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Liver Trauma

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Abstract

The liver is the most frequently injured abdominal organ. Abdominal injuries occur in 31% of patients of polytrauma with 13 and 16% spleen and liver injuries respectively, and pelvic injuries in 28% of cases, making differential diagnosis between pelvic or intractable abdominal injury difficult.[1] Liver trauma is the most common cause of death after abdominal injury. The most common cause of liver injury is blunt abdominal trauma. Identification of serious intra-abdominal trauma is often challenging; many injuries may not manifest during the initial assessment and treatment period. Liver frequently injured following abdominal trauma and associated injuries contribute significantly to mortality and morbidity, and may mask the liver injury and causes delay in diagnosis. Management of hepatic injuries has evolved over the past 30 years. Prior to that time, a diagnostic peritoneal lavage (DPL) positive for blood, was an indication for exploratory celiotomy because of concern about ongoing hemorrhage and/or missed intra-abdominal injuries needing repair. The recognition that between 50 and 80 per cent of liver injuries stop bleeding spontaneously, coupled with better imaging of the injured liver by computed tomography (CT) and efficient ICU management, has led progressively to the acceptance of nonoperative management (NOM) with a resultant decrease in mortality rates.

Keywords: Blunt liver trauma, penetrating liver trauma, liver trauma grade, liver laceration, subcapsular hematoma, bile leak, hemobilia, biloma, parenchymal destruction, FAST, DPL, stab wound, hepatic artery embolization, nonoperative management

1. Introduction

Abdominal trauma is an emergency condition and, if not treated properly, is associated with significant morbidity and mortality. Today despite advancement in recognition, diagnosis, and management, the mortality remains high. Trauma is the second largest cause of hospital admission with 16% of global burden of all health cost. As per the estimate of the World Health Organization, by 2020, trauma will be the first or second leading cause of *years of productive life lost* for the entire world population [1].

The liver remains the most frequently and seriously injured abdominal organ due to trauma. About 31% patients of polytrauma have abdominal injuries. Almost 13% and 16% of cases have spleen and liver injuries, respectively, and pelvic injuries are seen in about 28% of cases. In close location of many organs, it is difficult to make differential diagnosis between pelvic or intractable abdominal injuries [2, 3].

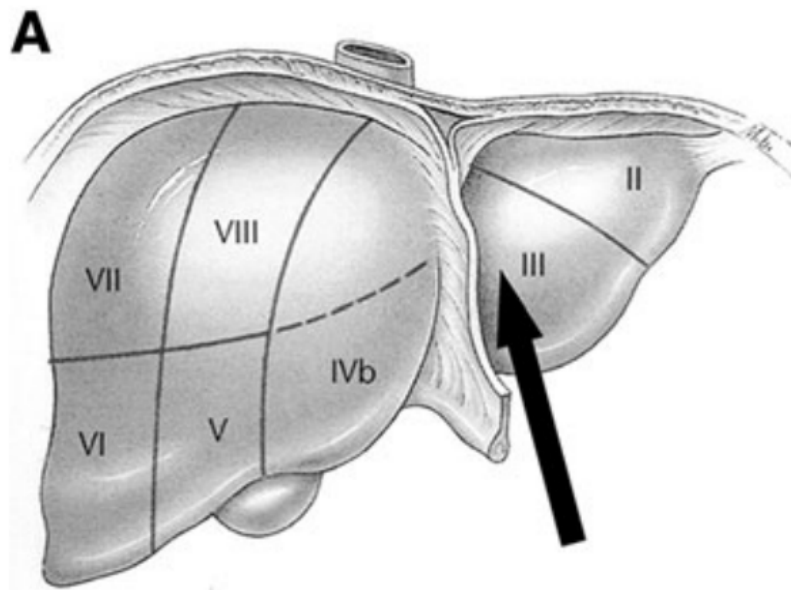
In abdominal injuries, liver trauma is the leading cause of death. The most common way liver gets injured is in blunt abdominal trauma. By trauma, the identification of serious intra-abdominal injuries is a challenging task; many injuries may not be apparent during the initial assessment and treatment period. Since the liver gets frequently injured with other abdominal organs following abdominal trauma, associated injuries contribute significantly to mortality and morbidity and may cause the liver injury to be masked and diagnosis delayed. The management of hepatic injuries has evolved over the past 30 years. Previously, a diagnostic peritoneal lavage (DPL) was done to find out active bleeding and to diagnose missed intra-abdominal injuries needing surgical intervention. If DPL is positive for blood, it was an indication for exploratory celiotomy. Nowadays, it is recognized that between 50% and 80% of liver injuries stop bleeding spontaneously. In addition, there is better imaging of the injured liver by computed tomography (CT). Both these factors have led progressively to the acceptance of nonoperative management (NOM) and a resultant decrease in mortality rates [4, 5].

2. Mechanism of injury

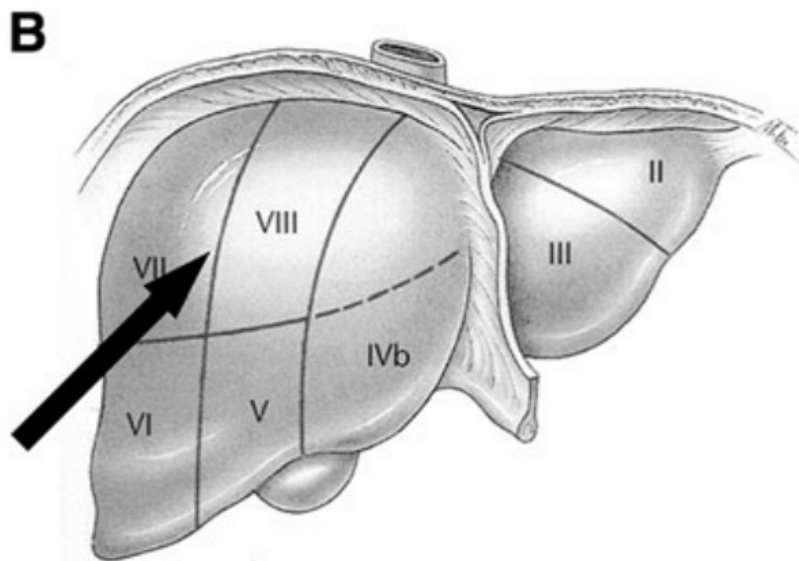
Injury to liver ranges from major and serious to minor non serious injuries. It can extend from minor subcapsular hematomas and small capsular lacerations to major deep parenchymal lacerations, major crush injury, and vascular avulsion. Many factors contribute to the vulnerability of liver to injury in trauma. The liver is the biggest solid abdominal organ. It is surrounded by many organs and have attachments with peritoneal ligaments, giving it a relatively fixed position. Liver is anterior in the abdominal cavity in right upper quadrant. It is highly vascular in nature and has fragile parenchyma. The support of Glisson's capsule is easily disrupted making this organ vulnerable to injury. Motor vehicle accident is the most common cause of blunt liver injury.

Not surprisingly, even in the penetrating abdominal trauma, the liver is the second most commonly injured organ [6]. Most common cause of penetrating liver injury are due to knife assaults and gunshot wound. The severity of penetrating injury depends upon the trajectory of the missile or implements. The injuries can range from simple parenchymal injuries or serious and major vascular laceration [7].

During respiration, the liver margin, which can usually be palpated 2 to 3 cm below the right rib margin, rises and falls with the diaphragm. With expiration the dome of the liver rises as high as the level of nipple which is T4. This association with chest wall also makes liver vulnerable during injuries to chest. Furthermore, the penetrating injuries in the lower abdomen can cause serious trauma to liver as the inferior margin of the liver descends to as low as T12 with deep inspiration. [8].



Type A injury: Patients suffer from rupture of the left liver lobe mostly along the falciform ligament, including segment II, III, or IV of the liver. This injury pattern is observed when the trauma has a direct frontal impact of the trauma energy.



Type B injury: These injuries represent mechanisms of trauma with a more complex pattern of energy, with impacts coming from several directions, affecting segments V–VIII of the liver.

Figure 1. Mechanism of blunt liver trauma and the type of liver injury

The right liver lobe is more often involved, owing to its larger size and proximity to the ribs. Compression against the fixed ribs, spine or posterior abdominal wall generally result in predominant damage to posterior segments (segments 6, 7, and 8) of the liver (>85%). Inversely, a blow to the right hemithorax may propagate through the diaphragm producing contusion

of dome of right lobe of liver. Liver’s ligamentous attachments to diaphragm and posterior abdominal wall act as sites of shearing forces during deceleration injury. Liver injury can also occur as a result of transmission of excessively high venous pressure to remote body sites at the time of impact. Weaker connective tissue framework, relatively large size, and incomplete maturation and more flexible ribs account for higher chance of liver injury in children compared to adults. Deceleration injuries producing shearing forces may tear hepatic lobes and often involve the inferior vena cava and hepatic veins. While a steering column injury can damage an entire lobe. In general, liver trauma may result in subcapsular/intrahepatic hematomas, lacerations, contusions, hepatic vascular injury, and bile duct injury [9, 10].

Based on the mechanism and site of blunt liver trauma, the liver injury could be classified into two types, type A and B as described in (Figure 1) [11].

3. Assessment of liver trauma

The initial resuscitation and evaluation of the patient with blunt or penetrating abdominal or thoracic trauma is similar. Most commonly, the initial resuscitation, diagnostic evaluation, and management of the trauma patient with blunt or penetrating trauma are based upon protocols from the Advanced Trauma Life Support (ATLS) guidelines, established by the American College of Surgeons Committee on Trauma (Table 1) [12].

Primary examination
Airway
Breathing
Tension pneumothorax
Open pneumothorax
Flail chest
Massive hemothorax
Circulation
Massive hemothorax
Cardiac tamponade
Secondary examination (thoracic injury that endanger life)
Simple pneumothorax
Pulmonary contusion
Tracheobronchial lesions
Closed cardiac injuries
Traumatic aortic rupture
Traumatic diaphragm injury
Lesions crossing the mediastinum

Table 1. Systematic survey in ATLS

Accordingly, hemodynamically unstable trauma patients need to be transferred immediately to the operating room for emergency explore laparotomy for better life-saving evaluation and management. If the clinical setting allows, a Focused Assessment with Sonography for Trauma (FAST) exam, DPL, or CT may be performed [13].

Plain films obtained during the trauma evaluation are generally nonspecific but may demonstrate right-sided rib fractures, which increase the suspicion for liver injury [14].

3.1. History and physical examination

Trauma generally causes irritation of diaphragm and patient complaints of pain in the right upper abdomen, right chest wall, or right shoulder. The suspicion for liver injury increases if patient gives history of trauma to the right upper quadrant, right rib cage, or right flank. Clinically, most apparent findings like abdominal pain, tenderness, and distention are seen in cases of severe abdominal hemorrhage, including hemorrhagic shock.

Even though the most common findings indicative of intra-abdominal injury are abdominal tenderness and other peritoneal signs, these findings are not sensitive or specific for liver injury. Commonly seen physical findings due to liver injury include generalized abdominal tenderness or localized tenderness on right upper quadrant or lower chest wall, presence of abdominal wall contusion or hematoma (e.g., seat belt sign), or chest wall instability due to rib fractures. Sometimes significant liver damage can occur without a wound in close proximity to site of injury. Any penetrating injury to right chest, abdomen, flank, or back increases the seriousness of injury. A negative history and normal physical examination does not reliably exclude liver injury.

Many times, physical examination findings can be unreliable due to many reasons. Such mechanisms of injury often result in other associated injuries and that can divert the physician's attention from serious life-threatening intra-abdominal pathology. The injury can be underestimated due to nonspecific signs and symptoms, an altered mental state, drug and alcohol intoxication, and interpatient variability in reactions to intra-abdominal injury [1].

In about 80% of patients, other concurrent injuries can be present with blunt liver injury, which can include lower rib fractures, pelvic fracture, spinal cord injury, or combination of injuries. Such concurrent injuries can lead to rupture of vena cava, colon, diaphragm, right lung, duodenum, kidney, and extrahepatic portal structures [15].

4. Diagnosis

The physical stress of trauma is common in patients of liver injury, and this can cause disturbed biochemical blood test. Initial rise in white blood cell count and low red blood cell count is a nonspecific finding. The degree of anemia correlated to the volume of blood loss. Such loss can be from liver or other than the liver. Other causes include amount of crystalloids or colloids used during initial resuscitation. In posttraumatic hemorrhage, the duration and course of developing anemia is variable and as already explained related to the frequency, amount, and

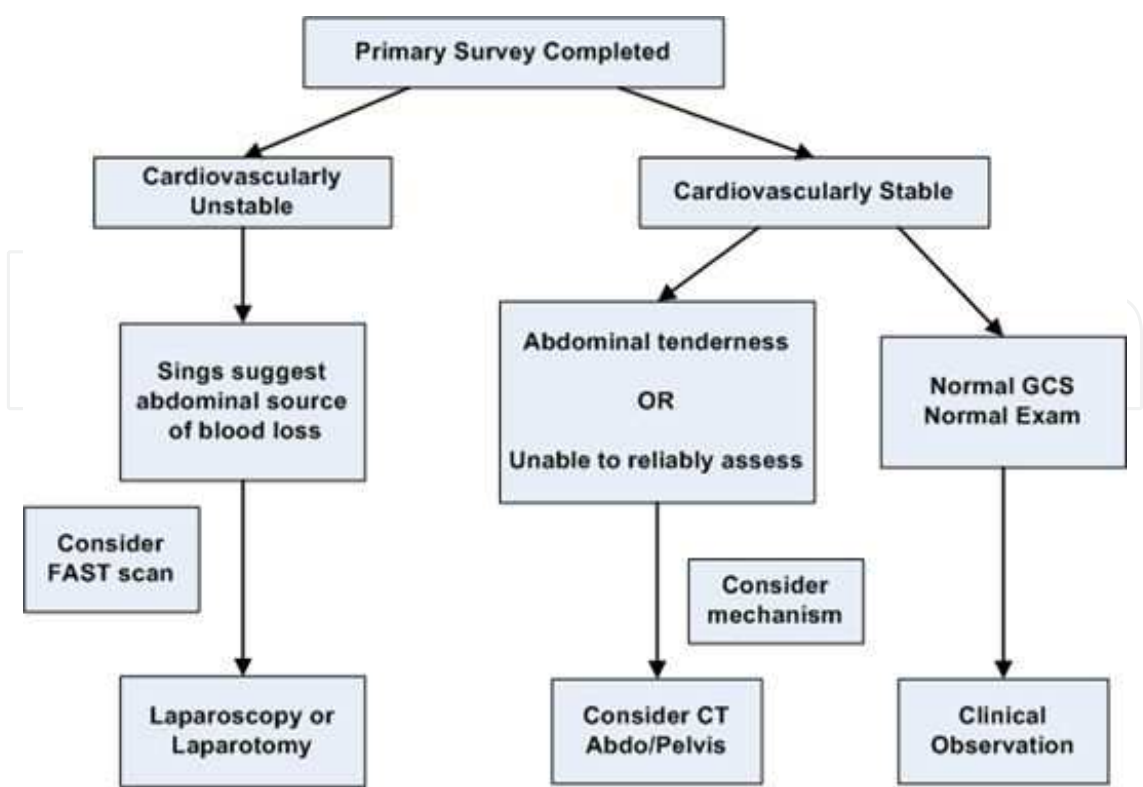


Figure 2. Assessment of trauma patient

rapidity of exogenous fluid administration and endogenous fluid shifts. Therefore, it is important to anticipate that significant liver trauma-related bleeding can happen irrespective of the presence or absence of anemia at the time of initial patient presentation.

In the hemodynamically stable patient, diagnosis of liver injury may be suspected based upon history of mechanism of injury, findings on physical examination, or laboratory findings of blood or other body fluids [16].

Imaging, especially using computed tomography (CT) with intravenous contrast of the abdomen, confirms the injury and also helps in defining the grade of injury. The characteristic pattern of pooling of intravenous contrast in or around the liver suggests ongoing bleeding and thus warrants the need for intervention. The imaging with the help of CT scan is also useful in identifying concurrent intra-abdominal and chest injuries [2, 17, 18].

The role of FAST examination comes when patient is hemodynamically unstable. However, in cases of intraparenchymal injuries, a negative FAST examination is not sufficient to exclude liver injury. Signs of liver injury on FAST examination include the presence of a hypoechoic (black) rim of subcapsular fluid, fluid in Morrison’s pouch (hepatorenal space), or intraperitoneal fluid around the liver. The main objective of this investigation is quick bedside assessment for hemoperitoneum and hemopericardium. The primary utility of this investigation is identifying the presence of blood and bleeding and not the identification of or defining the degree of organ injuries [19, 20] (Table 2).

-
- It detects free fluid in the abdomen or pericardium
 - It will not reliably detect less than 100 mL of free blood
 - It does not identify injury to hollow viscus
 - It cannot reliably exclude injury in penetrating trauma
 - It may need repeating or supplementing with other investigations
-

Table 2. Value of The Focused Assessment with Sonography in Trauma (FAST)

Even if diagnostic peritoneal aspiration or lavage (DPL) has largely been replaced by the FAST examination, it may still be useful in selected patients, if the FAST is equivocal. In addition, the ATLS still includes DPL modality, and it remains one of the skills that physicians need to learn for ATLS certification. However, a recent Cochrane review has put a question mark on the reliability of ultrasonography for early diagnostic investigations in patients with suspected blunt abdominal trauma [21].

Detailed systematic abdominal ultrasound examination in the radiology suit and/or magnetic resonance imaging (MRI) is time consuming and not feasible in the setting of hemodynamic instability of trauma in the initial diagnosis of liver injury. Furthermore, it puts the patient in a location remote from trauma management area. However, MRI may be useful in a subset of hemodynamically stable patients who cannot undergo CT scan (e.g., IV contrast allergy), and patients with suspected bile ductal injury. Arteriography is generally reserved for patients who have indications for hepatic embolization to manage intrahepatic arterial hemorrhage [22, 23].

Recently, studies have tried to find out other markers that will help in grading the severity and deciding the conservative management of blunt hepatic injury. Koca et al. [24] found that liver transaminases can predict the hepatic injury with higher accuracy as the grade rises, and it can be superior to FAST in terms of determining the need for laparotomy.

Out of multiple modalities available for evaluating stable patients, CT scan along with hemodynamic stability are best in evaluating which patient requires surgery or in deciding which patient can be safely discharged from emergency. The main drawbacks of CT scan are its cost, low sensitivity in detecting bowel injuries, and hemodynamically unstable patients [1]. In

Table 3 some important summary points regarding investigation of blunt abdominal trauma [25].

-
- The diagnosis of abdominal injury by clinical examination alone is unreliable
 - FAST is the investigation of choice in hemodynamically unstable trauma victim
 - CT scan with IV contrast is the investigation of choice in hemodynamically stable trauma victim
 - Solid organ injury in hemodynamically stable patients with no associated injuries (requiring urgent surgery) can often be managed without surgery
-

Table 3. Investigation of blunt abdominal trauma: key points

5. Hepatic injury grading

One of the most widely accepted injury grading scale to grade hepatic injuries is the American Association for the Surgery of Trauma (AAST) classification system. A study done using the National Trauma Data Bank (NTDB) in 2008 about the solid organ injuries showed that about 67% of hepatic injuries are Grade I, II, or III [26].

The nonoperative management (NOM) can give rise to higher successful outcome for low-grade injuries (Grades I, II, and III) and less success in cases of high-grade injuries (Grades IV and V). The major benefit of AAST grading system is for predicting the likelihood of success with NOM (see Figure 3).

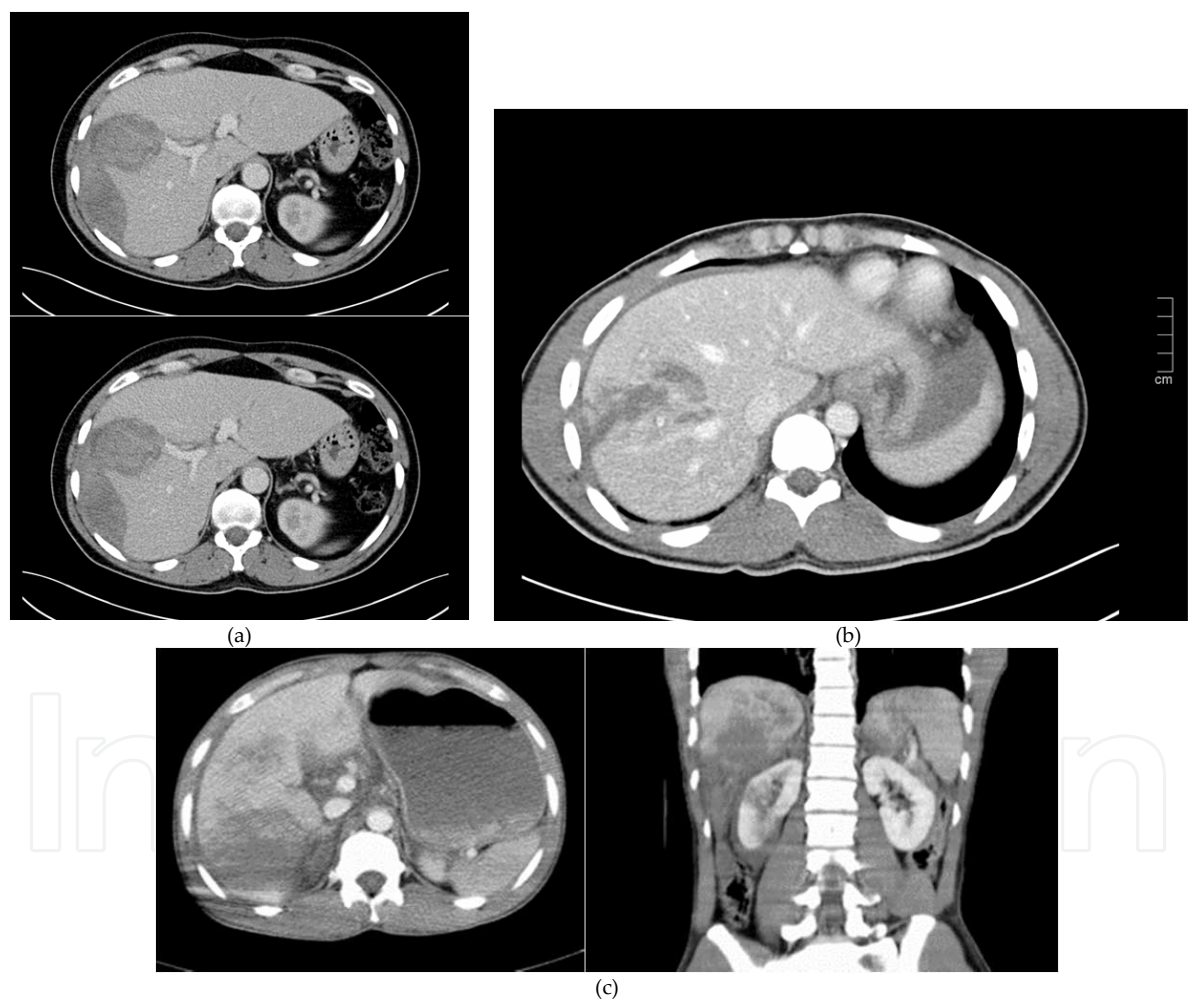


Figure 3. CT scan images show (A) Grad II Subcapsular, nonexpanding, 10-50% surface area; intraparenchymal nonexpanding <10 cm diameter; (B) Grad III liver injury with >3 cm laceration in the left lobe; (C) CT showing Grade IV liver injury with parenchymal disruption involving more than 25% of the liver.

Patients with Grade VI injuries are universally hemodynamically unstable and surgical intervention is required. The grades of hepatic injury are described in Table 4 [27-29].

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	Hematoma	Parenchymal disruption involving >75% of hepatic lobe or >3 Couinaud's segments within a single lobe
	Laceration	Juxtahepatic venous injuries (i.e., retrohepatic vena cava/central major hepatic veins)
VI	Hematoma	Hepatic avulsion

Table 4. Grading of liver injury based on the American Association of Surgery for trauma (AAST; 1994 revision) (data adopted from Moore EE, Cogbill TH, Gregory JJ, Shackford SR, Malangoni MA, Howard CR. Organ injury scaling: spleen and liver. *J Trauma* 1995;38:323-4)

In high-grade liver injury patients, liver-related complication rates are 11-13%. These can be predicted by the volume of packed red blood cells transfused at 24 hours post-injury and the grade of liver injury [30, 31].

6. Management

In the last 30 years, the management of liver injury has evolved significantly. The advancement of imaging studies has played an important role in the conservative approach for management. A shift from operative to nonoperative management for most hemodynamically stable patients with hepatic injury has been prompted by the speed and sensitivity of diagnostic imaging, particularly due to CT scanning and by advances in critical care monitoring [32, 33].

The operative versus NOM strategy depends upon presence of other injuries and medical comorbidities, hemodynamic status of the patient, and grade of liver injury (Table 5).

A positive FAST scan and DPL in hemodynamically unstable liver trauma patient promotes emergency abdominal exploration to establish the source of intraperitoneal hemorrhage. If the source is liver itself, an exploratory laparotomy is performed. The bleeding is control may be achieved through a damage-control approach or by using specific techniques for liver

hemostasis. The approach depends upon the extent of the liver injury and presence and extent of associated injuries.

Hemodynamically “normal”	Investigation can be completed before treatment is planned.
Hemodynamically “stable”	Investigation is more limited. It is aimed at establishing whether the patient can be managed nonoperatively, whether angioembolization can be used or whether surgery is required.
Hemodynamically “unstable”	Investigations need to be suspended as immediate surgical correction of the bleeding is required.

Table 5. Classification of patients as per their physiological conditions after abdominal trauma

Hemodynamically stable patients with blunt liver injury who do not have other indications for abdominal exploration can be kept under observation. Patients with right-sided penetrating thoracoabdominal injuries, which can lacerate the liver, can remain hemodynamically stable. Such patients can also be kept under observation provided there are no associated intra-abdominal injuries. Nonoperative management generally fails in patients with higher-grade injuries than those with lower-grade injuries. Still such patients should be treated with NOM as long as they are hemodynamically stable. Other patients who suffer extra-abdominal injuries but requiring intervention can also be kept under observation. Nonoperatively managed patients who continue to bleed, and even with ongoing blood transfusion have hemodynamic instability need surgical exploration. It is also indicated in those patients who manifest a persistent systemic inflammatory response syndrome (SIRS), like presence of ileus, fever, tachycardia, and oliguria. Grade III and higher injuries often requires a combined angiographic and surgical management [34].

6.1. Nonoperative management

Nonoperative management (NOM) is widely accepted as the treatment of choice for hemodynamically stable patients with hepatic injury and with no other associated injuries indicating urgent intervention. Nonoperative management (NOM) consists of repeated assessment, close monitoring, and supportive intensive

2e care management with utilization of indicated arteriography and hepatic embolization. Furthermore, NOM is now recommended for penetrating injury (stab wound) as well as low-velocity gunshot wound to right upper quadrant in stable patients after exclusion of other injuries requiring urgent laparotomy. Most of the injuries that fall in this category are Grade I and II liver injuries [35].

In the positive response of trauma victim to initial fluid resuscitation with stable hemodynamic status, allows for further better imaging by CT scan of abdomen and pelvis. Angiogram and angioembolization are part of the management of all NOM algorithms if contrast extravasation is demonstrated to improve the success rate of NOM. Operative intervention is currently reserved to hemodynamically unstable patients, associated injuries requiring laparotomy, and failure of NOM [36].

The grade of liver injury alone and the volume of hemoperitoneum are not considered definitive criteria for selecting operative versus NOM [37].

Large retrospective reviews reported that more than 80% of patients with blunt hepatic injury could be treated by NOM with success rates more than 90% [38-40].

A recent Cochrane review also supported nonoperative management by concluding that currently there is no evidence to support the use of surgery over NOM for patients with abdominal trauma [41].

Some of the contraindications to nonoperative management of liver injury are listed in Table 6.

• Hemodynamic instability after initial resuscitation
• Other indication for abdominal surgery (e.g., peritonitis)
• Gunshot injury (relative contraindication)

Table 6. Contraindications to nonoperative management

Patients with isolated penetrating hepatic injuries due to abdominal stab wounds has been managed using nonoperative approach but management of patients with gunshot wounds remains controversial. Up to one third of patients of gunshot wound, who are treated using NOM approach, showed failure due to continuous bleeding and development of abdominal compartment syndrome. One of the most important concerns is missed injuries to the gastrointestinal tract [42].

Patients that are managed by NOM needs to be admitted in hospital, placed on bed rest, and monitored continuously. If patients have a normal abdominal examination and stable hemoglobin for at least 24 hours, they can be discharged from hospitals. Large observational studies support this practice of discharging patients with liver injury regardless of the grade of injury. The clinical judgment of surgeon is important for deciding the length of observation [43]. Intensive care monitoring for at least 48-72 hours of hemodynamics and overall clinical condition is required for the rest of the cases. Other investigations and repeated clinical examinations and follow up investigations are done as indicated [44].

Thromboprophylaxis is indicated in patients with liver injury or other severe injuries who require hospitalization and are at a high risk for thromboembolism. At the same time, delay in the chemical thromboprophylaxis may be needed due to an increased risk of cerebral or bleeding from other sites. Success of pharmacologic prophylaxis is seen in patients in whom there are no other contraindications to pharmacologic prophylaxis and used when the hemoglobin gets stabilized with less than 1 g hemoglobin decrement over a 24-hour period of time [45].

6.2. Hepatic embolization

Hepatic embolization can be very useful way for prevention of bleeding. Success rates for embolization depends on many factors. Factors that determine the success includes institution policy, technique of embolization, access to arteries, skill of operator, and type of embolization

material used. A properly carried out hepatic embolization has replaced the need for initial operative intervention from many sites. The highest success of hepatic embolization appears to be when used preemptively in patients who demonstrate extravasation of contrast on the initial abdominal CT scan and when patient is hemodynamically stable. The technical success of this technique ranges from 68% to 87%. The incidence of recurrent hemorrhage is found to be low in retrospective reviews. Patients who have no success with observational management can be treated with hepatic embolization. It can also be used adjunctively to manage patients with ongoing bleeding or rebleeding from the liver after surgical treatment for liver injury [22].

6.3. Benefits and risks of nonoperative management

One of the main advantages of nonoperative management is that it reduces the risks inherent to surgery and anesthesia procedures. However, one of the main disadvantages associated with NOM includes an increased risk of missed intra-abdominal injury, particularly hollow viscus injury, risks associated with embolization, and transfusion-related illness.

Blood transfusion is a life-saving measure during excessive bleeding and related complications. However, it is also associated with many complications. Commonly seen complications include intravascular volume overload (transfusion associated circulatory overload (TACO)), transfusion-related acute lung injury (TRALI), immunologic and allergic reactions, as well as immunomodulation (transfusion-related immune modulation, TRIM), hypothermia, and coagulopathy. Hepatic embolization is also associated with additional risks. These includes risk of bleeding, complications at the arterial access site, necrosis of liver, abscess in the liver or subdiaphragmatic space, inadvertent embolization of other organs (e.g., bowel, pancreas) or lower extremities, arterial intimal dissection, contrast-induced allergic reactions, and contrast-induced renal toxicity and nephropathy. When embolization is performed following contrast CT scan, particularly in patients who with volume depletion, the risk of contrast-induced nephropathy is even greater. Repeated clinical monitoring and surgical intervention is a must if conservative treatment fails. Studies have shown statistically significant difference in terms of requirements for blood transfusion and intra-abdominal complications when comparing patients receiving operative and nonoperative treatment of liver injuries. However, it shows no difference in the length of hospital stay [46].

The underlying important requirement for use of conservative or NOM is that this should be under guidance of highly trained surgeons. This is because unexpected and difficult to manage complications can occur during observation, and surgeon should be able to convert this management to difficult surgical strategies [47].

6.4. Failure of nonoperative management

Failure of NOM is defined as the need for urgent surgical intervention and is generally related to hemodynamic instability and bleeding that becomes apparent by the need for ongoing fluid resuscitation or transfusion. Patients who become hemodynamically unstable, by definition, have failed NOM. The option here is almost limited to the life-saving emergency exploration laparotomy. Arterial embolization is less favored after NOM failure, mainly due to the time

needed to set up the interventional radiology suite, the complexity of the embolization procedure, and the possible failure that will delay a definitive surgical intervention [48].



Figure 4. Patient with Grade IV liver injury, as shown in Figure 3C, who was hemodynamically unstable and showed extravasation of contrast and was unfit for angioembolization underwent laparotomy and resection of the fragmented right posterior liver segment.

A number of complications should be anticipated in NOM. One of the most common complications is biliary tree disruption with formation of biloma and/or persistent bile leak. Furthermore, hepatic necrosis can be seen following angioembolization for hepatic injury. It may also be seen following other procedures like laparotomy and hepatorrhaphy. Factors that may contribute to or indicate failure of NOM include advanced age of patient, delayed bleeding, sudden and severe hypotension, and active extravasation of contrast not controlled by angioembolization [35, 49, 50].

6.5. Surgical management

The operative management of liver injuries that require surgical intervention can be a challenge even for experienced surgeons (Table 7).

-
- Complex anatomical structure of the liver
 - Large size
 - High blood supply (vascularity), which is dual in nature
 - Rich and difficult-to-access venous drainage
-

Table 7. Operative challenges in the management of liver injury

Operative intervention is most commonly preferred for penetrating abdominal or thoracic injuries with hemodynamically unstable patients. If the injury is a result of a high-velocity gunshot wound and if there is associated hollow viscus injury, it is always the preferred approach [51]. Hemodynamic status rather than grade of injury is more important indication for operative management in patients with blunt abdominal and chest injuries. As a general rule, a higher-grade injury usually has higher potential for failure of nonoperative management. Emergency laparotomy is also indicated in NOM if there is rebleeding, constant decline of hemoglobin, and increased transfusion requirement, as well as the failure of angioembolization of actively bleeding vessels [52].

Various surgical methods that are described include direct suture ligation of the parenchymal bleeding vessel, repair of venous injury under total vascular isolation and damage control surgery with utilization of preoperative, and/or postoperative angioembolization and perihepatic packing. Less preferred methods include anatomical resection of the liver, vascular ligation and use of the atriocaval shunt [53].

6.6. Damage control surgery

Damage control or damage limitation surgery is the concept originated from naval strategy, whereby a ship which has been damaged can be managed with minimal repairs to prevent it from sinking and definitive repairs can wait until it reaches port. One of the approaches includes perihepatic packing and closure of the abdominal incision using either a Bogata bag or a partial closure of proximal abdominal incision. With the similar approach, a minimum surgery is needed to stabilize the patient's condition, and in the meantime, the physiological derangement can be corrected. Damage control surgery is done with main objectives, including stopping any active surgical bleeding and controlling any contamination. The timing of reexploration depends upon many factors, including the correction of acidosis, coagulopathy, and hypothermia (i.e. trauma's lethal triad). The window considered safe during damage control surgery is 12-48 hours for reexploration and formal completion of the surgery [54, 55].

The algorithm for blunt liver trauma management is depicted in Figure 5.

7. Morbidity and mortality

Mortality rates for hepatic injury vary as per grade of the injury, associated injuries, and general condition of the patient. The outcome has improved over the years, and the major contributing factors are the new approaches in form of nonoperative management strategies, damage control, and use of perihepatic packing. Since mortality is rarely seen with Grade I and II injuries, the reduction seen was difficult to perceive. However, reduction in operative mortality has seen a great decline especially for higher-grade liver injuries (Grades III, IV, and V). The overall mortality rate may vary from 10% to 42% as per the higher grade of injuries [31].

Many studies have evaluated factors determining the mortality of hepatic injury treated by surgical management. Various factors have been found to have strong association with rate of

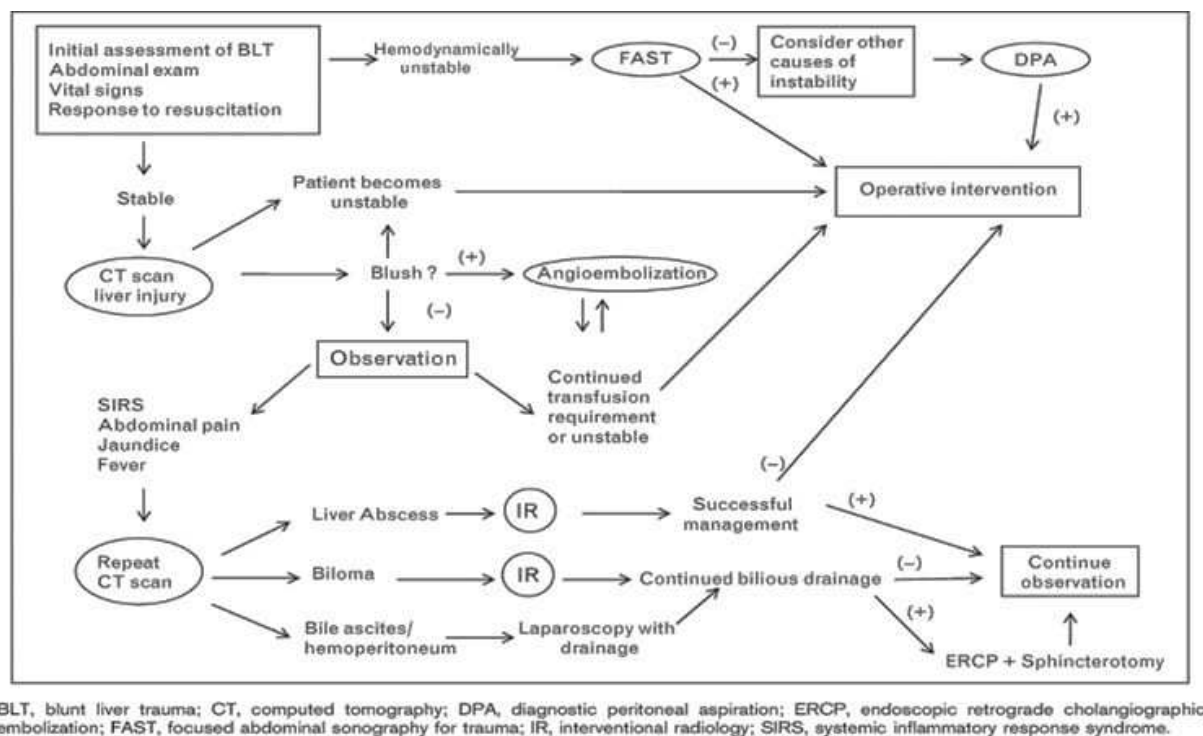


Figure 5. Algorithm For Nonoperative Management of Blunt Hepatic Trauma (adopted from Western Trauma Association critical decisions in trauma: nonoperative management of adult blunt hepatic trauma. *J Trauma*. 67:1144–1148, 2009).

mortality, which includes hemodynamic instability, coexisting musculoskeletal and chest injury, high levels of aspartate aminotransferase (AST), alanine aminotransferase (ALT), lactate dehydrogenase (LDH), long activated partial thromboplastin time (APTT), prothrombin time (PT), low fibrinogen levels, and platelet counts on admission. Not surprisingly, mortality is notably decreased when the liver trauma is managed by hepatobiliary surgeon if feasible [57].

8. Conclusion

- i. Liver injury is a significant cause of morbidity and mortality in trauma patients, and being the largest solid organ within the abdominal cavity, it is easily injured.
- ii. Chest X-ray and FAST are useful preliminary investigations in order to determine a correctable major injury. Diagnostic peritoneal lavage (DPL) may be preferred over FAST where the latter is not available.
- iii. Further radiological assessment may aid diagnosis, but it is applicable if that is not delaying operative management of a patient in whom FAST is positive and patient is hemodynamically unstable.

- iv. If FAST is positive and patient is hemodynamically stable, then CT scan remains the gold standard investigation as it delineates the extent of liver injury, identifies other associated injuries, and directs management.
- v. For hemodynamically stable patients with liver injury, irrespective of grade of liver injury, the nonoperative management is preferred over definitive surgical intervention.
- vi. Hepatic embolization may have better outcome for hemodynamically stable patients with liver injury who demonstrate pooling of intravenous contrast on initial or subsequent abdominal CT scan, rather than nonoperative management without embolization.
- vii. Hepatic embolization requires specialized imaging facilities and an appropriately trained interventionist experienced with celiac artery catheterization. Failure of hepatic embolization to control bleeding indicates the need for surgery.
- viii. Operative management involves initial control of hemorrhage and contamination followed by perihepatic packing and rapid closure, allowing for resuscitation to normal physiology in the intensive care unit and subsequent definitive reexploration.
- ix. If the patient is hemodynamically unstable despite attempts to halt bleeding, techniques such as Pringle's maneuver (clamping of the hepatoduodenal ligament), simple suture and compression, hepatotomy and vascular ligation, or atriocaval shunt may be considered.
- x. If these attempts also fail to achieve hemodynamic stability, transfer to a specialist liver surgery unit is advisable as there is substantial evidence to indicate that mortality is reduced when hepato-pancreato-biliary surgeons manage liver trauma.

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