its larger size and proximity to the ribs, the right hemi-liver is injured more commonly than the left. It's the second most commonly injured organ in abdominal trauma, but damage to the liver is the most common cause of death after abdominal injury [2], [3]. Management of Liver Trauma may vary widely from non operative management (NOM) with or without angioembolization to Damage Control Surgery (DCS) [4]. DCS is mainly centered on stopping the bleeding by packing, Pringles, and vascular exclusion to totally replacing the liver by a liver transplant [5].

Although blunt liver trauma accounts for 15-20% of abdominal injuries, it is responsible for more than 50% of deaths resulting from blunt abdominal trauma. The mortality rate is higher with blunt abdominal trauma than with penetrating injuries[6]. In Europe, blunt trauma predominates (80-90 per cent of all liver injuries)[6]-[8], while penetrating injuries account for 66 per cent of liver trauma in South Africa [9] and up to 88 per cent in North America [10]-[13]. Unfortunately, we don't have enough data for the Arab countries though we are one of the highest countries in motor vehicle accidents with more than 9000 deaths per year.

As a result of this high mortality rate, emergency surgery was frequently indicated in patients with hepatic injury in the past. However, advances in diagnostic imaging, better monitoring facilities and the introduction of damage control strategy in trauma has influenced our approach in the management of liver trauma [14].

## 2. Anatomy

In this part we will describe the anatomy of the liver and its attachments in relation to what is needed in liver trauma, to achieve good mobilization with haemorrhage control to reach the first stage of damage control.

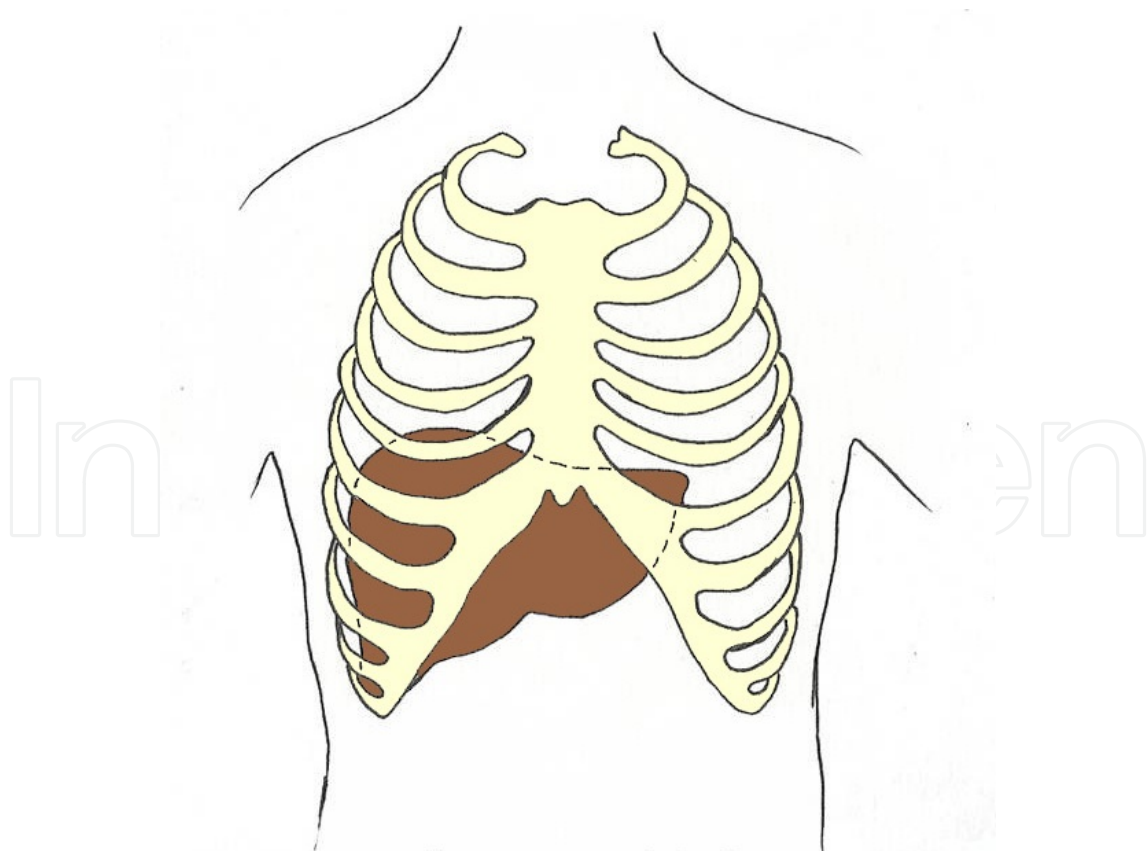
### 2.1. Surface anatomy

It's important to know the location of the liver and its surface anatomy to be able to choose the best incision, to determine if it is involved in a penetrating trauma, and to think of it when you have a chest trauma especially on the right lower chest. When viewed from the front (fig. 1), the normal liver surface markings are [15]:

Upper margin: at the xiphisternal joint arching upwards on both sides. On the left it runs for 7-8cm from the mid-line. On the right, it reaches the fifth rib.

Right boarder: it curves downward from the seventh to the eleventh rib in the mid axillary line.

Inferior boarder: along a line that joins both right lower and upper left points.



**Figure 1.** Surface anatomy of the liver

## 2.2. Gross anatomy

The liver has three surfaces [16]

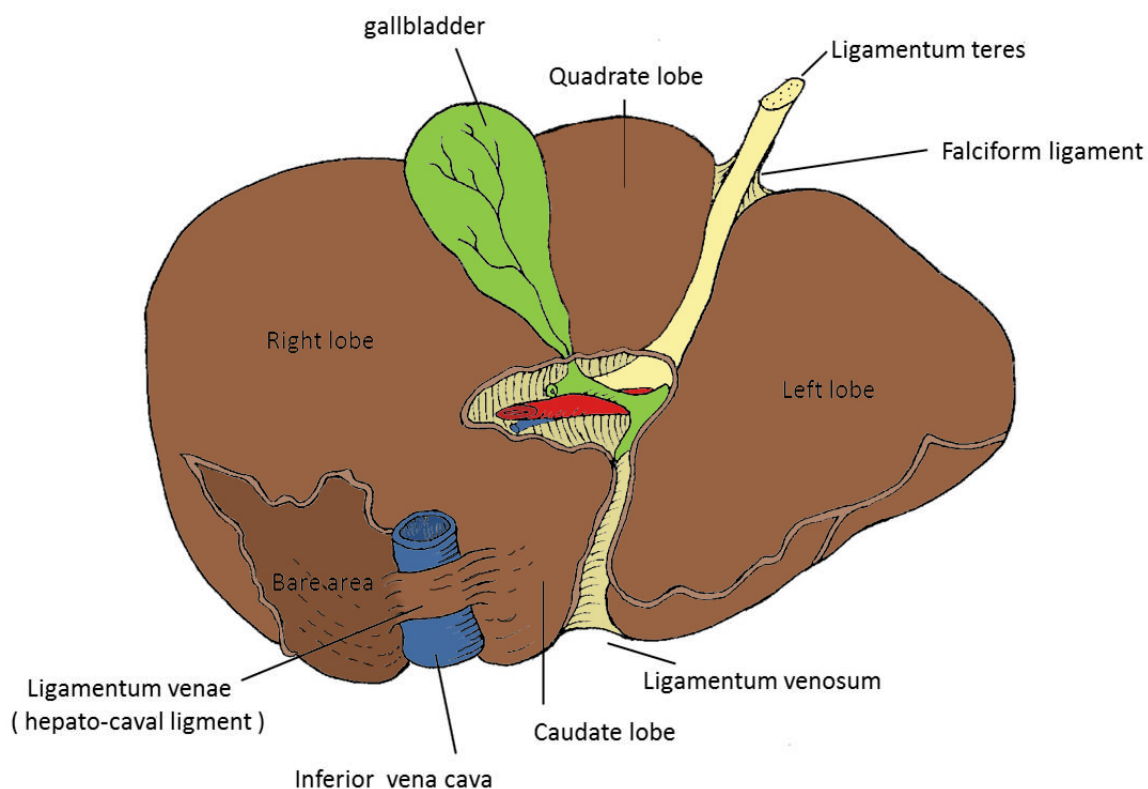
- Diaphragmatic Surface:

This is covered with peritoneum to act as a sheath around the liver. In the midline the falciform ligament is attached and divides the liver into the right and left anatomical liver, or better described it runs between the left lateral section (segment 2 and 3) and the left medial section (segment 4).

- Visceral Surface:

The sharp inferior border of the liver joins the diaphragmatic surface with the visceral surface of the liver. The main structures are lined in an H shaped. The cross part is made of the porta hepatis (hilum of the liver). The right limb is made of the inferior vena cava. The left limb is made of the continuity of the fissures for the ligamentum teres anteriorly and the ligamentum venosum posteriorly. On the left side lies the caudate lobe and on the right lies the bare area of the liver.

- Posterior Surface (fig 2):

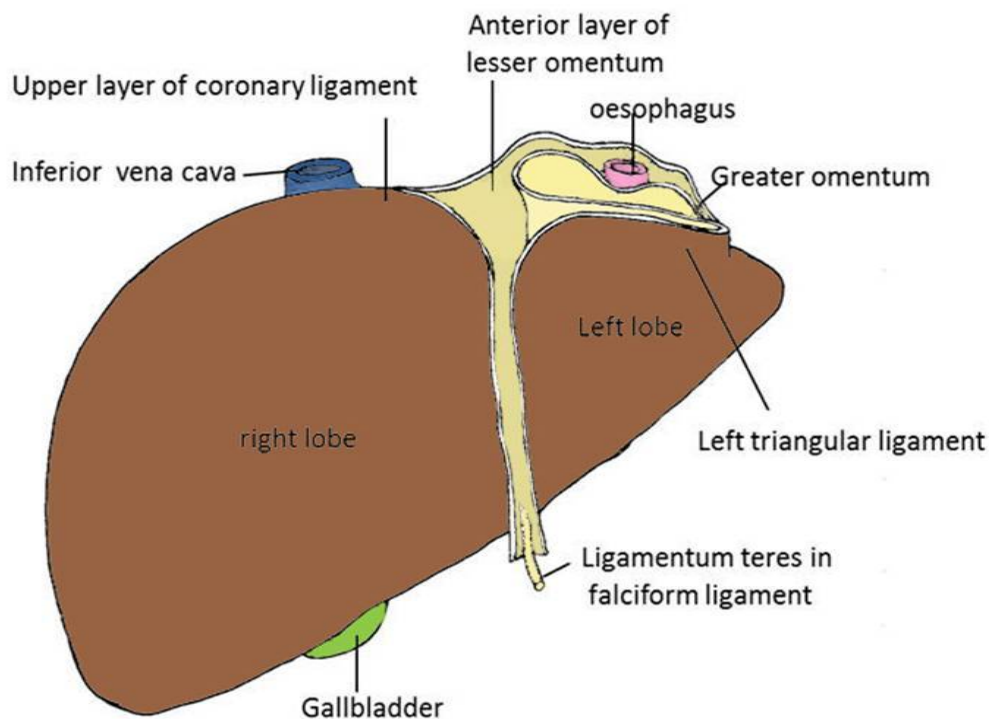


**Figure 2.** Visceral surface of the Liver

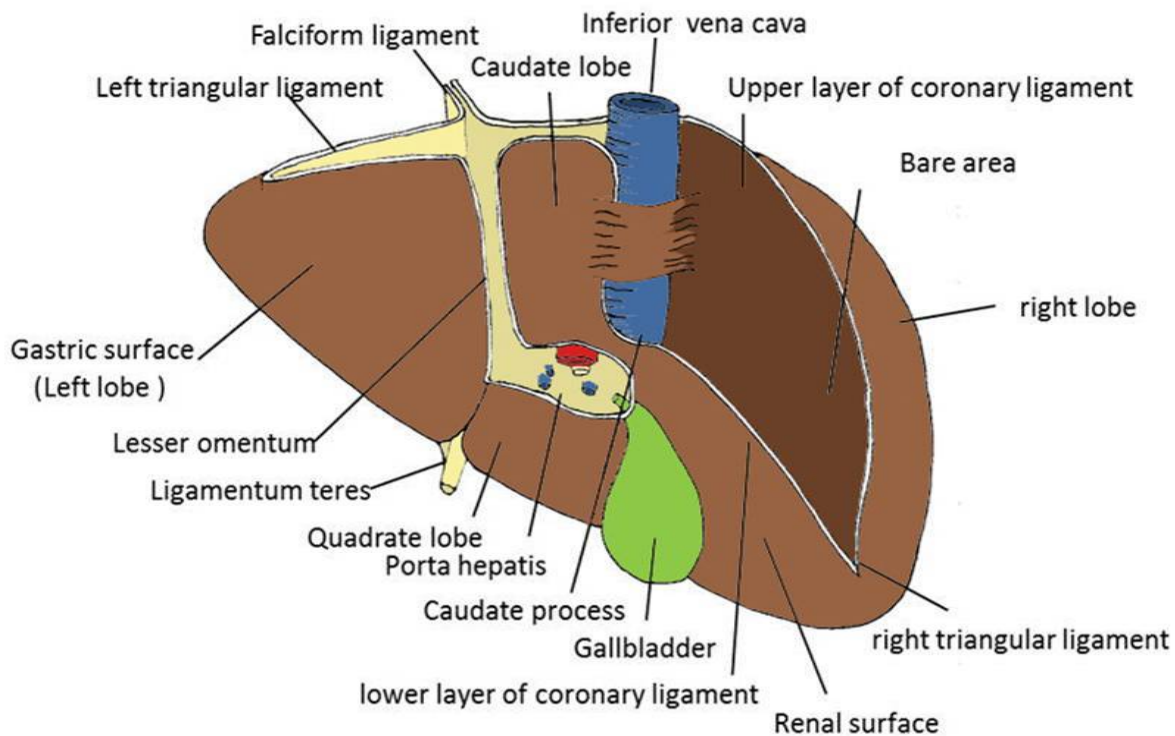
The IVC runs in the centre of the posterior surface. A fibrous band called the ligamentum venae cavae (hepato-caval ligament) covers part of the IVC posteriorly. The rest of the posterior surface is made of by the ligaments (the left and right triangular ligaments, and the coronary ligament) which attach the liver to the diaphragm.

### 2.3. Ligaments of the liver

The falciform ligament consists of two closely layers of peritoneum. The ligamentum teres runs on its free edge with a small paraumbilical vein. On the right it forms the upper layer of the coronary ligament, which continues inferiorly to form the right triangular ligament, then to the lower coronary ligament. On the left, the falciform ligament forms the anterior layer of the left triangular ligament. (fig 3 & 4)



**Figure 3.** Diaphragmatic surface of the liver and its ligaments



**Figure 4.** Posterior surface of the liver and its ligaments

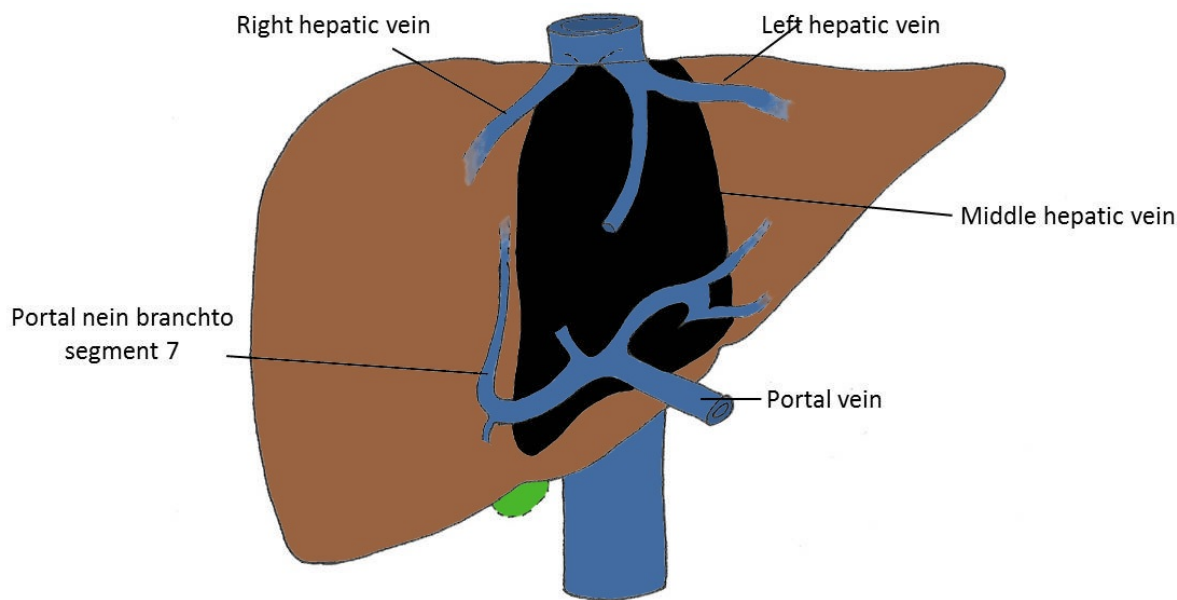
## 2.4. Caudate lobe

The caudate lobe is the dorsal portion of the liver lying posteriorly and embracing the retrohepatic IVC in a semi circumferential fashion. It lies between the IVC posteriorly, the portal triad inferiorly and the hepatic veins superiorly. There is a series of short hepatic veins which drains directly from the caudate lobe to the retrohepatic IVC. Thus it is surrounded by important structures that can be involved in liver trauma 17 (Fig 5).

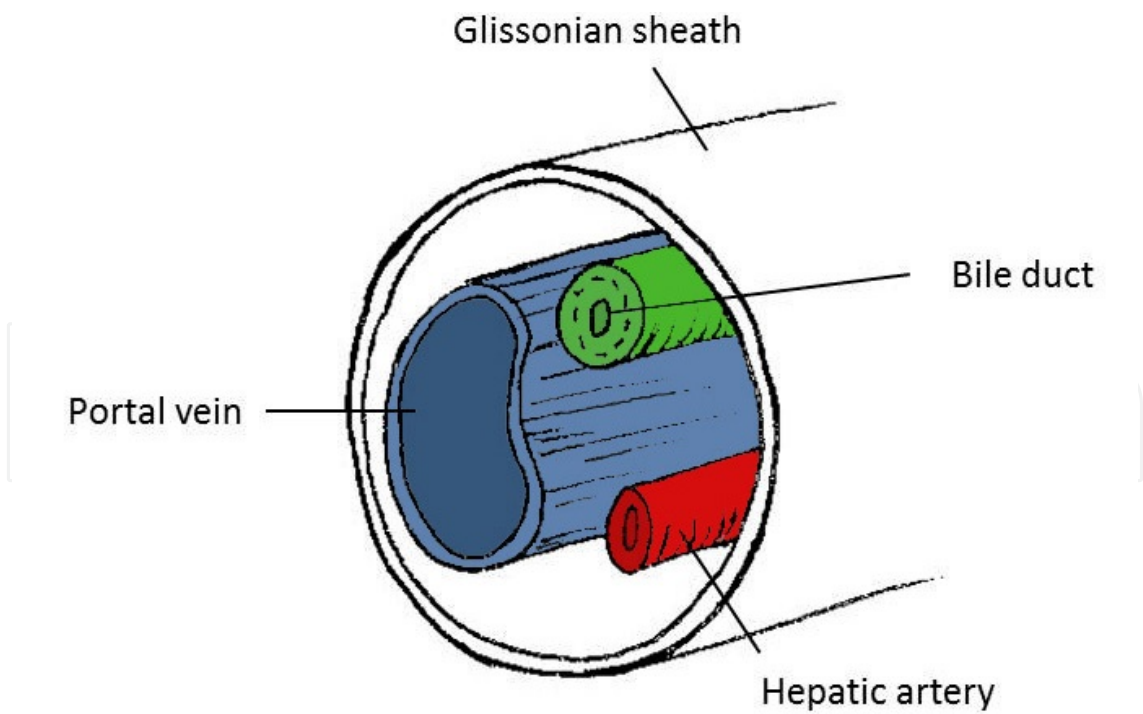
## 2.5. The glissonian sheath

Glisson's capsule which covers the liver extends into the liver at the hilus and covers the portal triad where it is called the Glisson's sheath. With relation to liver trauma it is important to know only the extrahepatic portion of the Glissonian pedicle which is called the hepatoduodenal ligament. This is very important when a Pringle manoeuvre is needed. It usually composed of connective tissue and peritoneum up to the hepatic hilum. They surround the portal vein posteriorly, the hepatic artery anteriorly and to the left, and the common bile duct anteriorly and to the right (fig 6) 18.





**Figure 5.** The caudate lobe: front view



**Figure 6.** Structures within the glissonian sheath

## 2.6. Retrohepatic IVC and its branches (fig 7)

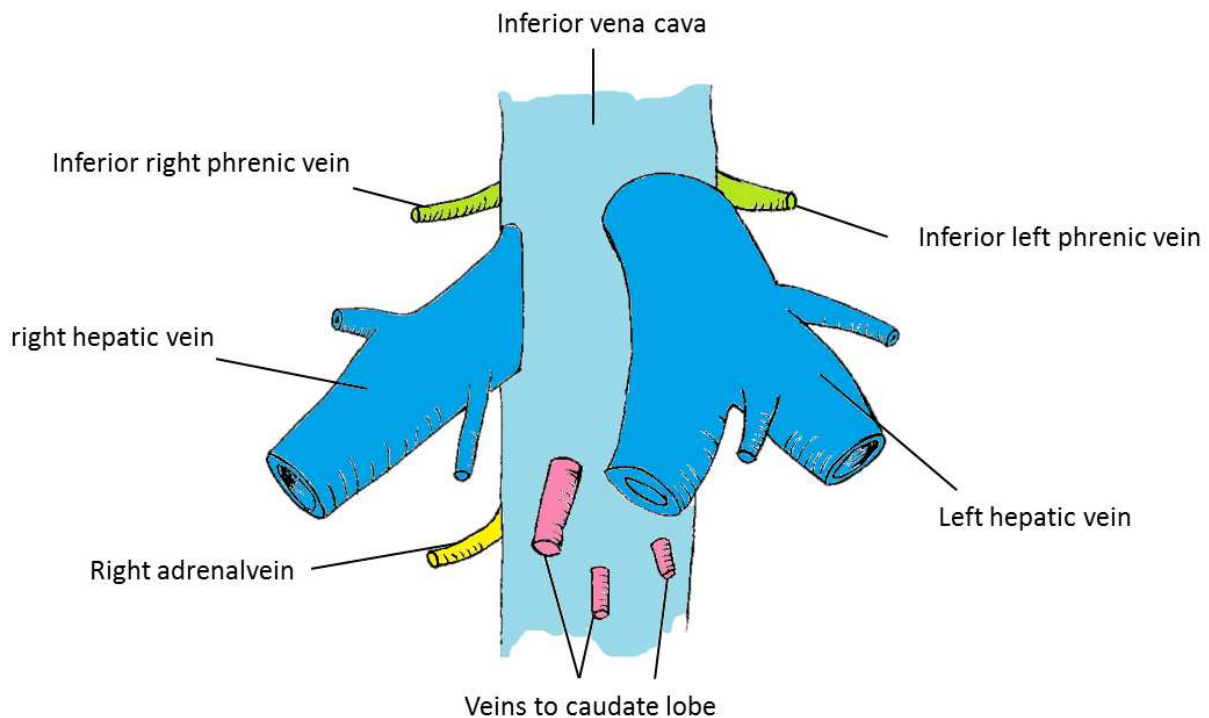
In relation to liver trauma we can divide the retrohepatic IVC into four parts:

The suprahepatic group; which is composed of both right and left inferior phrenic veins which drain the right and left diaphragm.

The hepatic veins; which are composed of the right, middle and left hepatic vein. There are multiple variations that can exist and its knowledge is important in liver surgery.

The retrohepatic group; which is composed of short veins that drain part of the right hemi-liver and the caudate lobe directly into the IVC. These veins are short and very fragile and are prone to injury.

Lastly, the infrahepatic group; which consists mainly of both the right and left adrenal veins. These veins are frequently injured in trauma and if not considered during mobilizing the right liver [19].



**Figure 7.** The abdominal inferior vena cava and its suprahepatic branches



### 3. Mechanism

Penetrating and blunt trauma are the two principal mechanisms for liver trauma. Motor vehicle accidents account for the majority of blunt trauma, whereas knife and gunshot wounds constitute the major cause of penetrating injuries.

Two types of blunt liver trauma have been described: deceleration (shearing) injuries occur in motor vehicle accidents and in falls from a height where there is movement of the liver in its relatively fixed position, thereby producing a laceration of its relatively thin capsule and parenchyma at the sites of attachment to the diaphragm[13].

The other type of liver injuries is crush injury. Crush injuries follow direct trauma to the abdomen over the liver area. Decelerating injuries typically create lacerations between the right posterior section (segments 6 and 7) and the right anterior section (segments 5 and 8), which can extend to involve major vessels. Crush injuries can lead to damage to the central portion of the liver (segment 4, 5 and 8) and also may cause bleeding from the caudate lobe (segment 1)[12]-[13]. Blunt trauma can cause parenchymal hepatic injury with intact Glisson's capsule, leading to an intraparenchymal or subcapsular haematoma[12]-[13].

Penetrating injuries are usually associated with gunshot or stab wounds, with the former usually resulting in more tissue damage due to the cavitation effect as the bullet traverses the liver substance [13]-[20]. These injuries usually require surgery more often than blunt injuries when the liver is involved.

### 4. Diagnosis

Signs and symptoms of hepatic injuries are related to the amount of blood loss, peritoneal irritation, right upper quadrant tenderness, and guarding. Rebound abdominal tenderness is common but nonspecific. Occasionally, patients with blunt abdominal trauma do well initially, but they subsequently develop a liver abscess, presumably due to unrecognized liver damage. These patients present with signs and symptoms of deep-seated infection [21]. Patients may present with severe peritonism due to bile peritonitis resulting from bile leaks. Signs of blood loss, such as shock, hypotension, and a falling hematocrit level, may dominate the picture [21]. As resuscitation proceeds, a detailed physical examination is carried out. Most conventional texts emphasize the need for a careful history and physical examination of the abdomen. While this is undoubtedly important, it is extremely difficult to assess the abdomen in the trauma situation as the history may not be available and all the existing physical signs are misleading. Fresh blood is not a peritoneal irritant [22]. The mechanism of injury is critically important in assessing the potential for abdominal injury. This information may be obtained from the patient, relatives, police or emergency care personnel [22].

Following initial assessment, a conscious patient, who is haemodynamically unstable following blunt trauma and has generalized peritonism, should undergo immediate laparotomy without further investigation [13]. Urgent laparotomy is also indicated in patients who

have sustained a stab wound to the abdomen and are haemodynamically unstable. If the patient is stable and a liver injury is suspected, imaging studies should be performed [21]-[23]. However, haemodynamically stable patients with suspected liver injury can be investigated at this stage to define the nature of the injury.

Ultrasonography (FAST) has gained increased acceptance, particularly in the emergency department, for the rapid evaluation of patients with blunt or penetrating abdominal trauma [24]-[29]. It is cheap, portable and noninvasive, compare to peritoneal lavage and it does not use radiation or iodinated contrast media [30]-[32]. Its sensitivity for the presence of intra-abdominal fluid in patients with trauma ranges from 75 to 93.8% and the specificity from 97 to 100% [24]-[25]. However, some pitfalls remain in abdominal ultrasonography. Injuries at the dome or lateral segments of the liver can easily be missed with ultrasound, especially in the presence of ileus or if the patient cannot cooperate because of pain. Hepatic laceration or hematomas are usually difficult to distinguish, especially in the acute phase, because they are isoechoic to the normal liver [33]-[34].

Kalogeropoulou and colleagues (2006) demonstrated the usefulness of contrast enhanced ultrasonography in penetrating liver trauma [35]. It increases the sensitivity and the specificity of ultrasound in evaluation of abdominal trauma not only in detection of free peritoneal fluid but also in the visualization of the parenchymal lacerations. The use of contrast in addition to the conventional ultrasound scanning does not significantly prolong the examination time, compared with a contrast enhanced CT scan. Furthermore repeated doses of the contrast can be injected to scan the rest of the solid abdominal organs such spleen and kidneys if a more complex trauma is suspected [35]. However, US is operator dependent, were you may not find an expert ultrasonographer in the middle of the night. In addition, US contrast is not widely available in every casualty.

Computed tomography (CT) is the gold standard investigation for the evaluation of a stable patient with suspected liver trauma [36]-[39]. CT has high sensitivity and specificity for detecting liver injuries which increase as the time between injury and scanning increases, evidently because haematomas and lacerations become better defined [40]. Contrast-enhanced CT, is accurate in localizing the site and extent of liver and associated injuries, providing vital information for treatment in patients. CT without intravenous contrast enhancement is of limited value in hepatic trauma, but it can be useful in identifying or following up a hemoperitoneum [41]-[43].

CT scanning allows reasonably accurate grading of liver injuries and provides crude quantitation of the degree of hemoperitoneum. CT scanning is mandatory for patients with blunt trauma whose liver injury is to be managed nonoperatively. CT has also been useful for detecting missile tracts in penetrating trauma patients. Such information is imperative for surgeons who want to attempt nonoperative management of penetrating wounds [44]-[47]

Although CT is very useful in the evaluation of stable patients with abdominal trauma, most authors agree that unstable patients, with either blunt or penetrating trauma, are unlikely to benefit from this investigation because of the valuable time that it requires [44] (Fig 8)



**Figure 8.** A CT demonstrating a grade 4 liver injury that was treated surgically

False-positive errors in the diagnosis of liver injury with CT scans may occur as a result of beam-hardening artifacts from adjacent ribs, which can mimic contusion or hematoma. An air-contrast level within the stomach in a patient with a nasogastric tube can produce streak artifacts throughout the left lateral section of the liver; these may mimic intrahepatic lacerations and/or hemorrhage. The nature of these artifacts can be confirmed if the patient is scanned in a decubitus position [48].

False-negative findings may occur in the setting of a fatty liver only when contrast-enhanced CT scan are obtained. On these images, the enhanced fatty liver may become isoattenuating relative to the laceration or hematoma. In this situation, a nonenhanced CT scan may provide useful information regarding hepatic injury. Focal fatty infiltration may also mimic hepatic hematoma, laceration, or infarction. Hepatic lacerations with a branching pattern can mimic unopacified portal or hepatic veins or dilated intrahepatic bile ducts. Careful evaluation of all branching intrahepatic structures is important and the diagnosis is made with serial images to differentiate the various structures [48]-[49]

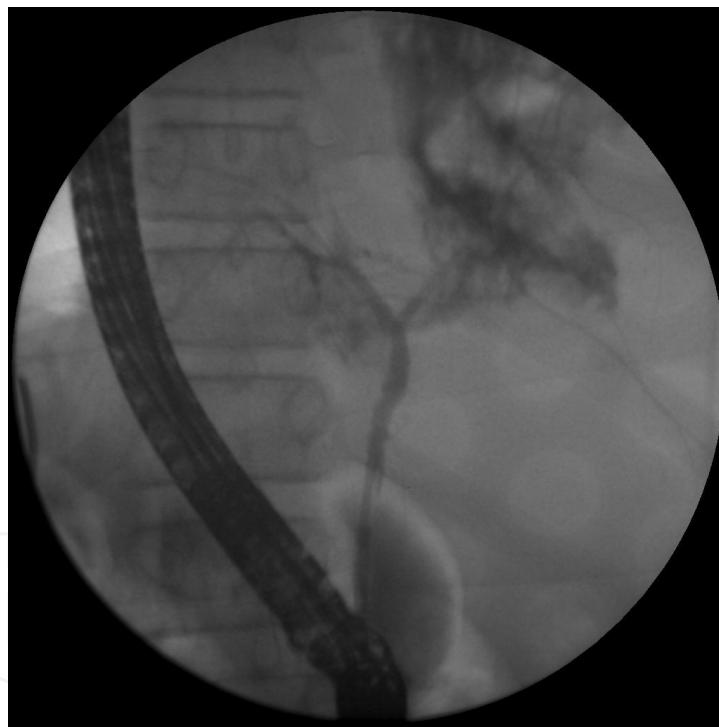
MRI has a limited role in the evaluation of blunt abdominal trauma, and it has no advantage over CT scanning. Theoretically, MRI can be used in follow-up monitoring of patients with blunt abdominal trauma, and MRI may be useful in young and pregnant women with abdominal trauma in whom the radiation dose is a concern [6], [50].

MRCP has been used in the assessment of pancreatic duct trauma and its sequelae, and it can be used to image biliary trauma. Another potential use of MRI is in patients with renal failure and in patients who are allergic to radiographic contrast medium. MRI offers no sig-

nificant advantage over CT scanning for routine evaluation of acute abdominal trauma. Experience is insufficient for assessing the value of the special circumstances mentioned above. Sufficient experience has not been gained in the use of MRI to establish false-positive and false-negative findings [6]

Angiography has no role in the evaluation of unstable patients. However, if the patient is stable, cross-sectional imaging may provide sufficient detail to treat the patient conservatively. A dynamic angiographic study may demonstrate the site of active bleeding. This when combined with angiographic embolization, especially in high-grade liver injury is of significant value and may be the only treatment required [51]-[52]. Although angiography is useful in selected patients, both false-positive and false-negative results occur in patients with hepatic trauma [6]

Endoscopic retrograde cholangiopancreatography (ERCP) may help in the delineation of the biliary tree in patient with liver trauma, and stents may be used to treat biliary Leaks [53]-[54] (Fig 9).



**Figure 9.** ERCP demonstrating a bile leak from the main right duct

Diagnostic laparoscopy has been used successfully in patients with abdominal trauma [55]-[58], and laparoscopic fibrin glue in managing liver injuries has also been reported [60]. The benefits of laparoscopic assessment include reducing negative and non-therapeutic laparotomy rates, patient morbidity rates, hospital stay and treatment costs [56]-[57]. Raphael and colleagues(1999) reviewed 37 studies with more than 1,900 trauma patients (including those with liver trauma), and laparoscopy was analyzed as a screening, diagnostic, or therapeutic

tool. They came out with the conclusion that "Laparoscopy has been applied safely and effectively as a screening tool in stable patients with acute trauma. Because of the large number of missed injuries when used as a diagnostic tool, its value in this context is limited. Laparoscopy has been reported infrequently as a therapeutic tool in selected patients, and its use in this context requires further study.[61].

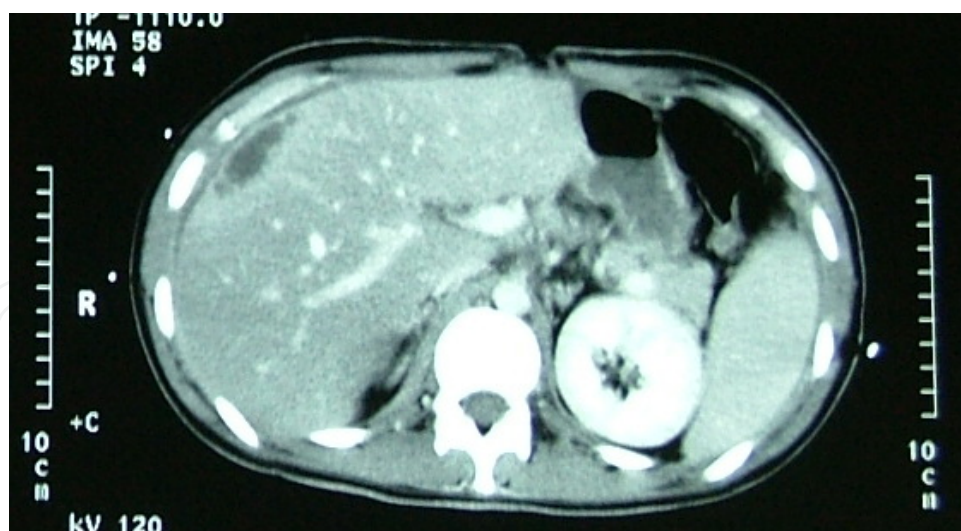
### 5. Classification of liver injury

Liver trauma ranges from a minor capsular tear, with or without parenchymal injury, to extensive disruption involving both hemi liver with associated hepatic vein or vena caval injury. In 1989, the Organ Injury Scaling Committee of the American Association for the Surgery of Trauma produced a Hepatic Injury Scale [62] by which hepatic injuries are described in most major trauma centers (Table 1). Grade I or II injuries are considered minor; they represent 80-90 per cent of all cases and usually require minimal or no operative treatment [1], [63]. Grade III-V injuries are generally considered severe and often require surgical intervention, while grade VI injuries are regarded as incompatible with survival.

| Grade        | Type of Injury         | Description of injury   |
|--------------|------------------------|---|
| I (fig 10)   | Hematoma<br>Laceration | Subcapsular, < 10% surface area<br>Capsular tear, < 1cm parenchymal depth   |
| II (Fig 11)  | Hematoma<br>Laceration | Subcapsular, 10% to 50% surface area<br>Capsular tear, 1-3cm parenchymal depth and < 10cm in length                                   |
| III (Fig 12) | Hematoma<br>Laceration | Subcapsular, > 50% surface area or expanding<br>Intraparenchymal hematoma > 2cm or expanding<br>Capsular tear, >3cm parenchymal depth |
| IV (Fig 13)  | Hematoma<br>Laceration | Ruptured intraparenchymal hematoma with active bleeding<br>Parenchymal disruption involving 25-50% of hepatic lobe                    |
| V            | Laceration<br>Vascular | Parenchymal disruption involving >50% of hepatic lobe<br>Juxtahepatic venous injuries   |
| VI           | Vascular               | Hepatic avulsion  |

**Table 1.** Classification of liver injury



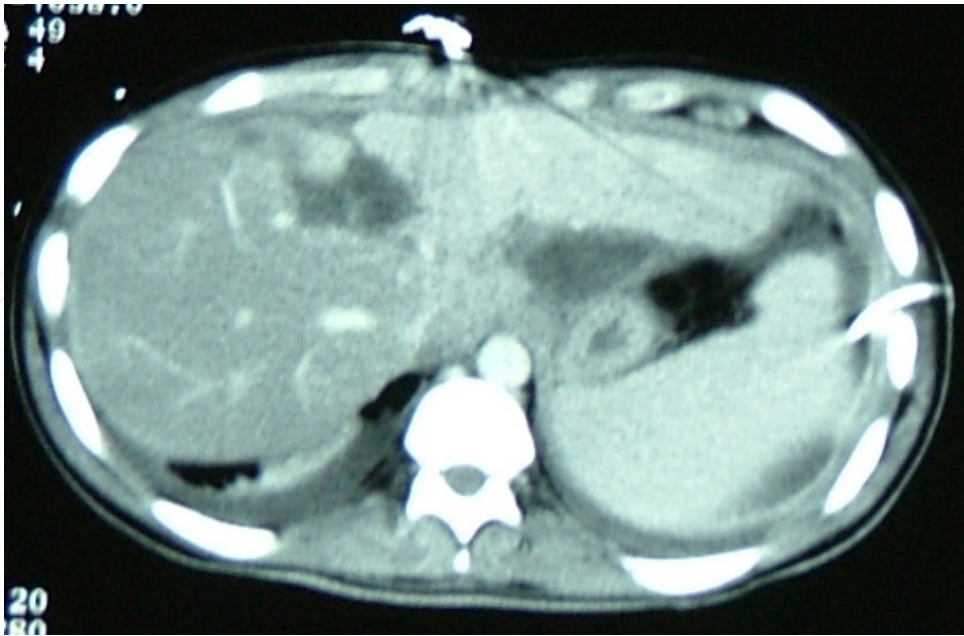


**Figure 10.** Grade 1 liver injury treated non surgically



**Figure 11.** Grade 2 liver injury





**Figure 12.** Grade 3 liver injury that was treated non surgically



**Figure 13.** Grade 4 liver injury that was treated non surgically

## 6. Management

### 6.1. Non operative

The countercurrent argument was that nonoperative treatment (NOM) was associated with virtually a 100% mortality rate, so all patients with suspected or diagnosed liver injuries must have an operation. Improved mortality rates during and after World War II assured the primacy of operative treatment [64].

Three observations prompted the move towards nonoperative treatment. First, the practice of nonoperative treatment was initially advocated for splenic injuries and then extended to the liver. The success in children led to attempts of nonoperative treatment in adults [65]-[66] Second, the high rate of nontherapeutic operations in many patients with blunt hepatic injuries was not in patients' best interest. Third, the advent of CT scanning greatly facilitated both diagnosis and grading of injuries and gave some reassurance that the intestinal injuries had not occurred.

There has been several reports started since 1985, were Trunkey *etal* [67], defined the criteria for NOM:

- haemodynamic stability
- absence of peritoneal sign
- Availability of CT
- Monitor in ICU
- Facility of immediate surgery
- Absence of other organ injuries

These criteria has become more and more less strict, were multiple reports are trending more to NOM [3]. There is no time limit for NOM, continues monitoring is the only key to take the patient to the operating room [68]. Other reports even went to the extreme as if the patient had risk factors by the injury severity score (ISS) [69] and all patients should be treated first by NOM regardless of their trauma [70]. However, all of these reports mentioned that this is possible with the addition of angiography and embolization that made the NOM more feasible and more successful.

The success rate of nonoperative treatment has been remarkably high. The necessity for operations for ongoing hemorrhage has been reported to be from 5% to 15%. There remains a concern over missed bowel injuries that have been reported from 1% to 3%.[71]-[75].

Nonoperative treatment of abdominal stab wounds has been practiced successfully in numerous centers and is on the rise. NOM of gunshot wounds has been more controversial, however, many reports are calling to add these group of patients to the NOM group [76]-[79] Demetriades and colleagues(2006) reported 152 patients with penetrating solid organ injuries. 28.4% of all liver injuries were successfully managed nonoperatively [80]. However,

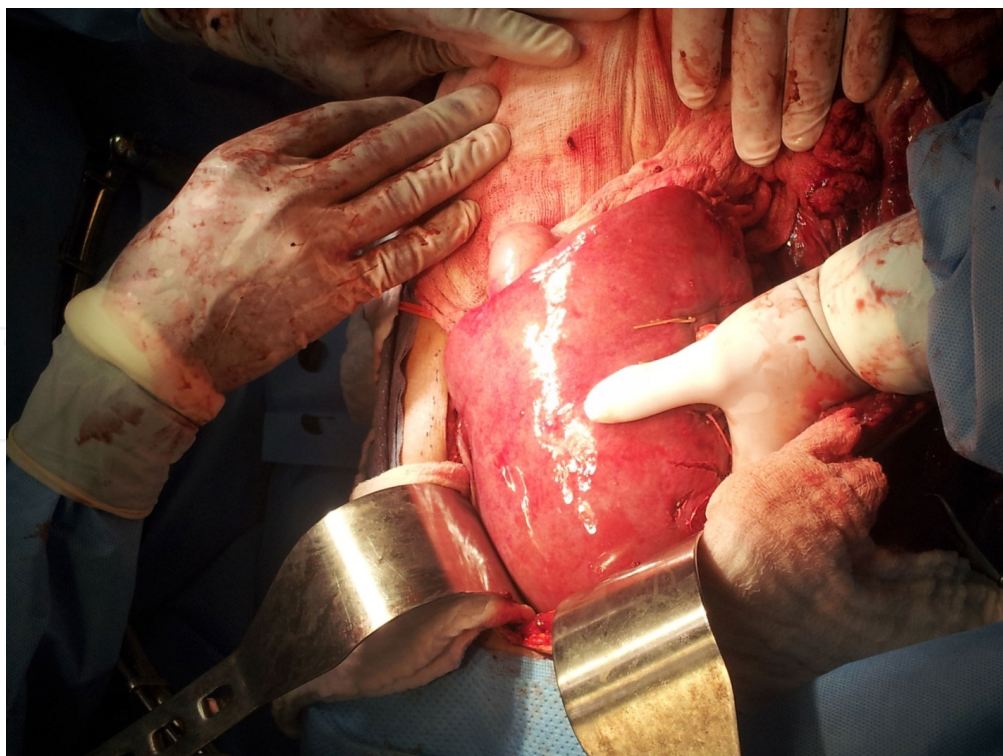
in the last few years NOM has emerged a huge mile stone. Appropriately selected patients with liver gunshot injuries deemed feasible, safe, and effective, regardless of the liver injury severity [77]. However, they all mentioned that CT scan was mandatory before adopting the NOM. Another report stated that regardless of the grade of liver trauma, NOM is safe and effective in appropriately selected patients with liver gun shoot injuries treated in centers with suitable facilities [79].

## 6.2. Operative

### 6.2.1. Damage control surgery

As the first intention when taking the patient to the operating room is to do damage control surgery (DCS). This usually implies saving the patient's life and stopping the bleeding. This will make the patient more stable and in a better physiologically and hemodynamically state to be able to have the definitive treatment.

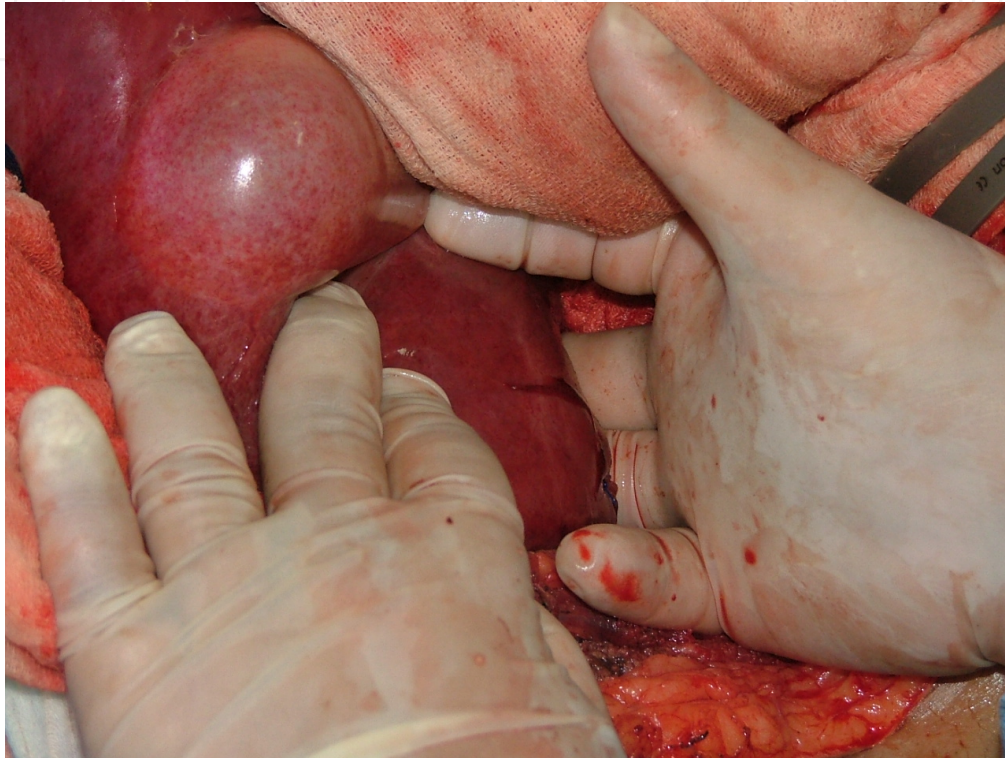
Skin preparation should allow for extension of a midline abdominal incision to a median sternotomy or right thoracotomy, if necessary, for adequate exposure of posterior liver injuries [81]-[82]. If the indication for surgery is an obvious penetrating through-and-through liver injury, or the patient failed the NOM and is clear liver injury only a bilateral subcostal incision is a useful alternative and has been adopted by some to have better liver exposure (fig 14).



**Figure 14.** Mobilization of the right hemi-liver to achieve excellent exposure of the injury



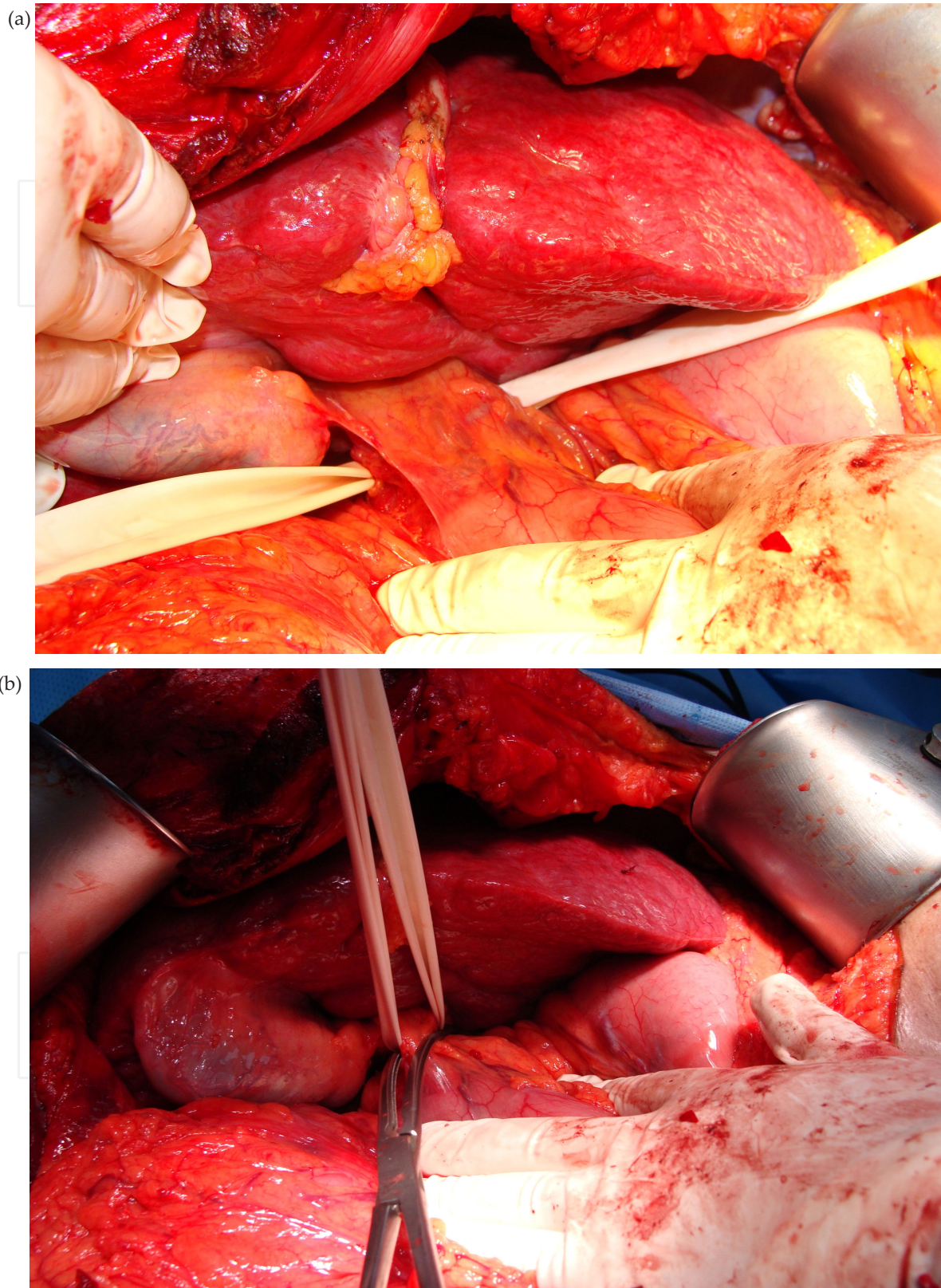
DCS includes perihepatic packing and partial abdominal closure or Bogota bag. Usually an average of six laparotomy pads can be packed to get the tamponade effect between the liver and the abdominal wall. The timing of re-exploration is controversy but usually 12-24 hours is safe time for re-exploration were the patients condition permits (fig 15).



**Figure 15.** Packs as it was done in the first DCS were the bleeding stopped, fingers demonstrating the liver laceration

Even 30 years after the resurrection of packing as a treatment alternative, it remains an important part of the armamentarium of surgeons in managing difficult hepatic injuries. It is always better to have a patient with packs to come and deal with on another day, than trying to stop the bleeding with no success, especially if the surgeon has limited experience, which usually happens in the first operation. As many hospitals have a general surgeon on-call with limited liver or trauma experience.

If a major liver injury is encountered, initial control of bleeding can be achieved with temporary tamponade of the right upper quadrant using packs, portal triad occlusion (Pringle manoeuvre) (Fig 16a &b), bimanual compression of the liver or even manual compression of the abdominal aorta above the coeliac trunk [83]-[84]. Attempts to evaluate the liver injury before adequate resuscitation may result in further blood loss and worsening hypotension.



**Figure 16.** a. Tape inserted around the portal triad. b. Pringles manouver were the clamp is gently applied to occlude the portal triad



Digital compression of the portal triad (Pringle manoeuvre) can be used diagnostically and compression can be maintained with an atraumatic vascular clamp if haemorrhage decreases [85]. The clamp should be occluded only to the degree necessary to compress the blood vessels in order not to injure the common bile duct. If haemorrhage is unaffected by portal triad occlusion, major vena cava injury or atypical vascular anatomy should be suspected [86-87]. Although the permitted occlusion time of the portal triad is controversial, most authors now agree that clamping of the hepatic pedicle for up to 1h is well tolerated with no adverse effects on liver function [81],[88].

After initial intraoperative resuscitation, the liver must be mobilized adequately to allow a thorough examination of the damaged area, unless the injury is already accessible through the incision [81,84,89]. The liver is mobilized by dividing the falciform, triangular and coronary ligaments, and by placing abdominal packs posteriorly to maintain this position [90]. This manoeuvre allows the surgeon to determine the nature and severity of the injury and to decide on the necessary surgical technique. Care should be taken to avoid impairing venous return, by either excessive lifting and/or rotation of the mobilized liver, or excessive packing causing caval compression [90].

There are several tricks to stop the bleeding other than the one mentioned before, however we advise that most of these should be done by experienced surgeons in a stable patient or if the patient is still bleeding after trying the previous methods mentioned. Several specific modalities began to be used more often to treat arterial bleeding. Hepatorrhaphy was used with increased frequency. When the arterial bleeding occurred deep within the hepatic parenchyma, a tractotomy was advocated to expose and suture ligate the arterial flow. But control of deep arterial bleeding was often technically difficult to accomplish.[91]-[93]

In response to futile attempts to directly suture ligate arterial bleeding, Dr Aaron's group performed ligation of the hepatic artery.[94] Initially performed at the Louisville General Hospital to control arterial hemorrhage from a ruptured hepatic adenoma, Mays found this technique useful to control arterial bleeding in trauma patients. A literal explosion in its use occurred in Louisville, and surgeons there proposed it to prevent rebleeding.[95]-[96] A high rate of infection led to reconsideration of its use, and it was subsequently used less frequently [103], although it remained an operation that could occasionally be life-saving.[97-98]

Major venous bleeding was recognized as a major source of mortality, particularly in patients who had been in high-speed motor vehicle crashes. The nearly uniform lethality of retrohepatic vena caval injuries with attempt at direct repair led to the development of the atriocaval shunt. This technique, developed by Schrock and associates, [99] theoretically bypassed the caval injury and allowed direct suture repair of the cava itself and main hepatic veins. The operation required opening the chest to expose the atria. This bicavitary exposure accelerated hypothermia and coagulopathy in many patients. Consequently, the mortality rate remained high, but the concept of direct repair of this deadly injury was very important.



Both previously mentioned bleeding problems often were treated initially with temporary inflow occlusion by clamping the portal triad. The concept of inflow occlusion actually predated Pringle, [85] but his work published in 1908 was rediscovered and popularized in the 1960s after rarely being mentioned in the literature for more than 50 years.

Diffuse bleeding from damaged or devitalized liver increasingly required surgical treatment. Reports on civilian liver injuries from the 1950s generally cautioned against debridement of damaged liver for fear it would worsen preexisting hemorrhage. Absorbable gauze packing and drainage were mostly used for this problem. As the forces of injury increased, other techniques were required.

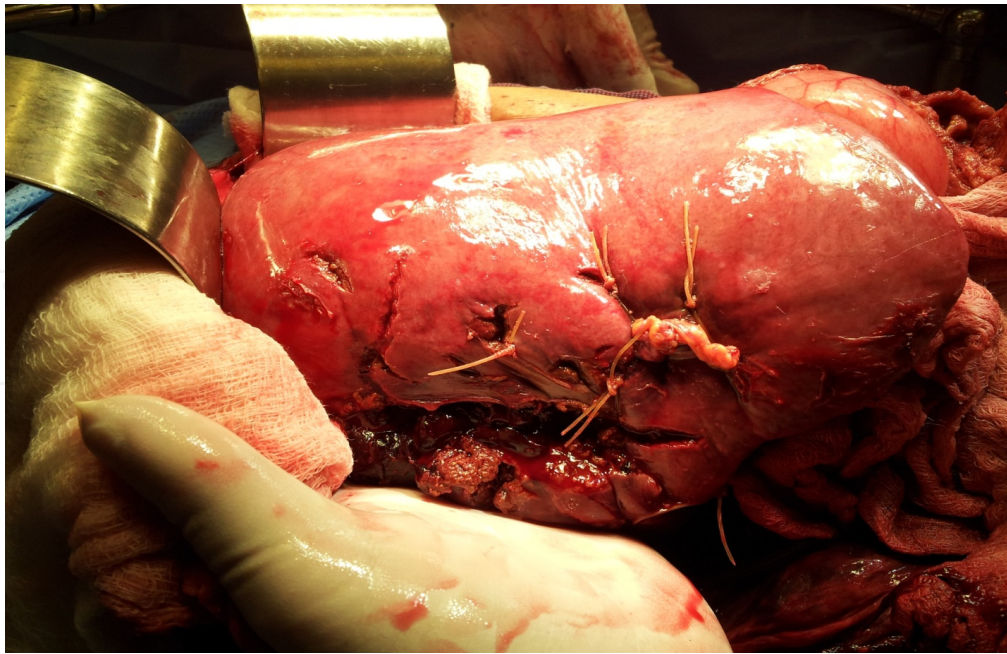
Resectioned debridement was increasingly used. There was a brief flurry of activity with use of major anatomic resections, but the high mortality rate of this procedure led to discontinuing its use in most centers.[100]-[101] The omental pedicle described for liver injury in 1910 and mentioned occasionally through the years was reintroduced by Stone and Lamb[102] and gained widespread popularity.

In summary; as a general surgeon facing a major hepatic injury in the middle of the night think of NOM and try not to rush to the operating room unless clearly indicated. However, if you were forced to the operating room do the minimal to stop the bleeding (DCS). If major procedure is required, the decision must be made early in the operation were technical /clinical expertise and speed are critical. Plan definitive surgeries in a stable patient were optimal condition ably.

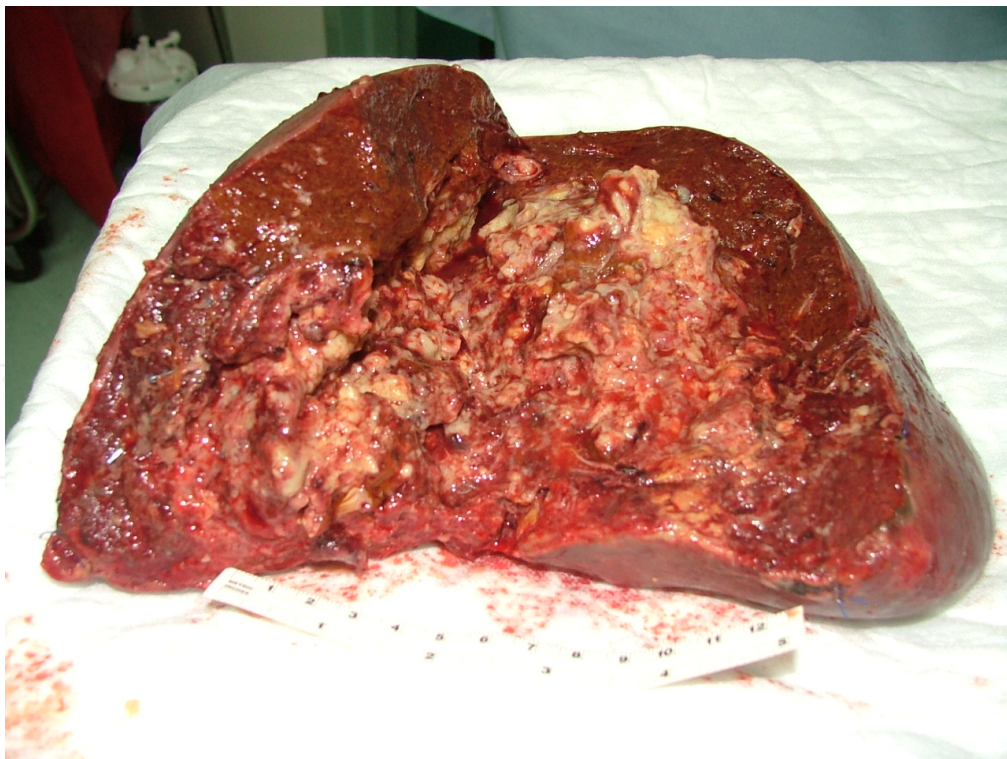
#### 6.2.2. *Definitive surgery*

This is usually carried out in a stable patient by an experienced surgeon at a second stage to deal with a certain problem (Fig 17). One of the commonest problem is bile leak and collection with an incidence of 6-20 %. This is usually after the patient recovered, were they develop an intra-abdominal collection that is best treated by a radiological applied drain. Then it can be investigated by MRCP or ERCP. The MRCP is non invasive, however with the collection it can have very little input. ERCP is advocated by some to be much better were the leak is identified and can be treated by sphinctrotomy and a stent [104] with very high success rate [105]. However, some of these patients fail and require surgical ligation of the leak which is much easier when the location is identified pre-operatively and a stent is in place to increase the success rate.

Another reason to go to the operating room is liver necrosis and abscess formation that occurs when bleeding stoops and demarcation of the live is obvious. Liver necrosis might increase with attempts to stop the bleeding with angioembolization in NOM or by arterial ligation and packing in DCS. The best option will be to drain the abscess radiologically were this might be sufficient. However, if not we advise operative drainage and an anatomical liver resection to maintain adequate live tissue and maintain a good vascular supply. This should be carried out by an experienced liver surgeon to get the best result (Fig 18).



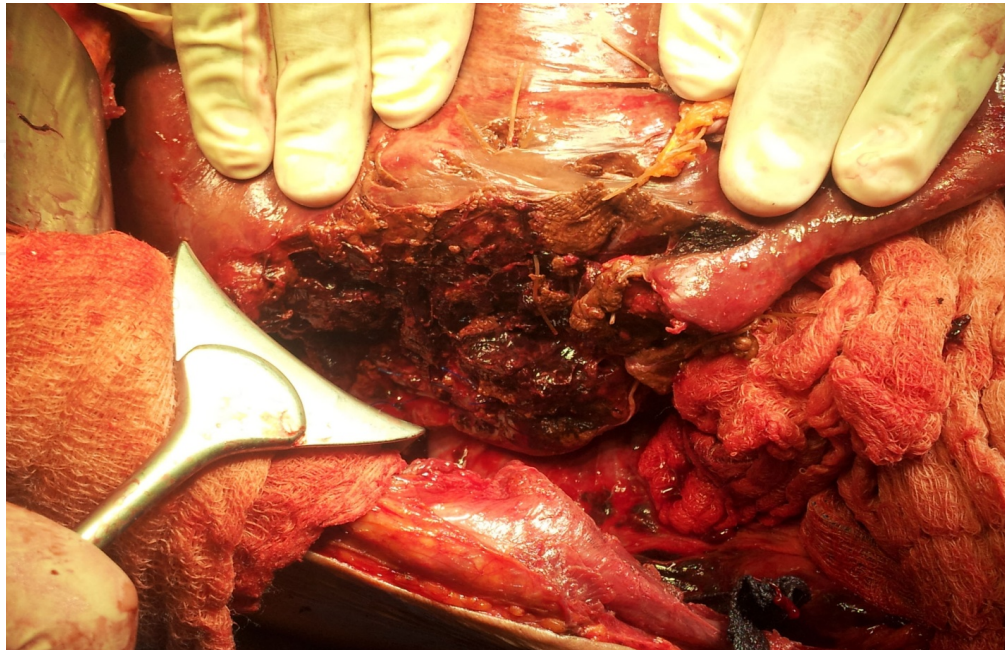
**Figure 17.** Full mobilization in a second look operation to stop the bleeding and to do definitive surgery.



**Figure 18.** Liver necrosis following embolization with NOM for bleeding. The patient was treated by right hemi hepatectomy because the necrosis could not be drained radiologically.



Liver resection might be necessary with reported frequency of 2% to 5% in most series, with an overall mortality of 17.8% and morbidity around 30%.[106-108] (Fig 19).



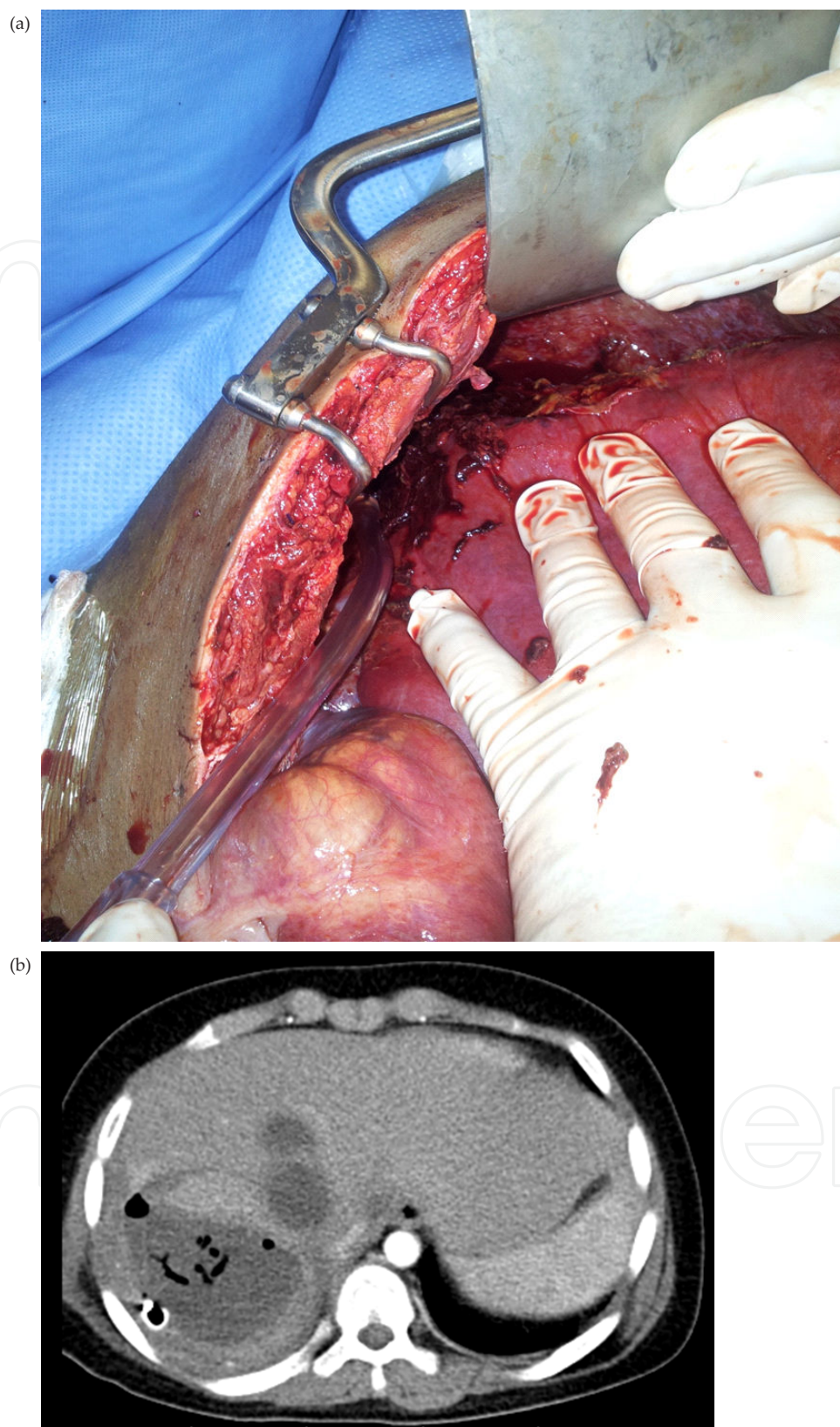
**Figure 19.** Liver trauma which was treated with a right posterior sectionectomy (seg 6&7)

Liver transplantation has been reported in the literature as an extreme intervention in cases of severe and complicated hepatic trauma. The main indications for liver transplant in such cases were uncontrollable bleeding and postoperative hepatic insufficiency. Liver transplant for trauma is a rare condition with 20 cases described in the literature [109]. Esquivel *et al.* first reported the use of liver transplantation in two patients with progressive hepatic failure and uncontrollable bleeding. [110]. The transplant decision is difficult because usual criteria are not validated, liver's potential recovery is difficult to evaluate and sepsis and head injuries often associated, complicating the decision because of their own prognosis. [111].

## 7. Complications

### 7.1. Non operative

The most common complication of NOM is failure, ending with the patient in the operating room. This is even more serious, because the patient most of the time is in a worse state than what he was and bleeding (the leading cause) is still ongoing. This also is more profound if it occurs in the middle of the night or with a surgeon of limited liver expertise. It should be borne in mind that this most common complication usually arises as a result of inappropriate selection of a patient for conservative management [23]. The failure rate ranges from 6-10% [68, 112] especially when it was combined with arterial embolization, however, the incidence of liver necrosis was higher [113] (Fig 20a &b).



**Figure 20.** a. Failed NOM showing the bleeding from the liver dome. b. Same patient with grade 4 liver injury that failed NOM, drain left in place.

Complications can arise from injuries that have not been recognized at the time of initial presentation or /and become apparent after initial delay. Associated injuries seem to be the most important factors predisposing to postoperative problems [114]-[117].

In a recent multicenter study, hepatic complications developed in 5% (13 of 264) of patients with grade 3 injuries, 22% (36 of 166) of patients with grade 4 injuries, and 52% (12 of 23) of patients with grade 5 injuries. Univariate analysis revealed 24-hour crystalloid, total and first 24-hour packed red blood cells, fresh frozen plasma, platelet, and cryoprecipitate requirements and liver injury grade to be significant, but only liver injury grade and 24-hour transfusion requirement predicted complications by multivariable analysis. They came out with the Conclusion that NOM of high-grade liver injuries is associated with significant morbidity and correlates with grade of liver injury. Screening patients with transfusion requirements and high-grade injuries may result in earlier diagnosis and treatment of hepatic-related complications [118]. We have discussed in the previous section the management of each of these complications as a part of the operative management to liver trauma.

## 7.2. Operative

Rebleeding in the postoperative period is a challenging problem. Delayed haemorrhage is the most common complication of the non-operative management of hepatic injuries and is the usual indication for a delayed operation [119]. Coagulopathy, inadequate initial surgical repair and missed retrohepatic venous injury may result in further haemorrhage. Confirmed coagulation defects should be corrected as rapidly as possible with fresh frozen plasma and platelet transfusions.

Some authors recommend reoperation after transfusion of 10 units of blood in 24 h [120], however the limit of 6 units in the first 12 h seems to be more reasonable [121]-[122]. In cases with slow rebleeding when the limit of 6 units has not been exceeded, embolization of the bleeding vessels may be helpful [122]. Multiple bleeding vessels is usually the cause of failure because the vascular lesions distal to the area of embolization with rich collateral circulation, or bleeding from the portal or hepatic veins [123]-[125]

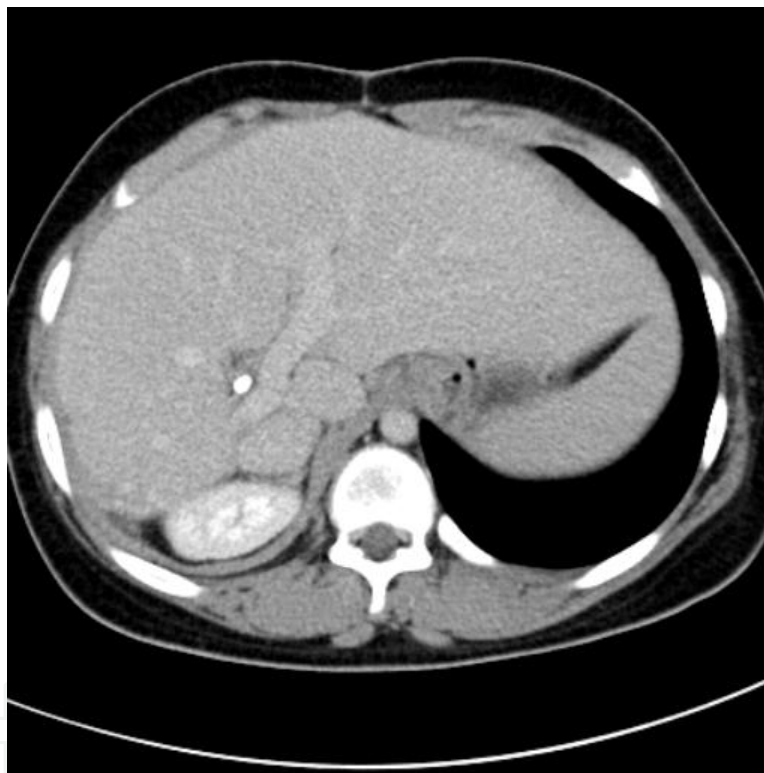
Late complications like sepsis, bile leak and liver failure occur at a later stage. Intra-abdominal sepsis in the postoperative period occurs in approximately 7-12 per cent of patients [126]. Predisposing factors include the presence of shock and increased transfusion requirements, increased severity of liver injury, associated injuries such as small bowel or colonic perforation, the use of perihepatic packs, superficial suturing of deep lacerations with intrahepatic haematoma formation, and the presence of devitalized parenchyma. Adequate initial surgical management in an effort to reduce transfusion requirements, with debridement of all devitalized tissue and early removal of perihepatic packs, has been recommended to reduce the incidence of septic complications [81],.

Arteriovenous fistula is not an uncommon complication with an incidence of less than 3%. It can manifest after liver injury as an arteriportal fistula that can result in portal hypertension and is usually treated by embolization [127].



## 8. Outcome

The mortality rate from liver trauma has fallen from 66 per cent in World War I, to 27 per cent in World War II, to current levels of 10-15 per cent [8],[10],[12],[128]-[129]. Better knowledge of liver pathophysiology and anatomy, and enhanced resuscitation, anaesthesia and intensive care, have contributed to this improvement. Schweizer et al,(1993) compared outcome to grade of injury. The overall mortality was 12% [9], specially with the livers excellent regeneration capability (Fig 21).



**Figure 21.** Liver regeneration post resection of the right liver

The mechanism of injury has an important bearing on mortality rate with blunt trauma carrying a higher mortality rate (10-30 per cent)[130]. than penetrating liver trauma (0-10 per cent)[10-11].

While most early deaths in patients with liver trauma seem to be due to uncontrolled haemorrhage and associated injuries, most late deaths result from head injuries and sepsis with multiple organ failure [131].



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