Treatment of Liver Injuries: An Overview

2

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Introduction

The liver is the largest organ in the body and the organ most frequently injured. This is true for both blunt and penetrating wounds [1, 2]. The morbidity and mortality associated with liver injury vary with the associated hemorrhagic shock insult, the severity of liver injury as judged by the Abbreviated Injury Score (AIS), and the presence or absence of bleeding at the time of operative intervention [3–5]. The severity of injury related to missile wounds correlates directly with the amount of energy that is dissipated as the missile traverses the liver, with the energy being calculated by the classic formula of $energy = mass \times volume^2 \div 2$. Thus, high velocity missiles have the greatest potential for creating the worst injuries. When a patient with a liver injury presents with severe hemorrhagic shock that is not rapidly reversible with preoperative resuscitation, the mortality is very high; when the hemorrhagic shock insult is corrected while in transit to the operating room, the mortality is low; when there is no associated hemorrhagic shock, the mortality is negligible [3, 5]. The presence or absence of bleeding at the time of operative intervention correlates closely with the AIS. Patients with major AIS (4, 5) have a 70 % chance of active bleeding at the time of operation compared to only a 30 % chance of active bleeding in patients with a minor liver injury (AIS 1, 2, 3) [3, 5]. Active bleeding in these patients appears to be the primary cause of death. In a prospective study of 637 patients treated over 5 years, 46 of the 68 patients who died in association with active intraoperative bleeding died within the first 24 h, whereas when bleeding from the liver was controlled with a temporary pack, only six of the 26 deaths occurred within the first 24 h [1, 2]. The mortality following liver injury is also related to the number of associated injuries, particularly those involving named intra-abdominal vessels. Mortality with isolated liver injury is less than 5 %, whereas mortality in patients with five or more associated injuries exceeds 75 % [1, 6].

Surgical Incision

Patients about to undergo operation for suspected liver injury should have full prep of the chest and abdomen in anticipation that the thoracic

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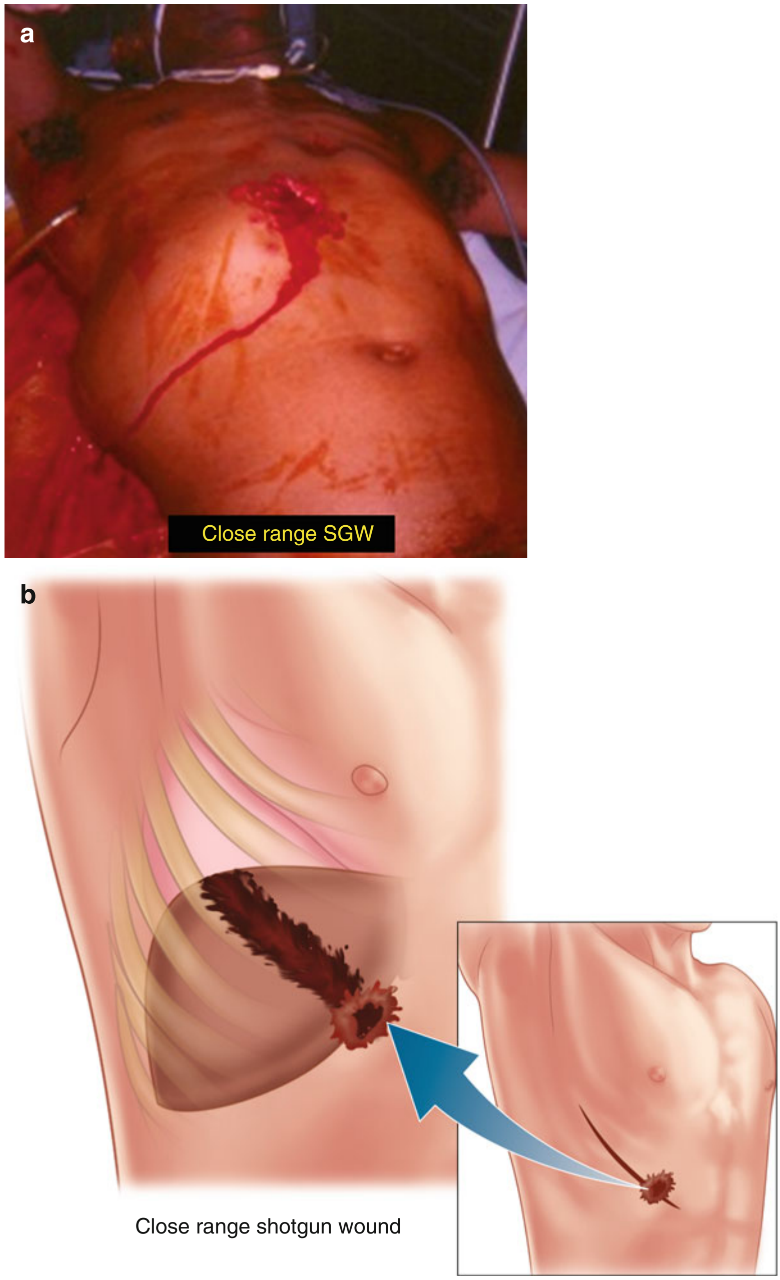


Fig. 2.1 Patients presenting with a large truncal defect in the right upper quadrant/right lower chest from a close-range shotgun blast or rifle wound (**a**) should be explored by an oblique incision which extends through the large defect and, if needed, can be extended inferiorly along the midline of the abdomen (**b**)

extension of an abdominal incision might be necessary [7–9]. The most efficient initial incision is the midline laparotomy extending from xiphoid to umbilicus or below depending upon intraoperative findings. Exceptions to this policy occur when a patient presents with a large truncal defect due to a high velocity rifle wound or a close-range shotgun wound. In this setting, the laparotomy or combined thoracoabdominal approach should incorporate the large truncal defect as part of the incision (Fig. 2.1) [2]. Although the thoracoabdominal incision provides excellent exposure to patients with major liver injuries, they tend to be associated with greater morbidity in comparison to the median sternotomy, which can be used to provide

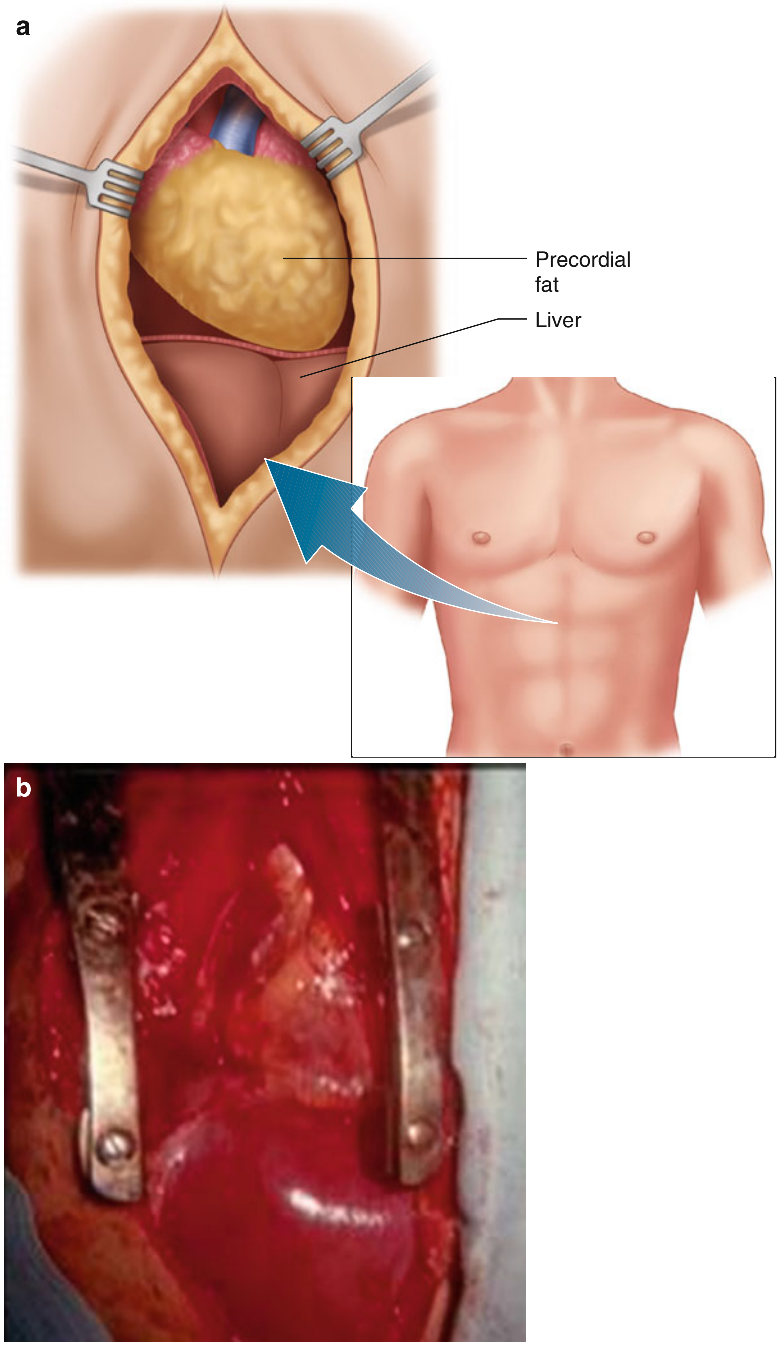


Fig. 2.2 The midline laparotomy provides the most practical approach to patients with both blunt and penetrating wounds involving the liver (**a**). This incision can then be extended superiorly as a median sternotomy in order to get control of bleeding from dome of the liver or from the hepatic veins (**a**). The diaphragm can be divided in the posterior midline to facilitate this control(**b**)

complete liver mobilization (Fig. 2.2) [2, 8]. Division of the diaphragm and the median plane from the crura anteriorly also allows for access to the IVC in patients in whom a retrohepatic IVC shunt is anticipated [2, 8].

Temporary Packs

Upon entering the abdomen, rapid packing of all four quadrants allows the anesthesia team to catch up so that sequential life-saving treatment

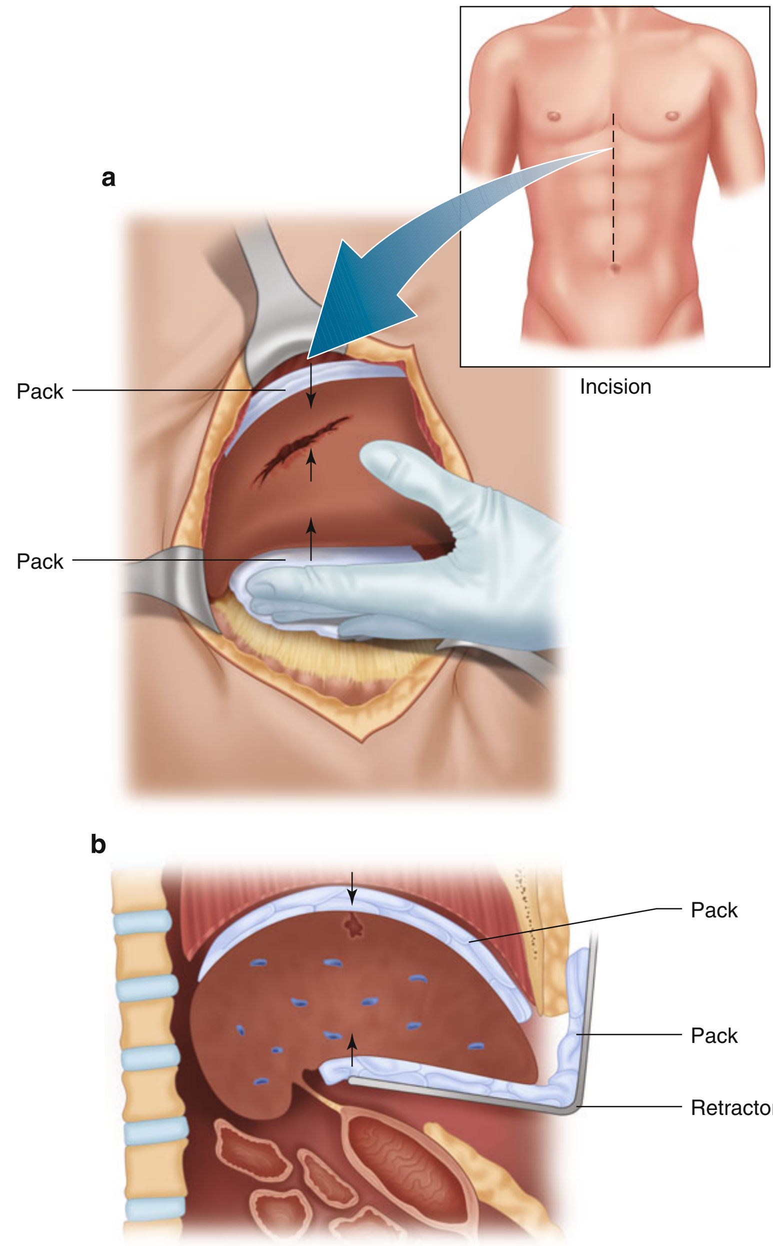


Fig. 2.3 Actively bleeding injuries from the right lobe can usually be temporarily contained by placing packs superiorly and inferiorly to the right lobe and then providing compression either digitally (**a**) or by way of the large right-angled retractor (**b**)

can be implemented on a priority basis [2, 10, 11]. When a major liver injury with active bleeding is identified, successful packing can usually be achieved by placing lap sponges above and below the liver and then using a large straight retractor to pull the liver up toward the diaphragm (Fig. 2.3). A penetrating wound adjacent to the gallbladder floss often can be controlled by a gauze pack but stressed by a Harrington retractor (Fig. 2.4) [2, 10]. The pack technique usually controls major hepatic bleeding; pressure should be maintained while bleeding from other sources is controlled and while a first-layer closure of hollow-viscus injuries is accomplished. When these latter objectives have been completed, the liver pack can be carefully removed. Often a major liver injury is no longer bleeding after pack removal. When this occurs, the injury should be

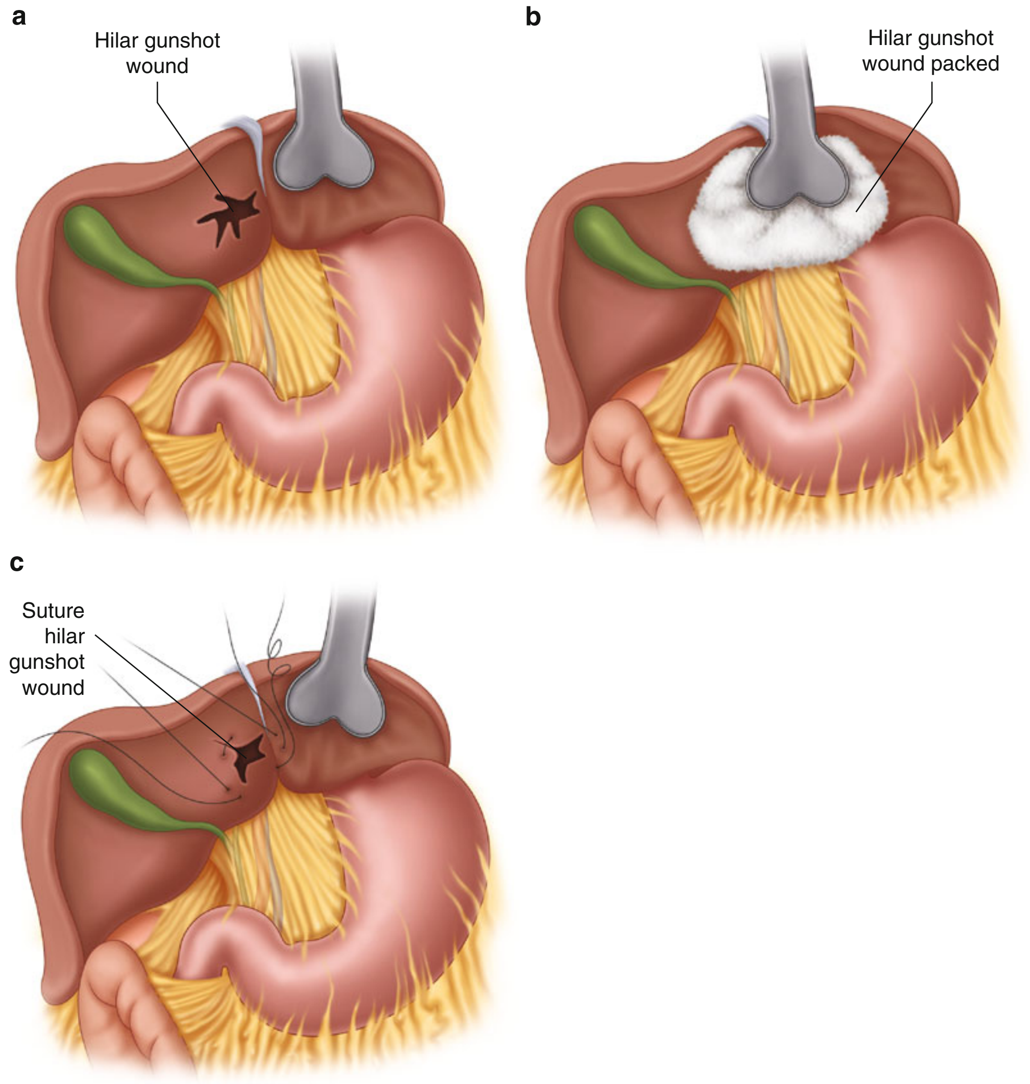


Fig. 2.4 Bleeding wounds near or at the hilum (**a**) can usually be contained by placing a pack and a Harrington retractor over the injury (**b**) until temporary hemostasis is obtained or slowed, at which time liver sutures placed on each side of the defect will provide hemostasis (**c**). Cholecystectomy is usually indicated in patients with these injuries

left alone; aggressive palpation manipulation, especially probing "to see if there is any mushiness" within the liver, may lead to recurrent hemorrhage that is lethal. When the liver rebleeds after pack removal, they should be reapplied and pressure retraction reinstituted. This will provide an opportunity to achieve proper mobilization of the portion of the liver that needs to be approached surgically [2, 12, 13].

Hepatic Mobilization (Right Lobe)

The approach to hepatic mobilization varies according to the site and extent of liver injury. Mobilization of the right hepatic lobe in patients with major injuries near the right hepatic vein, or "bare" area of the liver, is most challenging [2, 13]. The right triangular ligament extends along the dome of the right lobe and can be divided in

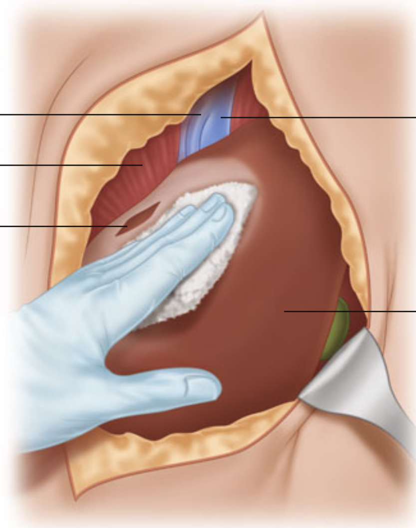


Fig. 2.5 Access to the right hepatic dome and right hepatic vein is achieved by mobilizing anteriorly and medially the right lobe beyond the bare area of the liver until the right hepatic vein is identified as it courses superiorly and posteriorly for about 2 cm to the IVC

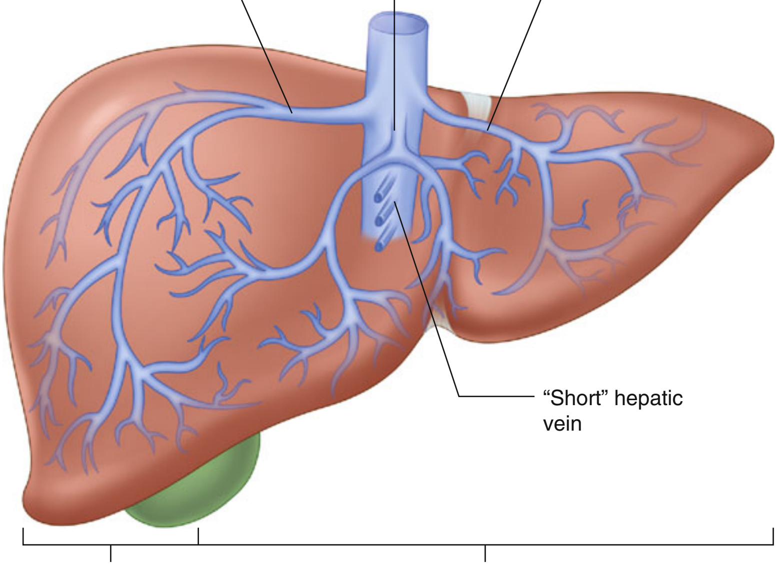


Fig. 2.6 The "short" hepatic veins run from the caudate lobe to the anterior portion of the IVC. The authors prefer that, when divided, these veins be controlled by suture ligature or ties rather than with clips which can be pulled off the vein when they get attached to a sponge being removed. The classic hepatic venous system has separate entrance of the right, middle, and left hepatic veins into the IVC. Sometimes the middle hepatic vein and left hepatic vein join before entrance into the IVC

its1–2 cm width between the dome of the liver and the right hemidiaphragm (Fig. 2.5). When suprahepatic packs must be left in place to contain bleeding, this ligament can be divided throughout most of its length by Braille dissection. The bulk of the right lobe can then be mobilized inferiorly as the so-called "bare" area between the liver and diaphragm is reached (Fig. 2.6). The liver is mobilized anteriorly and medially as the "bare" area is dissected, being careful not to inadvertently perforate the diaphragm superiorly or dissect into the liver substance inferiorly

[7, 13]. Further mobilization in the same direction provides access to the right hepatic vein, which rises on a superior portion of the liver and extends about 2 cm superiorly into the inferior vena cava (IVC, Fig. 2.5) [2, 12]. Careful dissection of the tissues medial to the right hepatic vein along with division of the diaphragmatic crura anteriorly permits access to the right hepatic vein/IVC junction.

When further mobilization on the right lobe is needed in order to achieve anatomic resection, the right lobe can be retracted anteriorly, being careful to avoid injury to the right adrenal gland with its numerous vessels and, more medially, the short hepatic veins, which run between the caudate lobe and the inferior vena cava [2]. These veins need to be divided; the authors prefer suture ligature rather than clips, which sometimes catch onto sponges and yank off the divided veins (Fig. 2.6).

Hepatic Mobilization (Left Lobe)

Mobilization of the left hepatic lobe is much less challenging. The left triangular ligament between the left lobe and the left hemidiaphragm is more accessible and, therefore, more safely divided beyond the left lateral segment; this ligament is divided to the left medial segment where the left hepatic vein will be seen exiting on it and passing superiorly toward the left side of the IVC (Fig. 2.7) [2, 13]. The left hepatic vein usually flows directly into the IVC but, on occasion, may join with the mid-hepatic vein, in which case the entrance into the cava will be more medial. The short hepatic veins between the caudate lobe and IVC are usually not identified while mobilizing the left lobe. The entrance of the short hepatic veins is about 2–3 cm distal to the entrance of the middle and left hepatic veins into the IVC (Fig. 2.6) [2]. With full mobilization on the left lobe, however, these veins may be divided.

Hepatic Inflow

Control of arterial inflow is an important adjunct to hepatic mobilization. Temporary control can be achieved by the Pringle maneuver whereby one digitally compresses the portal triad just distal to the insertion of the cystic duct into the common bile duct (Fig. 2.8) [2, 12]. Temporary digital control can be achieved by Braille technique; vascular non-crushing clamps are used for longer term control. Long-term occlusion should not extend beyond 20 min at one time [13]. The individual branches of the hepatic artery and portal vein can then be dissected as one mobilizes the injured portion of the liver.

Vascular Anomalies

Although there are several anomalies of the hepatic arterial inflow, the most common occurs when the right hepatic artery arises as the first branch of the superior mesenteric artery; when this occurs, the right hepatic artery courses posterior to the pancreas and duodenum before curving superiorly toward the liver as the most lateral structure of the portal triad (Fig. 2.9) [2, 13]. Other less common anomalies of the hepatic arterial system include a common hepatic artery that rises from the superior mesenteric artery, a very proximal bifurcation of the common hepatic artery into the right and left hepatic arteries, and an accessory left hepatic artery that originates from the left gastric artery and perfuses the left lateral segment. The anomalous right hepatic artery provides oxygenation to all of the right lobe and the left medial segment. When this anomaly occurs, the left hepatic artery typically arises from the left gastric artery, passes through the lesser omentum, and provides oxygenation to only the left lateral segment. Portal venous anomalies are much less common.

The Non-bleeding Wound

Often, when the packs that are used to obtain temporary control of the bleeding liver are removed, no rebleeding occurs. This wound should be observed and the surgeon should be certain that the patient is fully resuscitated and has stable vital signs. The non-bleeding, thus observed wound, should be left alone. Digital or instrument probing of the wound, as noted above,

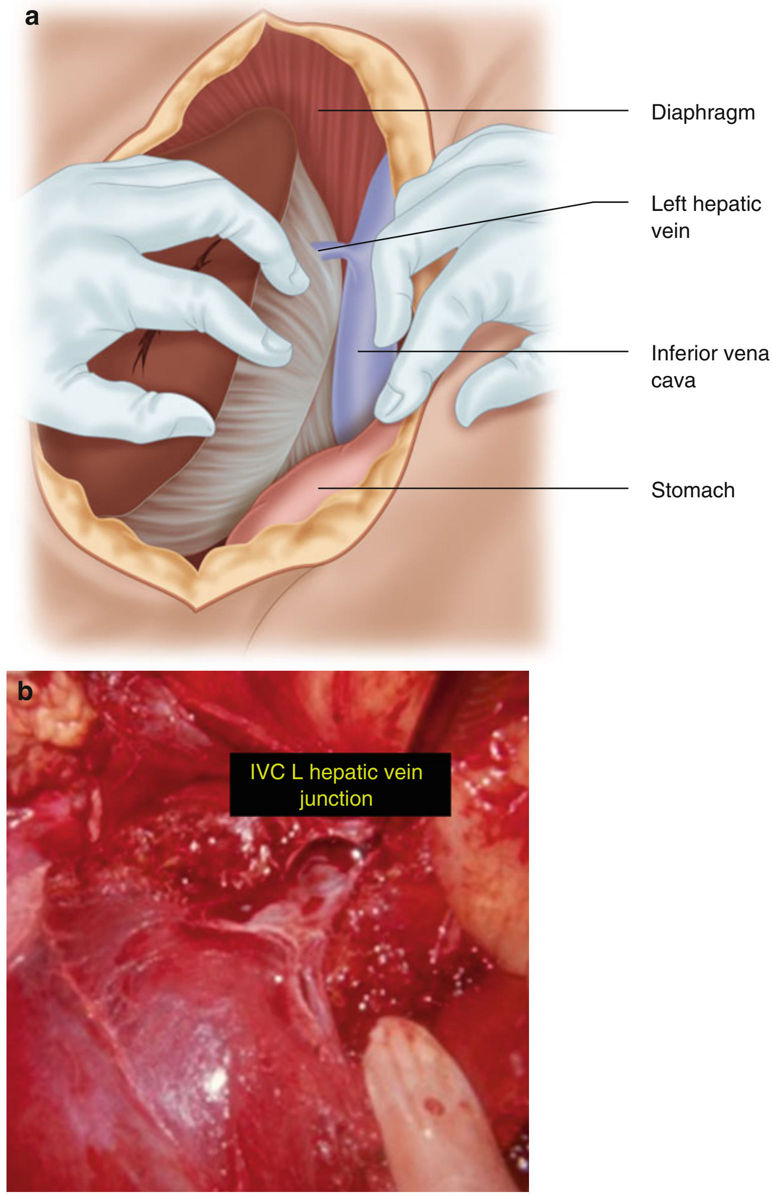


Fig. 2.7 The left hepatic vein usually flows superiorly and medially into the IVC and is accessed by dividing the left triangular ligament (**a**). After obtaining temporary control of the cava and left hepatic vein, the patient shown herein had rapid left hepatic lobectomy and oversewing of the left hepatic vein – IVC junction after placement of a Satinsky clamp (**b**). This type of patient salvage only occurs when God is not ready to receive the patient

may lead to recurrent and sometimes lethal bleeding. Likewise, when a bullet has passed through the liver parenchyma into the hepatic vein and inferior vena cava with embolization to the right heart, the tract should be left alone and the known perforation of the retrohepatic IVC should not be explored (Fig. 2.10) [2]. No hemostatic techniques should be employed in a stable patient with a non-bleeding wound.

During a prospective study of 637 patients who were operated upon for liver injury during a 5-year period, there were 280 patients in whom there was no bleeding after the liver packs were removed and the vital signs were stable [1, 2, 8]. These wounds were left alone, and not one patient had postoperative bleeding from the non-bleeding liver wound. Likewise, the isolated subcapsular hematoma should be left alone (see Fig. 2.13).

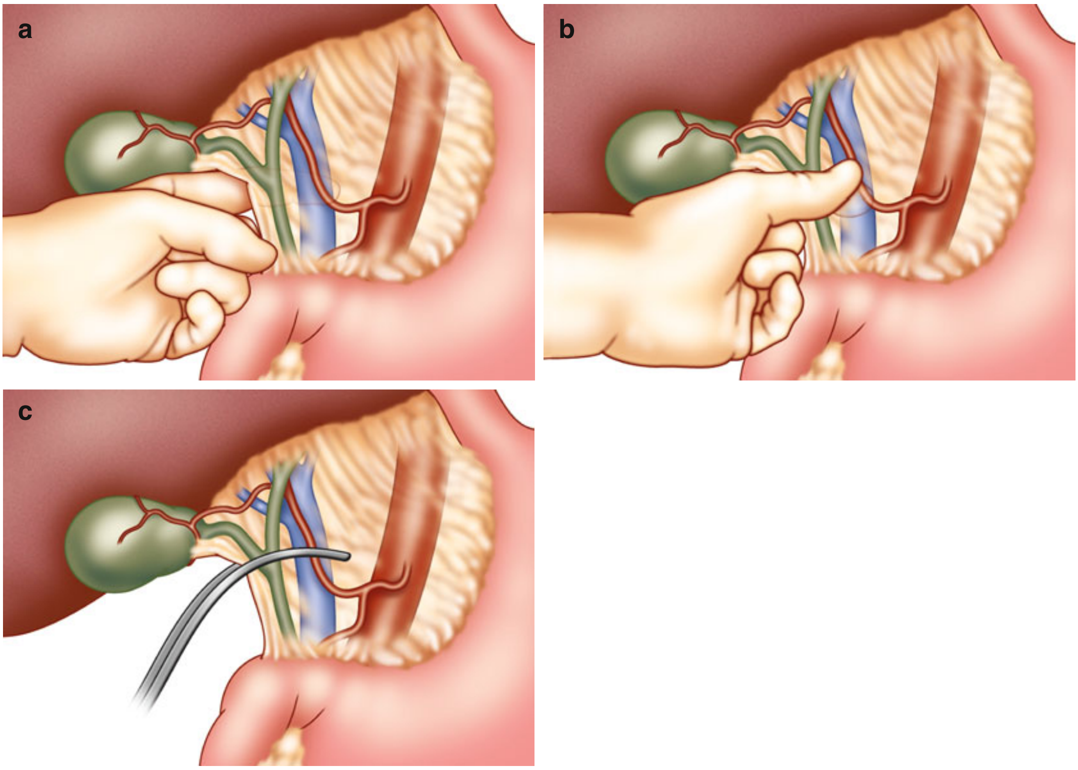


Fig. 2.8 The Pringle maneuver achieved with digital compression of the porta hepatis (**a**) not only provides good temporary inflow control of bleeding (**b**) but also is a predictor of the likelihood that hepatic dearterialization will contain active bleeding from a branch of the hepatic artery (**c**)

Patients treated nonoperatively for intrahepatic hematomas usually have normal resolution of the hematoma; some patients, particularly intravenous drug addicts, will have bacterial seeding of the hematoma leading to an abscess, which can usually be drained percutaneously.

Hemostatic Techniques/Liver Suture

The simplest and most successful technique for obtaining hemostasis from bleeding liver wounds is hepatorrhaphy using liver sutures [2, 12]. These sutures are blunt tipped, two inches in length, and swedged on to a 2-O chromic suture (Fig. 2.11) [2, 14]. The blunt-tipped needle minimizes parenchyma damage while passing through the liver and can be easily grasped by the surgeons without fear of a needle injury. The suture should be passed through the full depth of the two-inch needle, well away from the bleeding margins with large deep bites (Fig. 2.11) [2]. The sutures are then approximated in order to bring the liver substance together without strangling it and hence creating liver necrosis (Fig. 2.12) [2]. This can often be best achieved by having the first assistant hold one of the strategically placed sutures so that the liver is compressed but not strangled while the surgeon ties a second suture in order to achieve the exact degree of compression without tearing or strangulation.

One of the controversies regarding hepatorrhaphy concerns the patient with active bleeding through both the entrance and the exit sites of a liver gunshot wound. The fear of closing both the entrance and exit wounds is that there will be continued intrahepatic bleeding, which may cause a need for reoperation or become contaminated

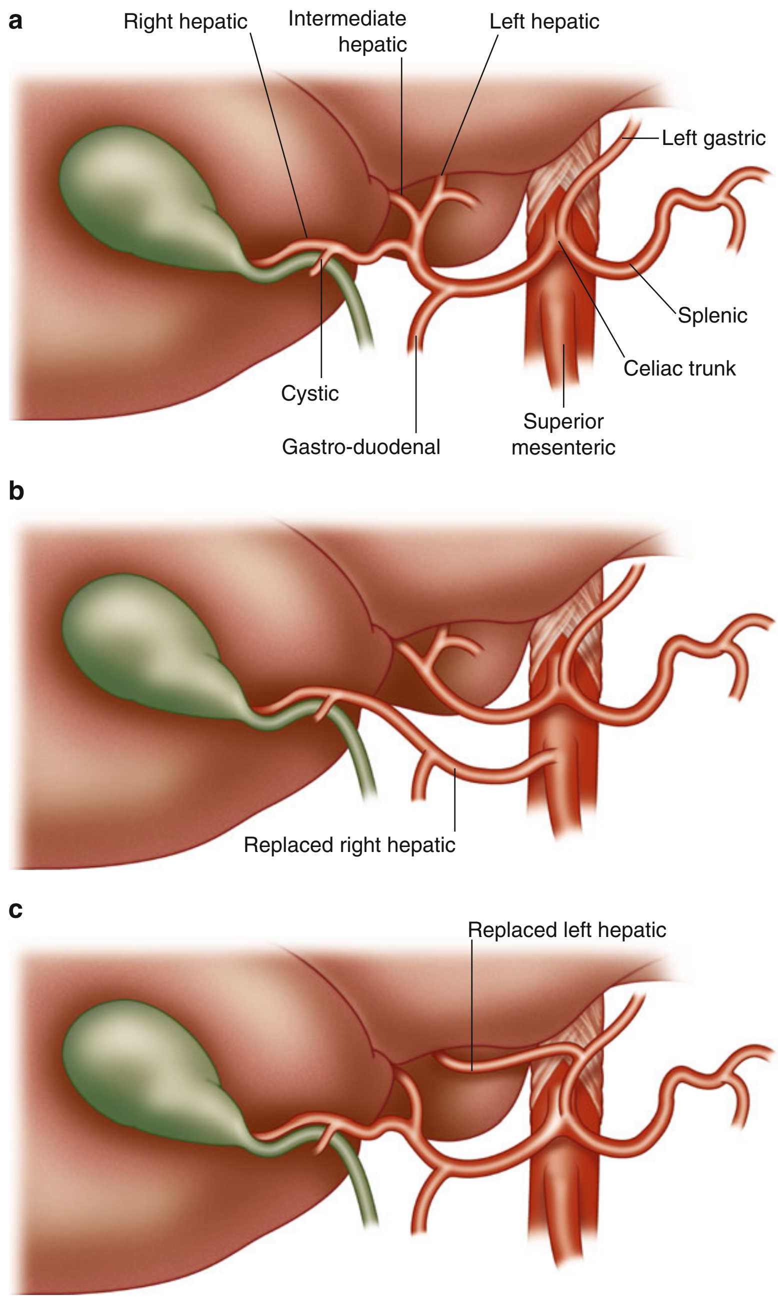


Fig. 2.9 Normal hepatic arterial inflow is shown (**a**) along with the two common anomalies, namely, the right hepatic artery originating from the superior mesenteric artery (**b**) and the left hepatic artery originating from the left gastric artery (**c**)

and result in an intrahepatic abscess [2]. Actually, most bleeding from the through-and-through liver wound arises from liver parenchyma within 2 cm of the capsule; the authors have successfully closed both ends of a through-and-through tract with a good hemostasis and without having the above complications [2]. In patients in whom both ends of the missile tract have been closed with liver sutures, rebleeding through the liver sutures from the unopposed deeper structures will be readily apparent within five minutes of tying the liver sutures. When this occurs, the liver suture must be removed and some other hemostatic technique employed.

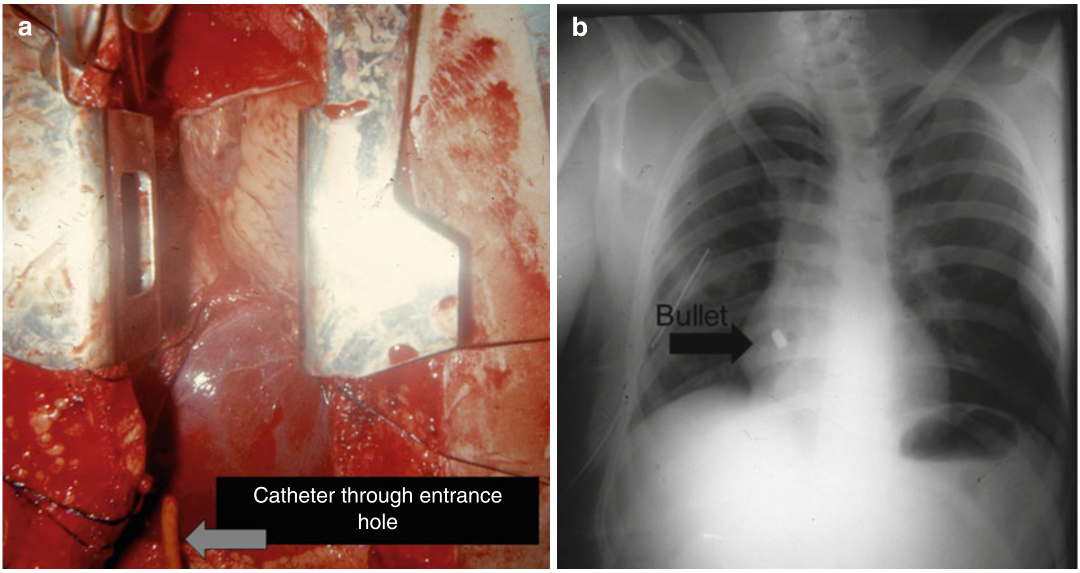


Fig. 2.10 When a missile passes through the substance of the liver with the tract depicted by the catheter (**a**) and ends up being embolized to the heart or lung (**b**), penetration of the anterior wall of the IVC is confirmed. This perforation along the anterior wall of the IVC should not be explored if there is no bleeding, whereas the bullet embolus can be dealt appropriately depending on its final location

Hepatotomy

The next step for this type of wound is tractotomy or hepatotomy, which is achieved by cutting through the normal liver down to the through-and-through tract [2, 8, 12]. This is performed by a combination of electrocoagulation, finger fracture, and ligation of the cross-linking vessels that are encountered while doing the tractotomy (Fig. 2.13) [2, 8]. Hemostasis along the two "cliffs" of the tractomy is best achieved by gauze compression until the bottom of the tract is reached, by which time one usually will see a partially severed artery and/or vein at the bottom of the crevice. The partial severance of an intrahepatic artery prevents retraction, contraction, and formation of a platelet plug. These vessels are best treated with simple ties or suture ligation depending upon the depth and accessibility. There are a number of instruments that may help in hepatic dissection. A long GIA stapler may be useful in providing quick division of the uninjured liver while doing a tractomy [8, 12]. Likewise, the argon beam laser can provide excellent access for parenchymal division, although the authors tend

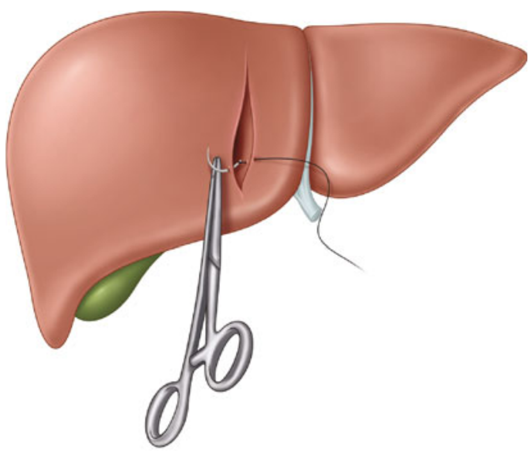


Fig. 2.11 Hepatorrhaphy or suture ligature of the liver is best achieved by using the 2″ blunt-tipped needle swedged onto a 2-O chromic suture. The sutures are placed well away from the wound and deep into the liver substance in order to obtain compression hemostasis of those vessels which are within 3 cm of the liver capsule

to rely on electrocoagulation for this purpose. Likewise, the cross-linking vessels that have to be divided in order to get to the bottom of the tract are best secured with ties or suture ligatures

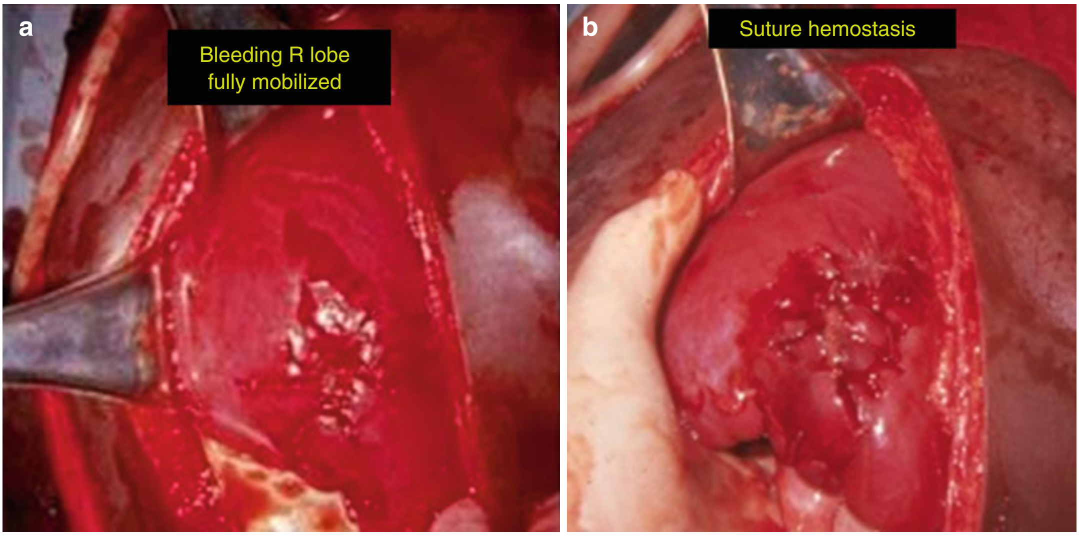
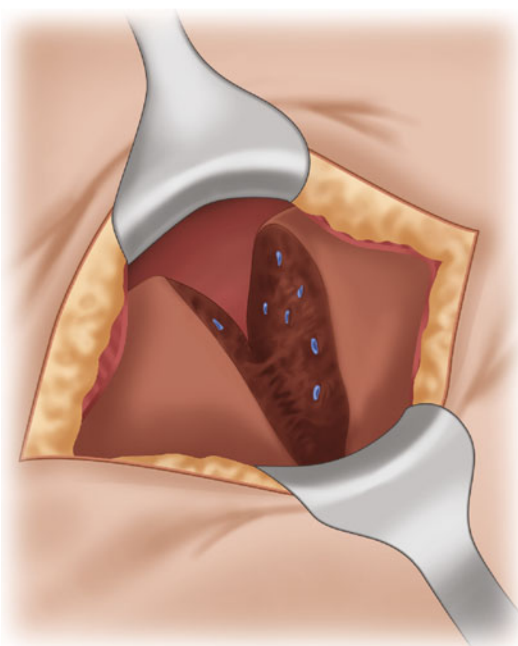


Fig. 2.12 After full mobilization of an actively bleeding right lobe of the liver (**a**), deep liver sutures usually achieve complete hemostasis without causing parenchymal ischemia (**b**)



Middle right lobe

Fig. 2.13 Hepatotomy or tractotomy is often indicated in patients with deep through-and-through gunshot wounds when hemostasis cannot be obtained by suture ligature of the entrance and/or exit wound. Hemostasis along the tract margin is obtained by a combination of electrocoagulation, suture ligature, and ties of cross-linking vessels until the bottom of the tract is reached

rather than clips, which may get attached to the gauze sponges and pulled off when removing the gauze sponges (Fig. 2.13) [2]. Once hemostasis has been achieved in the deep tract or crevice and the visible vessels have been ligated along the two sides leading to the tract, the divided liver is best re-approximated using the same liver suture technique described above (Fig. 2.14) [2].

Resectional Debridement

Some wounds do not lend themselves well to suture ligation or tractotomy. Examples would be patients who have a rifle wound or shotgun blast to a peripheral portion of the liver [3, 8, 9]. The extent of parenchymal damage in this setting is usually too excessive for containment by suture ligatures (Fig. 2.15) [2]. These patients are best treated by resectional debridement or wedge resection of that portion of the liver that is severely damaged. The margins of the resectional debridement should be carried out through the relatively uninvolved portion of the liver so that all of the ragged, shredded fragments get removed. The margins of resection are then contained with the liver suture technique after the ragged,

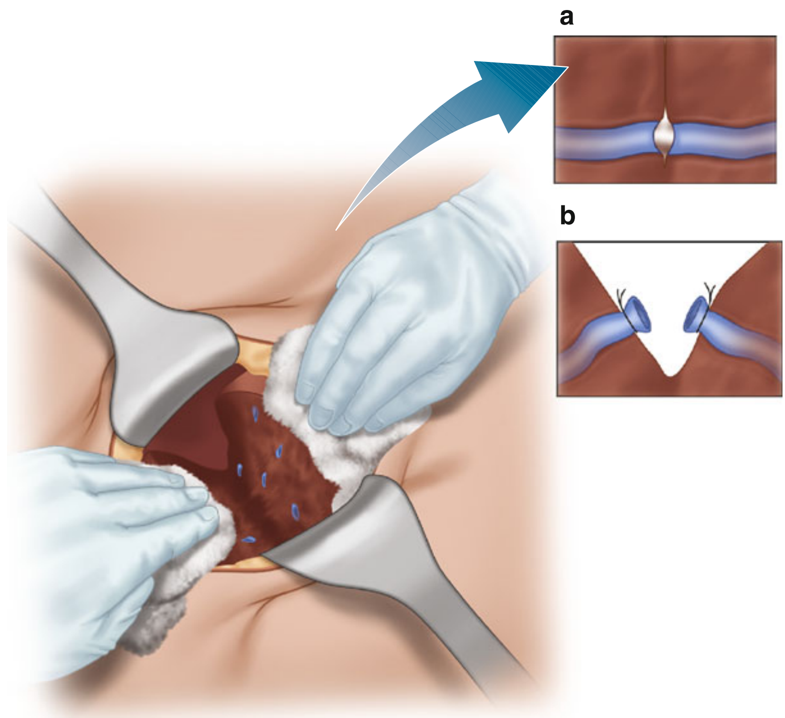


Fig. 2.14 When hemostasis has been achieved in the deep tract and all visible cross-linking vessels have been ligated (**b**), the divided liver is best re-approximated using the same liver suture technique described above (**a**)

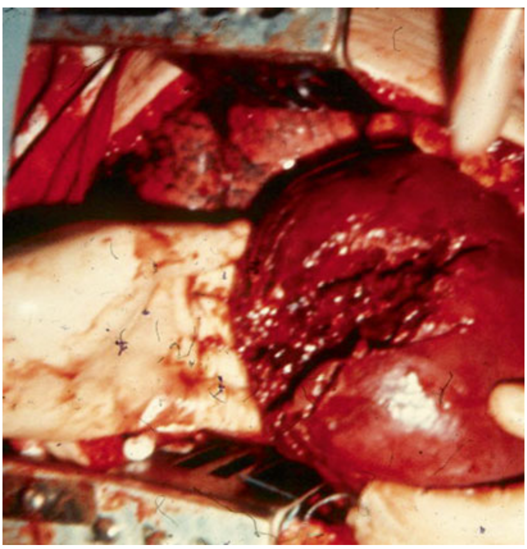


Fig. 2.15 Rifle wounds or short-range shotgun blasts often causes extensive parenchymal damage which is not amenable to suture ligation. These patients are best treated by resectional debridement or wedge resection of the severely injured tissue

shredded portion of the liver is removed. During the period of resection or debridement, digital pressure applied to both the anterior and posterior surfaces of the liver will usually help contain bleeding and may also assist in applying the liver sutures after the damaged portion of the liver has been removed. Often, the decision to perform nonanatomic hepatic resection rather than anatomic resection is determined by the injury whereby patients with obvious devitalized tissue require the so-called resection or debridement without formal anatomic lobectomy [2, 9, 15].

This type of resectional debridement is not easily implemented in patients with superior central liver injuries. An extension of the resection debridement type of incision proximally to the opposite surface will result in a so-called nonanatomic hepatic resection where a significant portion of liver is removed without following the typical anatomic plains. Hemostasis in this setting is usually achieved by manual compression of either the right lobe or left lobe proximal to that portion of the liver that is being removed in a nonanatomic manner [8, 15]. The Pringle maneuver is also helpful in this setting (Fig. 2.8). Hepatic arterial and portal venous injury can be distinguished from hepatic venous injury by the Pringle maneuver, which will cause cessation of bleeding from the hepatic artery and portal venous injuries but not from the hepatic venous injuries [2, 8]. Two mature surgeons should be present when nonanatomic resection is performed through the thick portion of the right lobe.

Hepatic Dearterialization

The use of hepatic artery interruption is not only useful in providing temporary hemostasis while performing nonanatomic resection but may also be used as the definitive hemostatic technique. This is particularly true in patients who have deep wounds, which are not readily accessible to suture ligation, tractotomy, or nonanatomic resectional debridement. A prediction about the likelihood of success is provided by cessation of bleeding with the Pringle maneuver (Fig. 2.8) [2, 8]. If hemostasis is achieved with the Pringle maneuver, then one can move peripherally along the branches of the hepatic artery to find the specific branch that, when occluded, stops bleeding [16]. The hepatic artery provides about 500 ml of blood flow per minute to the liver in comparison to about 1,000 ml of blood flow by way of the portal vein. Since the hepatic artery has a higher oxygen content, it supplies about 40 % of the hepatic oxygen consumption compared to 60 % by the portal vein. Thus, ligation of the hepatic artery should not produce liver necrosis [2]. When, however, there is an associated portal venous injury, the ligation of both will certainly produce necrosis to that segment of the liver. Maintaining good knowledge about the anatomy of the hepatic artery helps implement this technique. When the right hepatic artery is ligated, the gallbladder should be removed since the cystic artery branches of the right hepatic artery; ligation may cause a calculus cholecystitis and necrosis.

Anatomic Resection

Anatomic liver resection should be looked upon as a last resort in achieving hemostasis from the injured liver. Again, knowledge of hepatic artery anatomy is vital (Fig. 2.9) [2, 7]. The liver is divided into two lobes by the bilobar plane, which extends from the middle of the gallbladder fossa to the inferior vena cava. Anatomic hepatectomy is rarely needed for control of the bleeding from the injured liver and should be implemented by surgeons who are experienced with the handling of liver tissue and knowledgeable about the segmental divisions of the liver [9, 13, 15]. Although 70 % hepatic resection is compatible with life in a controlled operative situation, the combination of major liver resection for severe hemorrhage that insults the remaining liver is associated with significant morbidity and mortality. Anatomic resection in the injured patient requires appropriate occlusion and division of the hepatic artery and portal venous branches that are supplying the area to be resected. Patients who undergo major liver resection for a severe hemorrhagic shock insult will likely have impaired liver function in the early postoperative period and require additional fresh frozen plasma to restore procoagulants until the hepatic function improves.

When doing a left hepatectomy, control of ongoing hemorrhage can usually be achieved by digital pressure surrounding the liver after the left triangular ligament has been taken down [2, 8, 12]. One can also use an oval-shaped liver clamp to provide compression to the left of the bilobar plane and the IVC. Anatomic right hepatic lobectomy requires much more extensive mobilization as described. Dividing the right triangular ligament and mobilizing the right lobe away from the right adrenal is necessary for digital compression for the oval liver clamp to be effective [2, 8]. When a patient is actively bleeding, control of either the right hepatic vein or left hepatic vein is always dangerous and certainly more complicated in comparison to doing a standard right or left hepatectomy for metastatic cancer [8, 12, 15]. The operation, when done for cancer, is usually being achieved in a relatively avascular field, whereas when the operation is being done for injury, the first assistant is trying to contain the bleeding as much as possible while the surgeon does the anatomic resection. When doing an anatomic resection, the authors like to leave a margin of 1–2 cm from the bilobar plane in order to help contain digital control of bleeding during resection and to bring about approximation of the anterior and posterior surfaces of the liver following completion of anatomic resection [2]. The liver sutures are used for this purpose. This is achieved after any cross-linking vessels that are observed in the base of resection are ligated.

Damage Control

The observation that temporary liver packs will often provide control of bleeding while attention is directed to the treatment of other injured organs led the way for the pack to be left in place as the definitive part of the first operation [1, 2]. This is especially true in patients who have had the triad of acidosis, hypothermia, and coagulopathy as a result of a severe hemorrhagic shock insult requiring multiple transfusions [8, 9]. Damage control from the bleeding liver is more easily achieved with injuries to the right lobe in that the lap packs or Kerlix gauzes can be placed between the liver and the diaphragm and also between right rib cage and the diaphragm (Fig. 2.3) [2, 11]. This allows for there to be pack hemostasis by providing external pressure on the liver. These packs are then left in place while the patient is taken to the critical care area for correction of coagulopathy, acidosis, and rewarming. Packing of the liver is excellent in selected cases for hemostasis, but the pack serves as a tampon and compromises egress of associated bile leakage [2]. Drains outside or away from the pack are beneficial to provide egress of associated bile leakage. The timing of reoperation should be determined by the patient's degree of improvement but can usually be performed within 24 h. At the time of reoperation, the packs are slowly and sequentially removed. When the last pack is removed, the surgeon may be pleasantly surprised to see that there is no further bleeding [2, 6, 10]. When this occurs, the surgeon needs to simply get out of the abdomen and leave the liver alone. When rebleeding occurs following removal of packs, the pack is reapplied while the surgeon goes through the appropriate steps at mobilization and prepares to use whatever hemostatic technique is most appropriate for the injury. When the hemostatic technique fails and the patient is getting into trouble again, the liver can be repacked and plans can be made for a third operation. Rarely, when bleeding is not controlled by packs, the Pringle maneuver, and digital hepatic compression, vascular isolation of the liver may be necessary. This is achieved by combining the Pringle maneuver with placement of a retrohepatic shunt that extends from the IVC to the right atrium (Fig. 2.16) [2, 12, 16]. This provides a bloodless field in which one hopefully can identify and repair the injured vessels whether they be portal venous, hepatic venous, or IVC. Vascular isolation of the liver is achieved by combining the Pringle maneuver with a retrohepatic shunt extending from the IVC to the right atrium (Fig. 2.16) [8, 12, 16]. Application of this procedure is carried out in desperate situations; there are likely more published authors who have written about this technique than there are patient survivors.

The technique for packing varies, but the authors prefer to use either fluff or Kerlix gauzes [2, 11]. Some authors place rayon cloth between the packs of the liver with the hopes that the removal of the packs will not cause damage to the underlying macerated liver causing rebleeding [6, 10, 12]. Damage to the underlying liver can be avoided by carefully removing the packs in a very slow manner and removing that portion of the pack that yields to gentle tension. If this technique of pack removal is used, rayon cloth under the pack is not needed.

Different types of packs can be used to treat unusual injuries [11]. For example, a gauze plug may be used to fill up a through-and-through gunshot wound tract; a condom may be inflated with saline and placed in a through-and-through gunshot wound tract; additional saline inflations provide lateral compression against the intrahepatic bleeding sites (Fig. 2.17) [2]. An omental plug may be placed in a wound when the liver has been split open; the liver is sutured over the omentum. The authors do not prefer this omental pack technique in that omentum necrosis requiring subsequent omentectomy has been encountered. The pack can also be placed in an intrahepatic position

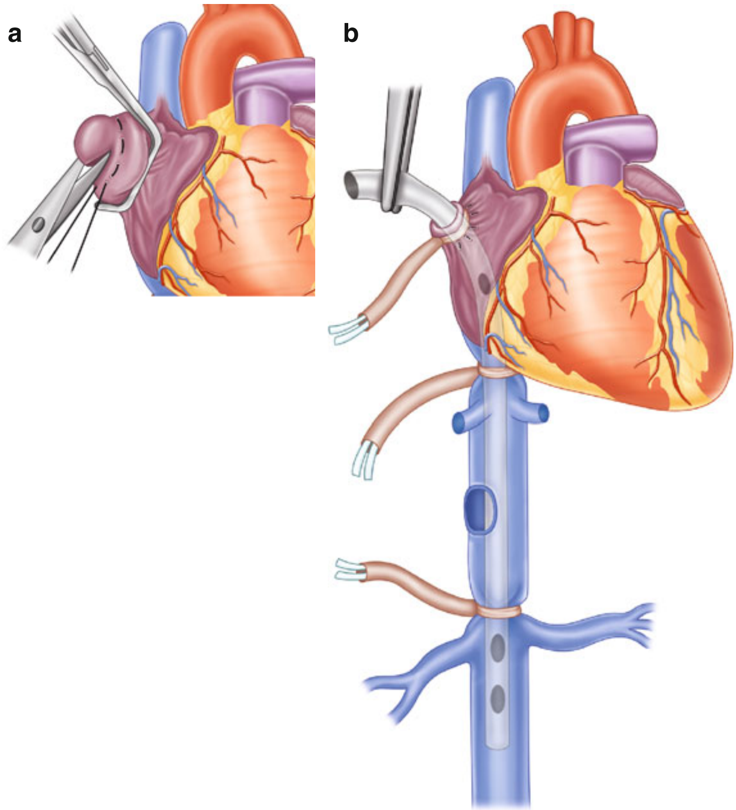


Fig. 2.16 The retrohepatic shunt with vascular isolation can also be achieved by way of the right atrium to the IVC (**a**) or from the IVC to the right atrium (**b**)

Fig. 2.17 Materials used to achieve hemostasis by liver packing include the gauze plug, the condom plug, fluff gauze, Kerlix roll, fine mesh gauze, and lap sponge

whereby the pack is actually sewed into the middle part of the liver with the liver closed around the pack. This has special merit for patients with left lobe injuries where there is no natural anatomic boundary to provide pressure against the oozing liver [2, 12]. When reoperation and removal of a pack leads to recurrent bleeding, which could not be readily contained by the techniques described above, the liver should be repacked and consideration then should be given to interventional radiography in order to determine whether there is a branch of one of the hepatic arteries that can be embolized [8, 12].

Dearterialization and Liver Packing

The combination of dearterialization and liver packing is hazardous. Once hepatic arterial flow has been interrupted, liver viability is dependent upon portal venous flow. The portal venous flow, in turn, is a low-pressure circulatory system so that a pack will tend to occlude portal venous flow and, thereby, eliminate oxygenation to that portion of the liver. This results in liver necrosis [17].

Nonoperative Therapy

The observation that hepatic bleeding commonly stops in patients who are no longer bleeding at the time of laparotomy led to the implementation of nonoperative therapy in patients with both blunt and penetrating wounds [2, 12, 18]. Following the success of early studies of nonoperative treatment of blunt splenic injury, the authors extended this principle to liver injuries. The authors predicted in 1983 that there would be "increased acceptance of expectant therapy for liver injuries over the next decade" [2]. Currently, most minor (AIS 1,2,3) injuries receive nonoperative management, whereas stable patients with major injuries (AIS 4,5) are treated nonoperatively (Fig. 2.18) [2, 12, 13]. This, of course, leads to less operative experience with getting hemostasis from the bleeding liver; this creates an educational crisis [19, 20]. Likewise, nonoperative treatment is excellent for non-bleeding intrahepatic hematomas; patients using street drugs, however, may feed the hematoma leading to a hepatic abscess.

Hepatic Injury with Blush

When treating a patient nonoperatively for major liver injury (AIS 4–5), there will often be a blush identified on the contrast CT of the liver. Although it is tempting to have interventional radiography embolize these blushes, one should remember that there are no free lunches and that hepatic necrosis may result from the embolization. The authors recommend that the stable non-bleeding patient with a hepatic blush on contrast CT be observed without intervention.

Hemobilia

Hemobilia is an unusual complication of liver injury [21]. This classic presentation includes a history of recent major trauma, followed some time later by the triad of right upper quadrant abdominal pain, hematemesis, and relief of abdominal pain. Hemobilia is due to the formation of a fistula between a branch of the hepatic artery and the bile duct. Intermittent bleeding into the injured parenchymal causes the right upper quadrant pain due to a intrahepatic rise in pressure within the false aneurysm [2, 19]. When the pressure rises, there will be decompression through the connecting bile duct and the blood rapidly exits through the ampulla at such a rate that the patient has hematemesis and simultaneous relief of pain, which is due to the high intrahepatic pressure. This sequence should make one think immediately of hemobilia, especially after a patient has sustained a major blunt injury.

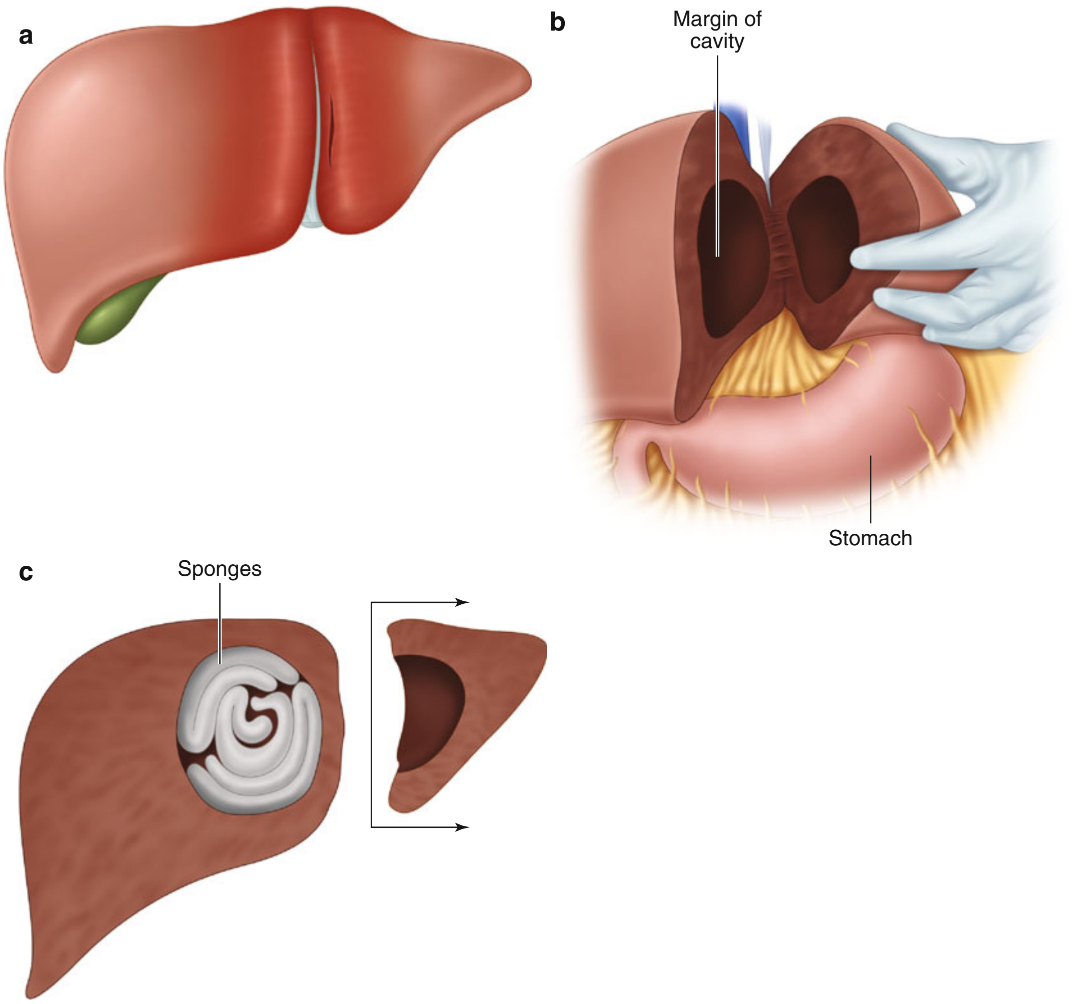


Fig. 2.18 Following severe blunt injury a large intrahepatic hematoma was continually oozing from a full-thickness crack (**a**) which was treated by left lateral segmentectomy and packing of the left medial segment and medial portion of the right lobe (**b**) with closure of the liver over the pack (**c**)

The first diagnostic test should be hepatic angiography and not upper endoscopy [2]. This confirms the suspected hepatic pseudoaneurysm.

The treatment for hemobilia may include embolization, hepatotomy with ligation of the partially severed cross-linking artery, or in unusual situations hepatic resection [21]. During exploration for patients with hemobilia, the diagnosis will be confirmed by the presence of a blood-filled gallbladder and extrahepatic bile ducts (Fig. 2.19) [2]. One can then ligate the hepatic artery which is feeding the false aneurysm and perform the hepatotomy by the techniques described above (Fig. 2.20) [2]. The source of the bleeding will almost invariably be a partially severed branch of the hepatic artery, which can be ligated and divided, after which the extrahepatic arterial occlusion can be released. If the patient has problems with recurrence or if there is evidence of hepatic necrosis due to an unrecognized portal venous injury, reoperation with hepatic resection is needed [21].

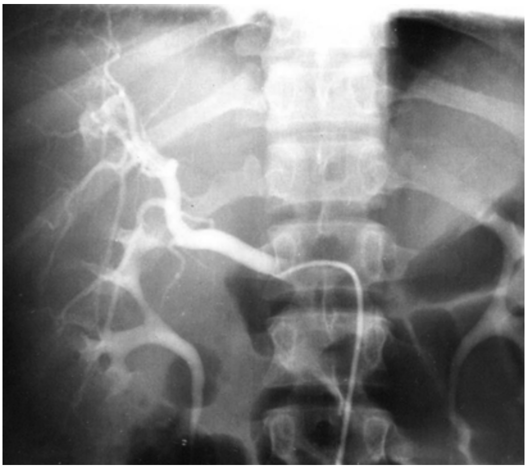


Fig. 2.19 Hepatic arteriography shows the early extravasation from a branch of the right hepatic artery

Fig. 2.20 During exploration for patients with hemobilia, the gallbladder and extrahepatic bile ducts will be observed to be full of blood

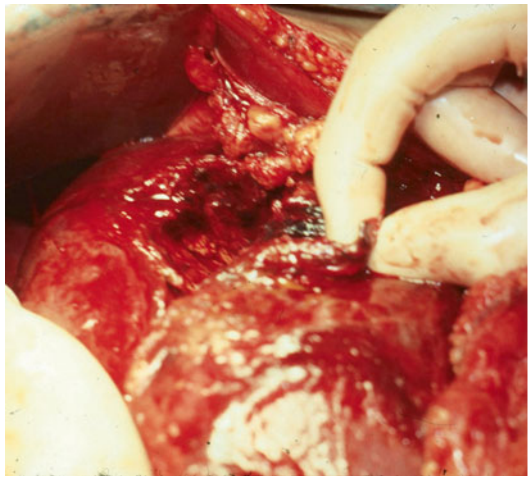


Fig. 2.21 When a liver crack is dissected down to the area of the false aneurysm causing hemobilia, there will be a pseudo-capsule which when entered will identify a partially severed artery which is communicating with the biliary system

Hepatic Drainage

Minor liver injuries (AIS 1,2,3) that are promptly made hemostatic by hepatic suture technique usually do not require any hepatic drainage [2, 3]. Major injuries (AIS 4,5), however, often have associated biliary radical severance with the result that there is potential for bile leakage. These patients are best treated with external drainage, which can typically be provided by the closed external drains, namely, the Jackson-Pratt drains. The use of extrahepatic bile duct drainage as a means of decreasing intrahepatic biliary pressure should be avoided since the bile fistulae in patients with major liver injuries are coming from bile radicals peripheral to the extrahepatic biliary system and are, therefore, not effectively decompressed by placement of extrahepatic biliary drains such as a T-tube drain (Fig. 2.21) [2, 22]. Controlled extrahepatic biliary drainage was assessed in a prospective randomized study of 119 patients treated for severe liver injury. The type of drainage, dictated by a double-sealed envelope drawn at the time of operation, included standard drainage alone in 37 patients, standard drainage plus cholecystostomy in 38 patients, and standard drainage plus t-tube choledochostomy in 54 patients. The morbidity consisting of intra-abdominal or subphrenic abscess, septic jaundice, cholangitis, wound sepsis, and erosive gastritis was significantly increased in the patients with t-tube choledochostomy. The mortality was insignificantly increased in this same group. The presence of controlled extrahepatic biliary drainage did not prevent hemobilia, reduce the output of a biliary cutaneous fistula, or reduce the likelihood of postoperative rebleeding from the injured liver [22, 23]. The same principle applies for the placement of extrahepatic biliary stents as a means of treating established bile fistulae [23]. Simple local care of the external bile fistula will result in slow but sure closure as collateralization develops and as fibrosis plugs the point of biliary leakage. A tincture of patience in this setting is a virtue.

Video Captions

Video 1 Initial hemorrhage control (MOV 48398 kb)

Video 7 Liver suture (MOV 39685 kb)

Video 11 Digital compression (MOV 16750 kb)

Video 14 Case 01. A 16-year-old boy was a victim of gunshot wound through the right flank (MOV 35988 kb)

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