THE LIVER

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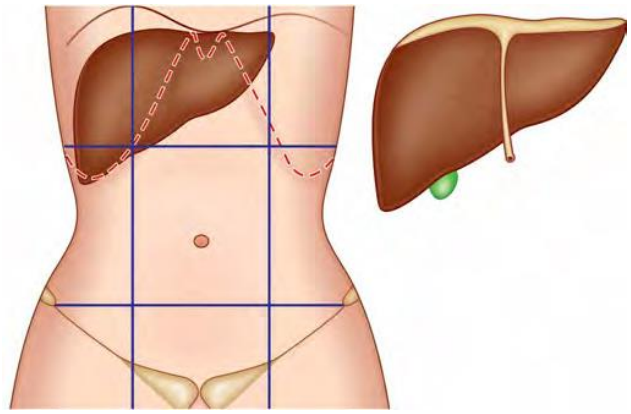
Anatomy of the liver

The liver is the largest organ in the body, with a weight varying from 1200 to 1600g. It sits in the right upper quadrant beneath the diaphragm, and is protected by the rib cage. The liver parenchyma is entirely covered by a thin capsule (Glisson's capsule) and by visceral peritoneum on all but the posterior surface of the liver, termed the 'bare area'. The liver is divided into a large right lobe, which constitutes three-quarters of the liver volume, and a smaller left lobe.

Morphology and topographical anatomy of

the liver surfaces The liver can be regarded as a wedge with rounded edges tapering to the left. It has three surfaces: anterosuperior, inferior and posterior. The anterosuperior surface is marked by the umbilical fissure in the depths of which (recessus of Rex) is inserted the round ligament (obliterated umbilical vein) attached to the cornu of the left portal vein. The umbilical fissure and the falciform ligament are the most conspicuous anatomical landmarks and divide the liver into right and left lobes. The posterior surface of the liver is largely formed of the bare area of

Liver blood supply The blood supply to the liver is unique, 80% being derived from the portal vein and 20% from the hepatic artery. The arterial blood supply in most individuals is derived from the coeliac trunk of the aorta, where the hepatic artery arises along with the splenic and left gastric artery. After supplying the gastroduodenal artery, the hepatic artery branches at a very variable level to produce the right and left hepatic arteries. The right artery supplies the majority of the liver parenchyma and is, therefore, the larger of the two arteries. There are many anatomical variations, knowledge of which is essential for safe surgery on the liver. The blood supply to the right lobe of the liver may be partly or completely supplied by a right hepatic artery arising directly from the superior mesenteric artery, rather than the coeliac trunk. This vessel passes posterior to the uncinate process and head of the pancreas, and runs to the liver on the posterior wall of the bile duct.

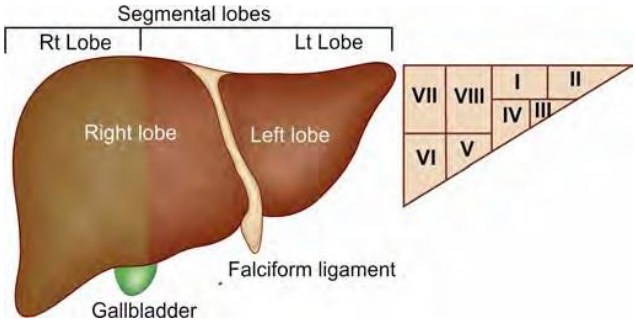


Similarly, the arterial blood supply to the left lobe of the liver may be derived from a branch of the left gastric artery. This vessel runs between the lesser curve of the stomach and the left lobe of the liver in the lesser omentum.. Hepatic artery ligation is one of the surgical palliation for advanced hepatocellular carcinoma and secondaries in liver as tumour tissue is supplied exclusively by hepatic artery but normal tissue is also supplied by portal vein. Superior mesenteric vein and splenic vein join dorsal to the neck of pancreas to form portal vein.

Hepatic artery, portal vein and bile duct are located in the free edge of the lesser omentum until it enters the liver.

Venous drainage is usually through the three major hepatic veins, right, left, and middle which drain into the IVC. Often inferior hepatic vein may be present.

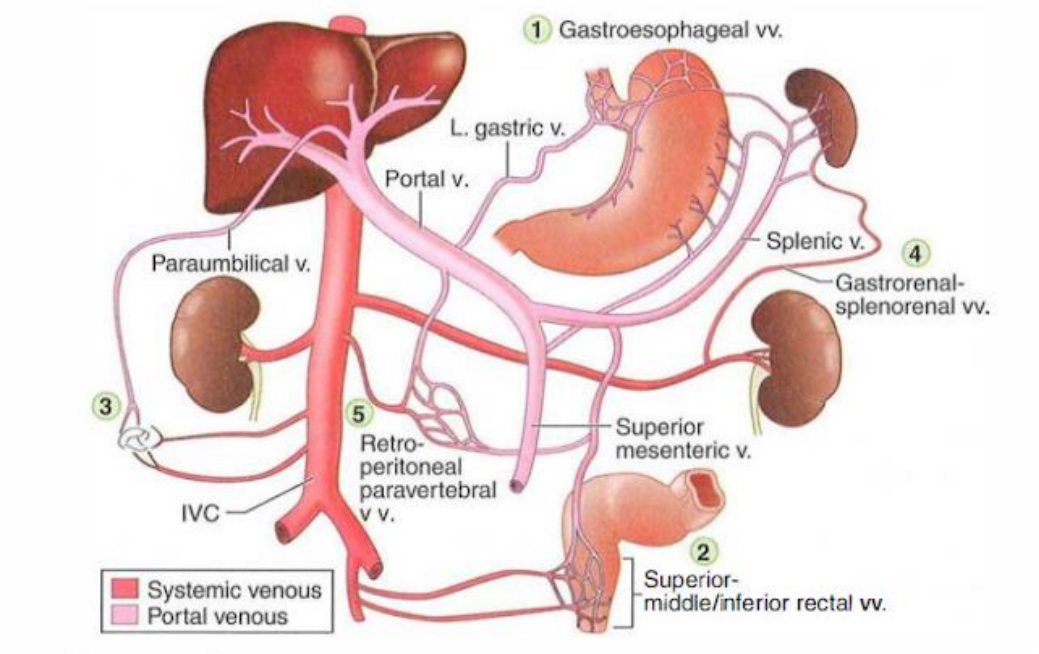
The liver parenchyma is entirely covered by a thin capsule called '*Glissons capsule'*and by visceral peritoneum in all but the posterior surface of liver termed 'bare area'



Segmental anatomy of the liver.

Segmental Anatomy of Liver

x Liver is divided into functional right and left lobes by a line passing from the left of the gallbladder fossa to the left of IVC—*Cantlie's line* creating *Couniaud's* segments. There are *eight segments*:
Segments I, II, III, and IV are of left lobe.
Segments V, VI, VII, VIII are of right lobe.
Segment I is the caudate lobe of the liver and has independent supply of portal and hepatic veins. This hepatic vein directly joins IVC.
x Right lobe is having right hepatic artery, right branch of portal vein, and right hepatic duct.
x Left lobe is having left hepatic artery, left portal vein, left branch of bile duct.
x *Bismuth's classification* is similar but separation of the sectors is by hepatic veins.
x *Functional unit is called as hepatic lobule and it contains central hepatic vein and portal triad (hepatic arteriole, portal venule, bile ductule)*



Portosystemic anastomoses. 1. Left gastric–azygos → esophageal varices. 2. Superior–middle/inferior rectal → hemorrhoids. 3. Paraumbilical–inferior epigastric → caput medusae (navel). 4. Gastrorenal-splenorenal. 5. Retroperitoneal paravertebral.

There are major anastomotic sites between the portal and systemic systems that open up in the presence of occlusion/ obstruction to portal blood flow to the liver:

- the cardio-oesophageal junction – left gastric (coronary) vein to the stem
- communications with the retroperitoneal veins of Sappey
- umbilicus – recanalized left umbilical vein to abdominal pindusae
- communications with the inferior rectal plexus

ACUTE AND CHRONIC LIVER DISEASE

Liver function and tests

Adequate liver function is essential to survival; humans will survive for only 24–48 hours in the anhepatic state despite full supportive therapy. The liver is central to many key metabolic pathways.

Main functions of the liver

- Maintaining core body temperature
- Synthesis of clotting factors
- Glucose metabolism, glycolysis and gluconeogenesis
- Urea formation from protein catabolism
- Bilirubin formation from haemoglobin degradation
- Drug and hormone metabolism and excretion
- Removal of gut endotoxins and foreign antigens.

Liver function tests and testing liver function

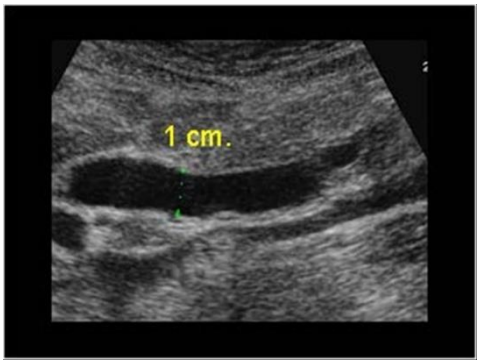
The analytes commonly called liver function tests (LFTs), alanine amino transaminase (ALT), aspartate transaminase (AST), alkaline phosphate and g-glutamyltransferase, do not give any information about liver function and are biomarkers of liver damage. The other biochemical analyses commonly performed as part of the LFTs group are albumin and bilirubin: these do give some indication of liver function but with important caveats. Other biochemical abnormalities include elevations of acute phase reactant proteins (a2-macroglobulin, C-reactive protein, etc.). Other changes include lowering of serum proteins, release of integral proteins, raised immunoglobulins and the appearance of abnormal protein antigens.

MAGING THE LIVER

the safety of liver surgery and surgical outcomes are in part due to improvements in preoperative imaging. The ideal choice of imaging modality is determined by the likely pathology as well as locally available equipment and radiological expertise.

Ultrasound

Ultrasound is conventionally the first line modality in imaging the liver and biliary tract for detection of focal liver lesions (FLL) and assessment of biliary tract dilatation Good quality ultrasound can characterize a definite benign lesion (e.g. cyst), from a definite malignant lesion (e.g. metastasis). However, due to considerable overlap in appearance of benign and malignant lesions, as well as inter operator variability, accurate characterization is often not possible using unenhanced ultrasound alone. Obese patients and those with variant anatomy can be particularly difficult to evaluate. . Although ultrasound is frequently used to assess biliary dilatation, it is less useful in determining the etiology. Dilatation of the ducts can suggest the presence of malignancy in a high-risk patient, but due to frequent overlying gastric and duodenal gas, the ducts rarely seen throughout their entire course.



Computed tomography

Modern spiral computed tomography (CT) technology has increased the accuracy of diagnosis and staging of liver lesions, and contrast-enhanced CT is currently the most widely used and best validated modality for liver imaging. It provides fine detail of liver lesions down to less than 1 cm in diameter and gives information on their nature . Oral contrast enhancement allows visualisation of the stomach and duodenum in relation to the liver hilum. The early arterial phase of the intravenous contrast vascular enhancement is particularly useful for detecting small primary liver cancers, owing to their preferential arterial blood supply. The venous phase maps the branches of the portal vein within the liver and the drainage via the hepatic veins. Inflammatory liver lesions often exhibit rim enhancement with intravenous contrast, whereas commonly found haemangiomas characteristically show late venous enhancement. The density of any liver lesion can be measured, which is useful in establishing the presence of a cystic lesion. CT has high accuracy in determining the stage, and high sensitivity and specificity in determining resectability, of liver tumours. Local and distant metastases can also be detected, although peritoneal

metastases are often missed on CT.

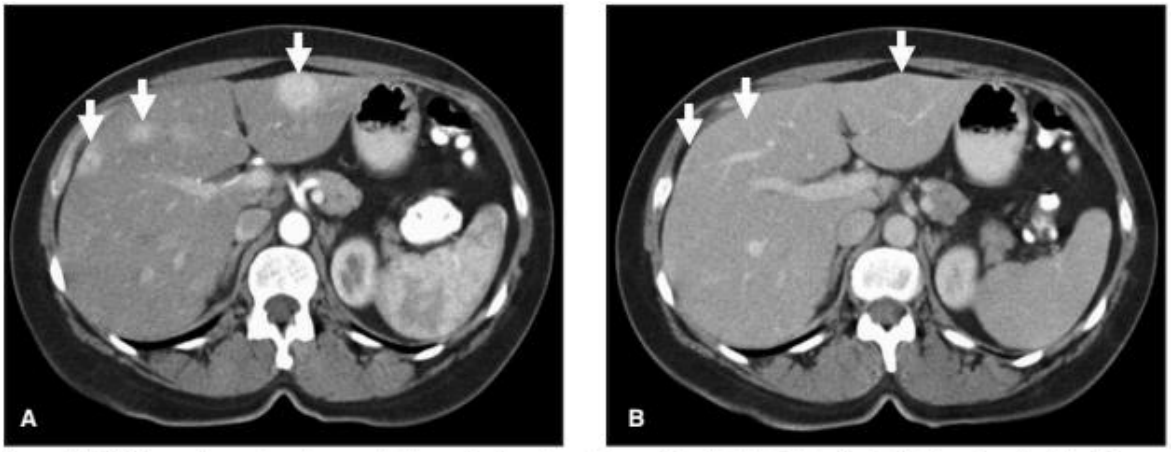


Fig. — (A) Axial CT scan image shows hypervascular liver metastases (arrows) are well visualized during hepatic arterial phase of contrast administration in this patient with metastatic carcinoid tumor. (B) During portal venous phase there is wash out of contrast and poor visualization of the same

Magnetic resonance imaging

Magnetic resonance (MR) of the liver is superior to CT in characterising liver lesions and detecting small liver metastases . The advent of liver-specific contrast agents has significantly improved lesion characterisation and detection, particularly in differentiating small hepatocellular carcinoma (HCC) from regenerative nodules. These contrast agents are taken up by normally functioning hepatocytes. A lesion not containing hepatocytes will not take up contrast, and will appear dark against an enhancing background liver.These contrast agents are now being used more frequently due to the increased detection of lesions on liver-specific phase CT scans. This observation is particularly important for colorectal liver metastases prior to consideration of liver resection. In addition to standard MR scanning, magnetic resonance cholangiopancreatography (MRCP) provides excellent quality non-invasive imaging of the biliary tract, the accuracy of which is comparable to direct cholangiography by endoscopic retrograde cholangiopancreatography (ERCP) or percutaneous transhepatic cholangiography (PTC).

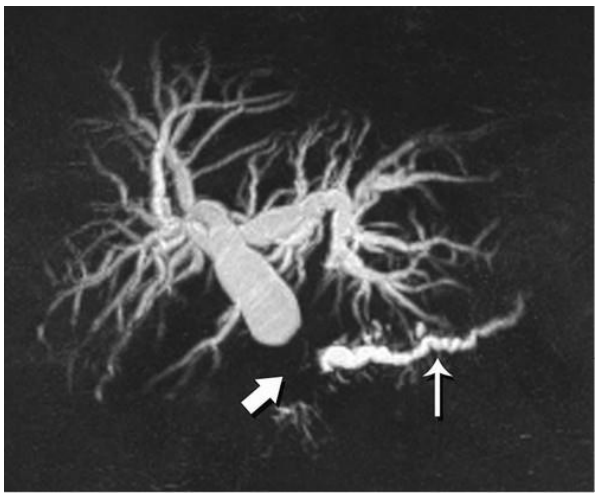


FIG: Double duct signs . Maximum-intensity reconstruction of a 3-D MR cholangiopancreatography (MRCP) acquisition shows the abrupt termination of the dilated pancreatic and bile ducts at the level of the pancreatic head, the classic sign of the presence of a carcinoma of the head of the pancreas .

Ultrasound vs CT vs MRI scanning for liver imaging

Focal liver lesions

Ultrasound is dependent on the skill of the operator, so reproducibility may be an issue in follow-up of challenging focal liver lesions. Nevertheless, in many situations, particularly for screening of high-risk patients and for follow-up of readily visualized focal liver lesions, the convenience and low cost of ultrasound may justify its use in preference to more costly MRI and CT which use ionizing radiation. CT and MRI may both be employed to detect and characterize focal liver lesions. Where focal liver lesion characterization proves challenging MRI has advantages over CT in that it allows for a greater range of tissue characteristics to be demonstrated, and hepatocyte-specific contrast agents may provide additional information which cannot be yielded by other means. Ultrasound using intravenous contrast agents may also assist the characterization of focal liver lesions. CT scanning retains a particularly valuable role in the evaluation of the profoundly unwell patient for whom the long duration and long breath-hold requirements of MRI scanning preclude practical application.

Diffuse liver disease

Diagnosis and evaluation of diffuse liver disease with noninvasive imaging techniques is a contentious area. There is no universally accepted technique, although some specialized methods involving ultrasound elastography are under evaluation. There are also MRI-based imaging techniques which may prove useful in this challenging diagnostic area.

Gallbladder and bile duct disease

Ultrasound remains the workhorse of suspected inflammatory gallbladder disease, and may be supplemented by CT evaluation if there is a clinical suspicion that sepsis has extended beyond the gallbladder. Ultrasound has limited utility in evaluation of the rest of the biliary tree in large part because it is only very rarely that the lower half of the common bile duct may be adequately visualized. For complex bile duct disease MRI using *T*2 weighted acquisition sequences (MRCP) has become the technique of choice for high-quality non-invasive evaluation of suspected pathology of both the intra- and extrahepatic bile ducts.

Positron emission tomography

Until fairly recently positron emission tomography (PET) has been used to investigate single organs, particularly the heart (myocardial perfusion, oxygen extraction, etc.) and the brain (metabolism, neurotransmitter function, etc.). With the advent of whole-body PET scanning, the technique is being introduced in oncology where it has potential and advantages over other imaging modalities:

- In principle, whole - body PET can identity a tumour and indicate the presence of spread anywhere in the body at an early stage (micrometastases).
- It can differentiate between benign and malignant tumours (metabolic activity of the

lesion).
• It differentiates viable from non-viable tumour, which may be increasingly important for *in situ* ablation of tumours, e.g. liver,prostate.

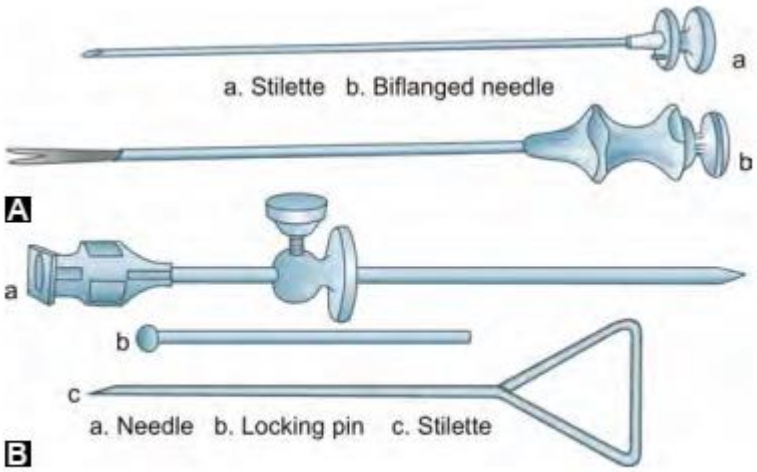
Needle biopsy of the liver and of focal liver lesions

Despite advances in non-invasive imaging techniques imaging guided biopsy still retains a valuable role in the evaluation of both diffuse liver disease and focal liver lesions. The indications for biopsy in suspected or confirmed diffuse liver disease are where there is doubt as to the diagnosis, or where it is clinically important to determine the degree of advancement of the disease process. The indications for biopsy of focal liver lesions are where there is clinical concern that a potentially life-threatening pathology may be passing undiagnosed at a stage where there is still potential for cure, or where potential for cure has passed but tissue confirmation is required before embarking on palliative therapy. There is a risk of causing tumor cell dissemination into the peritoneal cavity and chest or abdominal wall during the biopsy procedure itself . Imaging-guided liver biopsy may be performed as a day case and carries a very low mortality rate (less than 0.1%). Evaluation of diffuse liver disease can only be performed on core biopsies obtained using Tru-Cut-type needles. Similarly for evaluation of focal liver lesions core biopsies are far preferable to fine-needle aspiration cytology samples. All liver biopsies should be performed under conditions which minimize the likelihood of haemorrhagic complications:this includes the correction of any coagulopathy.

The most common complications of liver needle biopsy are:
• pleural effusion
• haemorrhage from the liver and thoracic wall
• intrahepatic haematoma
• hepatic arteriovenous fistulas
• haemobilia
• accidental puncture of the gallbladder and large bile ducts leading to bile peritonitis
• tumour cell implantation.

Contraindications

™ Hydatid disease, where it will precipitate anaphylaxis
™ Haemangioma, bleeding disorders
™ Ascites



Figs A and B: Liver biopsy needles. A. Vim-Silvermann, B. Menghini.

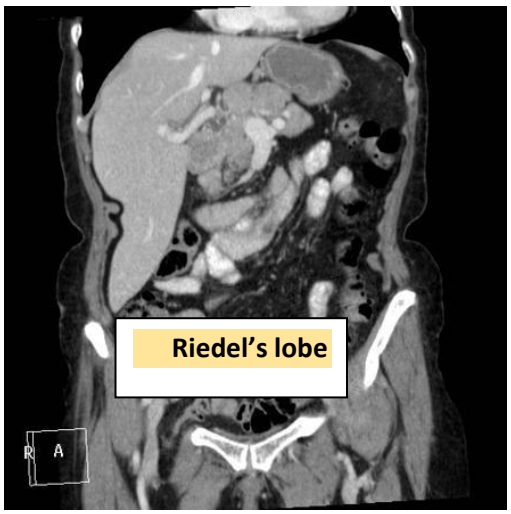
Laparoscopy with contact ultrasonography of the liver

Laparoscopy with contact ultrasound is an invaluable investigation that provides direct information on the state of the liver and the peritoneal cavity. It is particularly useful in the investigation of patients with jaundice, chronic liver disease, ascites of unknown origin and in the diagnosis and staging of both primary and secondary hepatic tumors. The advent of laparoscopic contact ultrasonography using high-resolution linear array probes has added considerably to the diagnostic yield of laparoscopy for the detection and staging of hepatic tumors. In addition to detecting secondary hepatic deposits in the liver and peritoneal cavity that are too small to be detected by CT scanning and MRI, laparoscopic contact ultrasonography permits the visualization of the hepatic vasculature (portal vein, hepatic artery, hepatic veins and retro- hepatic vena cava) and examination of the entire biliary tract. This accurate assessment of the extent of involvement of the liver by tumor and relation to hepatic veins enables surgical planning of the resection necessary in the individual case.

Congenital abnormalities

Riedel's lobe

This anatomical variant is a projection downwards from the right lobe of the liver of normally functioning liver tissue. It may present as a puzzling and symptomless abdominal mass.



Polycystic liver

This is often associated with polycystic disease of the kidneys (and occasionally pancreas), and comprises multiple cysts within the liver parenchyma. The liver may reach a very large size, but functions normally. The most common symptoms are discomfort and awareness of the grossly enlarged liver in the abdomen. Haemorrhage into the cysts and cholangitis are occasional complications.

LIVER INJURY

Causes

It can be due to blunt injury, stab, and gun shot injury. About 5% of all trauma admissions will have liver injury; liver is the most common organ injured in blunt abdominal trauma.

Types

It can be contusion, laceration, avulsion, extension into thorax and biliary tree may be associated with other organ injuries (spleen, kidney, duodenum, bowel, IVC) and with **f**racture ribs.

Liver injury can be:

x ***Penetrating***: It often requires surgical intervention. After laparotomy with rooftop incision, laceration is assessed,clots and blood in the peritoneal cavity is removed. Using *Pringle manoeuvre* bleeding is temporarily controlled. Often suprahepatic IVC and infrahepatic IVC control may be required. Liver wound is sutured using specialized needle with vicryl using *co-opting sutures*. Gelfoam or Surgicel is placed over it. Other injuries like of diaphragm, biliary system, bowel should be looked for. Adequate amount of blood, FFP should be kept for transfusions. Postoperative assessment of BT, CT, PT, platelet count, observation for sepsis is needed. Ideal antibiotic coverage using 3rd generation cephalosporins or higher are needed.

x ***Blunt trauma***: It is assessed by CT scan. It is usually treated conservatively. Indications for surgical intervention are—progressive deterioration and bleeding, grade 5 liver injury on CT scan, associated bowel injury. Commonly used procedure after laparotomy is keeping packs between liver and diaphragm which is removed in 48–72 hours. Occasionally venovenous bypass, hepatic resection may be required.

Clinical Features

The liver is an extremely well-vascularised organ, and blood loss is therefore the major early complication of liver injuries. Clinical suspicion of a possible liver injury is essential, as a laparotomy by an inexperienced surgeon with inadequate preoperative preparation is doomed to failure. All lower chest and upper abdominal stab wounds should be suspect, especially if considerable blood volume replacement has been required. Similarly, severe crushing injuries to the lower chest or upper abdomen often combine rib fractures, haemothorax and damage to the spleen and/or liver. Focused assessment sonography in trauma (FAST) performed in the emergency room by an experienced operator can reliably diagnose free intraperitoneal fluid. Patients with free intraperitoneal fluid on FAST and haemodynamic instability, and patients with a penetrating wound, will require a laparotomy and/or thoracotomy once active resuscitation is under way. Owing to the opportunity for massive ongoing blood loss and the rapid development of a coagulopathy, the patient should be directly transferred to the operating theatre while blood products are obtained and volume replacement is taking place enhanced CT scan of the chest and abdomen as the next step. This scan will demonstrate evidence of parenchymal damage to the liver or spleen, as well as associated traumatic injuries to their feeding vessels. Free fluid can also be clearly established. The chest scan will help to exclude injuries to the great vessels and demonstrate damage to the lung parenchyma.

x Features of shock due to severe torrential bleeding (pallor,hypotension, tachycardia, and sweating).

x Distension of abdomen with dull flank, guarding, tenderness and rigidity.

x Oliguria.

x Tachypnoea, respiratory distress and often cyanosis.

Grading of liver injury based on American Association of Surgery for trauma (AAST)

Grade	Type	Injury description
I	Hematoma	Subcapsular, nonexpanding, <10 cm surface area
	Laceration	Capsular tear, nonbleeding, <1 cm parenchymal depth
II	Hematoma	Subcapsular, nonexpanding, 10–50% surface area; intraparenchymal nonexpanding <10 cm diameter
	Laceration	Capsular tear, active bleeding, 1–3 cm parenchymal depth <10 cm in length
III	Hematoma	Subcapsular, >50% surface area or expanding; ruptured subcapsular hematoma with active bleeding; intraparenchymal hematoma >10 cm or expanding
	Laceration	>3 cm parenchymal depth
IV	Hematoma	Ruptured intraparenchymal hematoma with active bleeding
	Laceration	Parenchymal disruption involving 25–75% of hepatic lobe or one to three Couinaud's segments within a single lobe
V	Laceration	Parenchymal disruption involving >75% of hepatic lobe or >3 Couinaud's segments within a single lobe
	Vascular	Juxtahepatic venous injuries (i.e., retrohepatic vena cava/central major hepatic veins)
VI	Vascular	Hepatic avulsion

x Rupture of right lobe is more common than left lobe leading to *haemoperitoneum.*
x Occasionally can cause localized haematoma which may form an abscess.
x Bile leak from the injured site can lead to *biliary peritonitis*.

Investigations

x Chest X-ray to look for rib fractures.
x US abdomen, FAST (Focused assessment with sonography for trauma) CT scan of chest and abdomen (CT is ideal).
x Diagnostic peritoneal lavage. 10 ml gross blood on initial aspiration, > 1,00,000 cu mm RBCs, > 500 WBCs, and presence of enteric contents suggest positive DPL.
x Hb%, PCV, blood grouping and crossmatching. Adequate amount of blood (5-10-15 bottles of blood) must be kept ready for transfusion, i.e. requires massive transfusion.
x Arterial blood gas analysis.
x *Coagulation profile.*
x *Thromboelastography (TEG)* is dynamic form of assessing the coagulation status on table.
x Arteriography to visualise the bleeding branch/vessel in the liver and embolisation can be tried.

Treatment

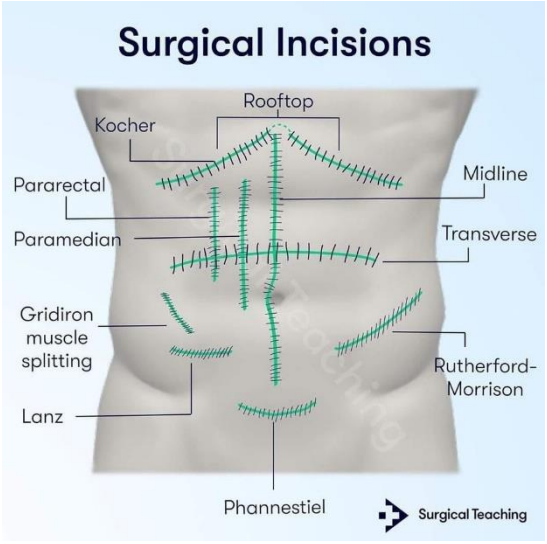
General measures

The initial management is maintenance of airway patency, breathing and circulation (ABC) following the principles of advanced trauma life support (ATLS). Peripheral venous access is gained with two large-bore cannulae and blood sent for cross-match of 10 units of blood, full blood count, urea and electrolytes, liver function tests, clotting screen, glucose and amylase. Initial volume replacement should be with blood. Arterial blood gases should be obtained and the patient intubated and ventilated if the gas exchange is inadequate. Intercostal chest drains should be inserted if associated pneumothorax or haemothorax is suspected. Once initial resuscitation has commenced, the patient should be transferred to the operating theatre, with further resuscitation performed on the operating table. The necessity for fresh frozen plasma and cryoprecipitate should be discussed with the blood transfusion service immediately the patient arrives in the hospital (often by activation of a major transfusion protocol), as these patients rapidly develop irreversible coagulopathies due to a lack of fibrinogen and clotting factors
x IV fluids, blood transfusion (massive), FFP.
x Have both central venous access, and peripheral venous access.
x Bladder catheterisation has to be done to measure the urine output.
x *Factor VII*—proconvertin (SPCA—0.6 mg/ml up to 4.8 mg); very effective, makes INR normal; but very expensive.

Initial conservative nonoperative management

x It is done in—nonprogressive liver injuries in patients who are haemodynamically stable, low grade (I-III) liver injury, need of less than 2 units of transfusion, without peritoneal signs, normal mental status.
x However, CT abdomen (absence of extravasation of contrast during arterial phase can be treated nonoperatively) and repeat CT or regular ultrasound follow-up is a must.
x Replacement of lost blood; prevention of sepsis; regular monitoring by haematocrit, liver function tests, prothrombin time are needed.

x *Angiographic embolisation* increases the success rate of nonoperative therapy.
x Intensive care unit (ICU) management for 2–5 days; repeat CT scan after 5 days; bedrest to be continued; patient can have normal activity only after 3 months.
x When at any time patient's condition worsens, he should be taken up for laparotomy.
x *Success rate* of nonoperative treatment is 85% in grade I-III injuries; 40% in grade IV–VI injuries. It is the associated injuries which decides the success.
x ***Intervention radiology*** methods like *angioembolization* through hepatic artery are used especially when there is pseudoaneurysm. But life-threatening hepatic necrosis and gallbladder necrosis can occur. Gallbladder necrosis warrants cholecystectomy.



Specific treatment

Good access is vital. A 'rooftop' incision with midline extension to the xiphisternum and retraction of the costal margins gives excellent access to the liver and spleen. If the laparotomy has been started through a midline incision, a transverse lateral extension to the right can be added to improve access to the liver

x *Push (direct compression); plug* (plugging the deep track injuries using silicone tube or SB tube); *Pringle's* manoeuvre; *pack* (liver wound is directly packed with mop).
x Laparotomy is done through a large *bucket handle* abdominal incision or thoracoabdominal incision, and extent of liver injury and also other associated injuries are looked for.
x Small liver tear is sutured with *vicryl* or *PDS* mattress sutures with placing of gel foam to control bleeding.
x To control bleeding on table, from hepatic artery and portal vein, both are temporarily occluded using fingers, compressing at foramen of *Winslow-Pringle maneuver*. Often bull-dog clamp or vascular clamps can be used.

In deep severe injuries, following methods are used:

™ Hepatic artery ligation, not usual.

™ Segmental resection.

™ Hemihepatectomy, not commonly used.

™ Packing the liver temporarily with mops and closing the abdomen

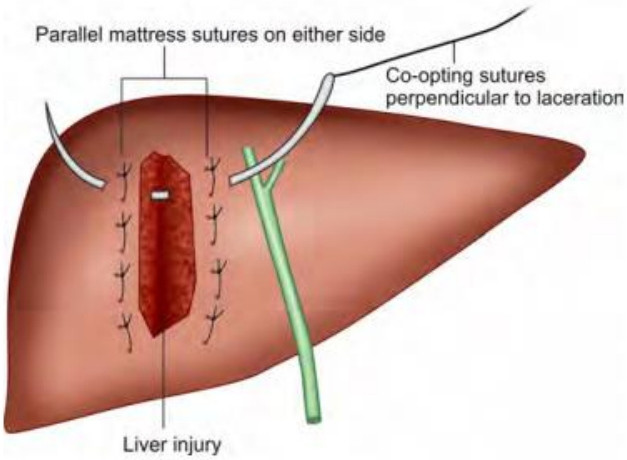


Fig. Co-opting sutures are placed perpendicular to already placed parallel mattress sutures.

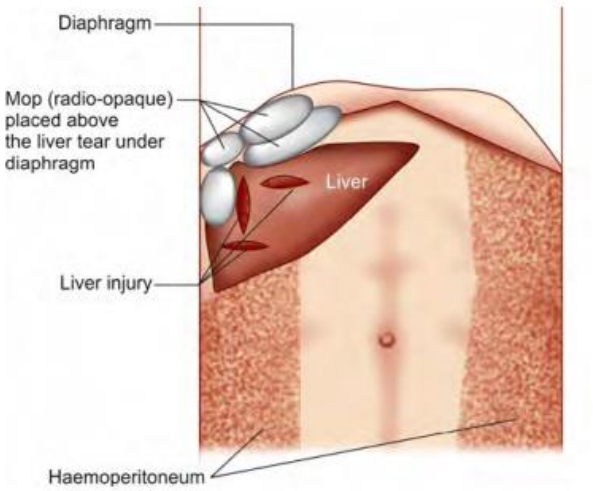


Fig. By placing 3–5 mops between injured liver and diaphragm tamponade can be achieved to control bleeding from the liver. After 48–72 hours abdomen is re-explored electively for further intervention. By then, often bleeding will be controlled and further management becomes easier. Sepsis should be taken care of by higher generation antibiotics.

Complications and sequelae of liver injury

- Shock and haemorrhage
- Liver abscess or septicaemia—7%
- Bile leak, biliary peritonitis, biliary fistulas—10%
- Disseminated intravascular coagulation
- Hepatic artery aneurysm, arteriovenous and arteriobiliary fistulas—haemobilia
- Intra-hepatic haematoma
- Intra-abdominal abscess—subphrenic, pelvic
- Complications of massive blood transfusion
- Electrolyte imbalance
- Respiratory complications
- Liver failure
- **Late sequelae** of liver trauma is *CBD stricture* causing obstructive jaundice. It can be managed by endoscopic stenting or by open Roux-en-Y hepaticojejunostomy
- Mortality is 10%; morbidity is 30%. Associated injuries increase the mortality from isolated liver injury of 3–20%.

Long-term outcome of liver trauma

The capacity of the liver to recover from extensive trauma is remarkable, and parenchymal regeneration occurs rapidly. Late complications are rare, but the development of biliary strictures many years after recovery from liver trauma has been reported. The treatment depends on the mode of presentation and the extent and site of structuring.