Liver is the largest abdominal organ that is often affected by injuries due to blunt or penetrating trauma (1). Road traffic accidents and violence are responsible for the majority of liver injuries (2). A high incidence of liver trauma currently is secondary to a dominant role of mechanized transportation and increasing violent behaviour (3). Blunt injuries are dominant in Europe (4, 5, 6), while in The United States of America and Republic of South Africa penetrating injuries are more common, especially gunshot wounds (7-13). Liver trauma are rarely isolated, they are frequently associated with injuries of other abdominal organs (spleen, pancreas, kidney), chest and head injuries (1, 4, 5, 6, 9, 10, 11, 14). Liver wounds are generally minor and do not require surgical intervention, while major wounds, both isolated and associated with other injuries, are difficult to manage and concerned with a high risk of death (1).

There are two mechanisms causing blunt liver injuries: deceleration and a direct blow (2, 15). Deceleration occurs during road traffic accidents and falls from height when on impact the liver remains still in move, what results in a laceration of its relatively thin capsule and parenchyma at the sites of their attachment to the diaphragm (2). A parenchymal laceration is usually caused by shearing stresses (16). The liver usually tears between the posterior sector (segments VI and VII) and anterior sector (segments V and VIII) of the right hepatic portion (2). In contrast, a direct blow to the abdomen, by a fist or other blunt object, can lead to crush injury with damage of the central portion of the liver (segments IV, V and VIII) (2). Blunt injuries can also cause disruption of the hepatic parenchyma underneath an intact Glisson’s capsule, causing a subcapsular or intraparenchymal hematoma (2). As the largest abdominal organ, the liver is also particularly susceptible to the ability of compressive abdominal injuries to rupture its relatively thin capsule (3). Penetrating liver injuries are generally secondary to gunshot or stab wounds, with the former usually causing more tissue damage due to the cavitation effect as the bullet traverses the liver parenchyma (2). Because of the rich vascularization of the organ, post-traumatic hemorrhage from the liver can be massive (3). The severity of liver trauma ranges from a minor capsular tear, with or without parenchymal injury, to extensive disruption involving both liver portions with the associated injuries of the hepatic veins and inferior vena cava (2).

The liver is partially protected from injury by the overlying ribs of the lower chest (3). However, this location implicates a possibility of producing a characteristic injury called „bear claw” which occurs when the ribs are compressed into the liver and cause typical, curvilinear lacerations across the dome and anterior surface of the right lobe (17). This injury is quite frequent in patients who were involved in a traffic collision as a passenger when the car was hit from the side, because the right portion of the liver is very susceptible to compression by the lateral ribs (17). It is necessary to remember that hepatic injuries can involve not only the liver parenchyma, but also the porta hepatis, hepatic veins and retrohepatic inferior vena cava.
The most widely accepted scale by which hepatic injuries are described is AAST Scale (American Association for Surgery of Trauma), called also Moore Scale (18). Grade I and II injuries are considered minor, grade III to V are considered severe and often requiring surgical treatment, while grade VI lesions are thought to be incompatible with survival (2).

Conditions necessary to successful treatment of liver injuries are: an experienced liver surgeon, adequate blood, platelets, fresh frozen plasma and cryoprecipitate, a fully equipped Intensive Care Unit and a diagnostic back-up to monitor and detect potential complications (2). A patient with liver injury, if coagulopathy symptoms are present, should be given as soon as possible fresh frozen plasma during resuscitation (14). The liver is responsible for the production of coagulation factors and this function is impaired due to injury (14, 15). Before the operation the patient ought to be given blood substitutes, also broad-spectrum antibiotics (for example a second generation cephalosporin with metronidazole) and tetanus prophylaxis in case of penetrating injuries (2, 9, 15).

SURGICAL MANAGEMENT OF LIVER TRAUMA

Perihepatic packing

Use of perihepatic packing may be the first procedure performed by a surgeon in order to arrest or decrease hemorrhage after opening the abdomen of the patient operated on due to liver trauma. It is also often the surgical procedure terminating the operation when other methods of management have failed. The most common indications for perihepatic packing in case of liver trauma are intraoperative acidosis, coagulopathy and hypothermia (12, 17, 19-22). Other indications for perihepatic packing are: persistent bleeding when other surgical techniques have failed (2, 8, 12, 20, 21, 23), hemodynamic instability (2, 3, 20, 21) and major liver injuries (for example a parenchymal disruption or fragmentation) (12, 20, 21) and also unavailable or ineffective omental packing (12). Appropriate time for packing is still controversial, but many authors think that it should be performed when there is a suspicion of coagulopathy and long before irreversible shock due to blood loss, hypothermia and acidosis is present (2). Sharp and Locicero consider packing before hypothermia, acidosis and coagulopathy are present for either liver or non-liver injuries when the patient requires transfusion of more than 10 units of blood (20). They also use it if there is an intraoperative drop of patient’s temperature below 33°C, pH below 7.18 or coagulopathy is present (20). If the patient arrives to the operating room cold, acidic and coagulopathic, they recommend packing long before 10 units of blood must be transfused. Pachter and Hofstetter recommend perihepatic packing after 5 to 6 units of blood have been transfused (22). Cox et al. indicate a critical point during bleeding when the clotting factors are completely consumed and the clotting time is extended to infinity (14). Although this point can not always be precisely

<table>
<thead>
<tr>
<th>Grade</th>
<th>Injury description</th>
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<tbody>
<tr>
<td>I</td>
<td>hematoma subcapsular, &lt; 10 % surface area</td>
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<tr>
<td></td>
<td>laceration capsular tear; &lt; 1 cm parenchymal tear</td>
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<tr>
<td>II</td>
<td>hematoma subcapsular, 10-50 % surface area; intraparenchymal, &lt; 10 cm in diameter</td>
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<td>laceration 1-3 cm parenchymal depth, &lt; 10 cm in length</td>
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<tr>
<td>III</td>
<td>hematoma subcapsular, &gt; 50 % surface area or expanding; ruptured subcapsular or parenchymal hematoma</td>
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<tr>
<td></td>
<td>laceration &gt; 3 cm parenchymal depth</td>
</tr>
<tr>
<td>IV</td>
<td>laceration parenchymal disruption involving 25-75 % of hepatic lobe or 1-3 Couinaud’s segments within a single lobe</td>
</tr>
<tr>
<td>V</td>
<td>laceration parenchymal disruption involving &gt; 75 % of hepatic lobe or &gt; 3 Couinaud’s segments within a single lobe</td>
</tr>
<tr>
<td></td>
<td>vascular juxtahepatic venous injuries (the retrohepatic inferior vena cava, the major hepatic vein)</td>
</tr>
<tr>
<td>VI</td>
<td>vascular hepatic avulsion</td>
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determined, it usually comes after 6 to 8 transfusions of red blood cells, whether stored blood or autotransfusion is used (14). After recognition of this point, they recommend packing and replacement of red blood cells and clotting factors in the Intensive Care Unit (14). Richardson et al. performed packing after average transfusion of 6.8 units of blood in comparison with 15 units in the earlier period (24). Its early use declines significantly mortality rates in patients with severe hepatic injuries (14, 24). All patients with perihepatic packing must be transferred to the Intensive Care Unit to have acidosis, coagulopathy and hypothermia corrected (2, 8, 14, 17, 21).

Perihepatic packing can control almost all venous hemorrhage in the liver (15, 17). It is necessary to realize that it is more difficult to control arterial bleeding and before liver packing all bleeding arterial vessels should be controlled (8, 15). The technique of perihepatic packing involves manual approximation of the liver parenchyma and placing dry laparotomy pads around the liver directly over the injury or bleeding sites in order to provide tamponade to a bleeding wound (2, 20). They are placed between the liver and the diaphragm (14, 22). The pads ought not to be withdrawn through holes in the abdominal wall, because if they are placed loosely they may be unable to control bleeding and can lead to delayed hemorrhage (15, 20). They must not be placed into a laceration area as this manoeuvre can extend the site of injury and increase bleeding (2, 8). The abdomen may be closed under tension to provide additional compression (20). No drains are used (14, 15, 16). Subhepatic packing may be used to compress the hepatic parenchyma against the diaphragm, but this manoeuvre is associated with a high risk of infrahepatic inferior vena cava and renal veins compression (2, 14).

It is necessary to remember that after liver packing, during stay in the Intensive Care Unit, patients should be observed particularly because of a possibility of abdominal compartment syndrome (8). The intraabdominal pressure should be measured by the method of the urinary bladder measurement using a bladder catheter (25). The urinary bladder pressure exceeding 25 cm of water associated with renal insufficiency and respiratory compromise is diagnostic for abdominal compartment syndrome (25). It is also an indication for a repeat laparotomy and decompression of the abdominal cavity (8).

Perihepatic packing must be removed after correction of hypothermia, coagulopathy, acidosis and shock (8, 12, 20-23). Appropriate time of the packs removal is controversial. It usually takes 3-6 hours (17), 12-36 hours (2, 8), 18-36 hours (23), 24 hours (12) or 48-72 hours (16, 20). The presence of laparotomy pads or gauze packs in the abdomen, as a foreign body, is thought to increase the risk of development of septic complications (12, 19). That is why they ought to be removed as soon as possible (12, 23). Caruso et al. recommend removing packing after more than 36 hours (between 36 and 72 hours), because in this group the rate of rebleeding was significantly lower than in patients whose packs were removed within 36 hours (21). Time of packs removal was not associated with the increased liver related complications rates (biloma, persistent bile leak, intraabdominal or liver abscess), length of hospital stay and mortality. Nicol et al. recommend the removal of packing after at least 48 hours, since the risk of rebleeding was significantly lower than in patients with packing removed after 24 hours (8). The total duration of liver packing did not also result in an increased incidence of intraabdominal collections and septic or liver related complications. In our department we try to leave packing in the abdomen for no longer than 48 hours. In patients requiring repacking it may be successfully removed after 2 days (21). If the second attempt of the packs removal fails due to bleeding from the liver, angiography and embolization may be performed (8).

**Pringle manoeuvre**

Pringle manoeuvre, first described in 1908, involves shutting off blood inflow to the liver by compression of the hepatoduodenal ligament (26). It is often the first procedure performed to decrease hemorrhage after opening the abdomen in patient suffering from liver trauma. Pringle manoeuvre is best achieved by placing a vascular clamp across the hepatoduodenal ligament, efficiently arresting arterial and venous blood inflow to the liver (22). The clamp ought to be occluded only to the degree necessary to compress the blood vessels in order not to injure the common bile
duct (2). Instead of the vascular clamp, Rumel tourniquet may be used alternatively (22). Pringle manoeuvre has both a diagnostic and therapeutic role (9). It usually controls hemorrhage originating from the intrahepatic branches of the portal vein and hepatic artery, while its failure suggests injury of the retrohepatic inferior vena cava or hepatic veins (10, 13, 15). It is also necessary to remember that another reason for failure of Pringle manoeuvre is the presence of accessory or aberrant left hepatic arteries in approximately 25% of patients which may not be occluded after compression of the hepatoduodenal ligament (13). Pringle manoeuvre alone is not a method of final treatment of hepatic trauma ensuring definitive hemostasis. It often allows to decrease bleeding intensity, but it is not a strategy of management of the injured vessels and hepatic parenchyma, it also does not eliminate the cause of bleeding. However, it can be useful and even necessary after hepatic trauma when other procedures, such as resectional debridement or liver resection, must be performed. Its prolonged use is thought to be an indicator of liver injury severity (9). There is no widely accepted maximal time of occlusion of the hepatoduodenal ligament, but cases of applying Pringle manoeuvre for over an hour without subsequent liver failure or necrosis were described (23), also in our department.

Topical hemostatic agents and techniques

Topical hemostatic agents and techniques are usually inefficient in case of extensive liver injury and massive hemorrhage, but they often help in situations where parenchymal oozing on the raw wound surface of the liver is the dominant problem (3). Such hemostatic agents and techniques include microfibrillar collagen, collagen sheets and sponges, oxidized regenerated cellulose gauze pads, gel foam soaked in thrombin and fibrin glue, while cauterization techniques include the neodymium-YAG laser, the argon beam coagulator, electrocautery etc. (3, 12, 17, 23). Using of fibrin glue which is the combination of fibrinogen, thrombin and calcium chloride, is efficient in controlling oozing from raw liver surfaces after resectional debridement or partial liver resection (2, 19). Topical hemostatic agents and techniques, in conjunction with selective ligation of superficial bleeding vessels, are usually successful for grades I and II injuries (12, 23).

Selective hepatic artery ligation

This method is currently used very rarely (1, 3, 24). It is not always efficient (14), also in our own experience. However, selective hepatic artery ligation should be considered when arterial bleeding is controlled by Pringle manoeuvre (24). It can be also useful for inaccessible hepatic artery bleeding or an extensive and dissecting subcapsular hematoma with arterial bleeding (12). Its use in hepatic trauma is questionable because additional occlusion of arterial blood inflow to the liver in a hypotensive patient with previously declined hepatic perfusion may cause liver ischemia, able to result in necrosis and sepsis in further perspective (11). Besides, in injuries involving lobar branches of the portal vein, the retrohepatic inferior vena cava and hepatic veins, selective hepatic artery ligation is an ineffective strategy (10).

Hepatorrhaphy

In the past large, horizontal, mattress sutures were sometimes recommended to compress the liver parenchyma and bleeding vessels. Mattress sutures passed deeply through parenchymal lacerations or around missile tracts are associated with two complications: the first is frequent lack of hemostatic effect while the second is the significant amount of parenchymal necrosis beneath the applied sutures (2, 7). Extensive necrosis is secondary to compression necessary to arrest hemorrhage causing also devascularization of the liver parenchyma (2). That is why deep mattress sutures currently are not recommended to achieve hemostasis (8, 12). Instead of this procedure, selective vessels ligation is performed (3). Basing on their own experience, the authors also recommend abandoning hepatorrhaphy and passing the parenchymal sutures what is often performed in surgical wards in which patients are treated directly after the trauma.

Hepatotomy

This is a technique especially indicated for severe parenchymal liver injuries and it involves division of normal hepatic parenchyma,
using for example an ultrasonic dissector or other methods, to expose damaged vessels and hepatic ducts which can be ligated, clipped or repaired under direct vision (2). Unfortunately, it is concerned with a high risk of rebleeding, necrosis and sepsis. It is indicated for deep, penetrating injuries when either arterial or profuse venous bleeding is present (12). During this procedure increased bleeding usually does not occur because the liver parenchyma is dissected under control (22). Particular attention should be turned to location of the main hepatic ducts, right and left, to avoid injuring them inadvertently (11, 22). At the beginning of hepatotomy, Pringle manoeuvre is first performed, then Glisson’s capsule is incised with electrocautery and the hepatic parenchyma is dissected in the direction of the site of injury using “finger fracture” technique, retractors, the ultrasonic dissector or other blunt technique to allow ligation of bleeding vessels and lacerated bile ducts under direct vision (2, 7, 10, 22). Extension of the fracture line is necessary to gain access to the damaged structures (1). Next the lacerated vessels can be ligated (using 2-0 or 3-0 sutures) or clipped selectively, on occasion large intralobar branches of the hepatic veins can be repaired with polypropylene sutures (7). Occlusion of blood inflow to the liver helps to identify venous injury, while the intermittent release of occlusion reveals inflow bleeding places and estimates the effect of management (1). The position of the first assistant is very important because his left hand placed behind brings the liver forward to improve exposure for the operator and decrease hemorrhage from within the hepatic parenchyma by exerting posterior compression (11, 22). After ligation or repair of the injured intrahepatic vessels and achieving hemostasis, the vascular clamp is slowly released and any further bleeding places are secured with sutures (22). All nonviable portions of the liver parenchyma must be debried precisely to avoid intrahepatic or perihepatic abscesses and a pedicle of omentum may be placed into the area of injury (10, 11, 22). Drains are placed anteriorly and posteriorly to the site of injury (10, 11, 22).

Resectional debridement

This method is the removal of nonviable liver tissue that borders the injured area (1). It involves the removal of all necrotic tissue down to the normal hepatic parenchyma using the lines of injury, rather than anatomical planes, as the borders of resection (2). First Pringle manoeuvre should be performed and then the hepatic parenchyma is dissected just outside the area of injury using the finger fracture technique or an ultrasonic dissector (2). This procedure ought to be limited only to obviously necrotic tissue (10). It is a rapid technique in comparison with standard, anatomic resection which is more time-consuming and removes more normal hepatic parenchyma (2). Adequate debridement of all non viable tissue is necessary to avoid parenchymal necrosis and intrahepatic, perihepatic or intraabdominal abscesses in the post-operative period (10, 11, 22).

Anatomic liver resection

Anatomic liver resections are performed in case of vast disruption of the hepatic parenchyma or the presence of devitalized tissue within the liver segments (24). However, they are performed immediately very seldom, because due to severe general condition and significant blood volume depletion the patient probably would not survive this procedure and the prime target of the surgeon is to arrest bleeding. They should be reserved only for situations in which no other procedures achieved hemostasis (1, 2). Anatomic liver resection has two roles: removes the source of bleeding and the necrotic area (1). It leaves a smooth resected surface with a viable hepatic parenchyma and low tendency to septic complications (1). Hepatic resections, independently on grade of liver injury, should be performed only in hemodynamically stable patients (1, 4). Control of hemorrhage allows to replace intravascular blood volume and restore hemodynamic stability of the patient who can better tolerate the resection (1). To stabilize the patient hemodynamically, temporary perihepatic packing and bimanual compression of the liver may be used, even for an hour, and than resectional debridement and liver resection may be performed (1, 4). Liver resections should be performed only by surgeons experienced in liver surgery. In case of postresectional oozing perihepatic packing may be used in particular situations (1). In practice, liver resection is usually performed during a relaparotomy in patients with an extensive liver disruption and necrosis of the hepatic parenchyma that have
perihepatic packing placed during the first operation. It is necessary to restore the continuity of previously cut the falciform ligament with sutures after extended right hemihepatectomy to avoid the rotation of the left segments II and III around the left hepatic vein, what can cause the occlusion of this vein and blocking the blood drainage from the liver through the only remaining hepatic vein.

Nonanatomic liver resection

Nonanatomic resection for liver trauma is performed in two ways: partial resection and resectional debridement (1). Partial resection removes the injured, devascularized and partially detached portions of the liver parenchyma peripheral to the fracture line, leaving just one surface, requiring suture or ligation of bleeding vessels (1).

Mesh wrapping

Wrapping the liver with a synthetic absorbable mesh is performed in order to control hemorrhage by compression which should be tight enough to ensure hemostatic effect, but not so tight to cause liver ischemia (3). However, this method is used very rarely. It seems to be the most useful in patients with gaping lacerations, after hepatotomy, in major injuries involving the large portion of the liver, especially for stellate disruptions and the presence of viable disruptions fragments still attached to the liver hilum or decapsulation (3, 19). In surgical articles various techniques of wrapping the mesh around the liver are described (2, 3). It is necessary to perform cholecystectomy when the mesh is wrapped around the right lobe of the liver to avoid necrosis of the gall-bladder wall (2) and the assistant should compress the liver manually while the mesh is being prepared (3).

The advantage of this method in comparison with perihepatic packing is the avoidance of a relaparotomy because currently used meshes are made of absorbable materials (3, 19). Besides, achieved compression is specific only for the liver and replaces efficiently manual compression supplied by the surgeon, what allows in effect to close the abdomen definitively (3). The only disadvantage of this strategy is long time indispensable for total wrapping the mesh around the liver and closing the abdomen, so if it is necessary to finish the operation and achieve hemostasis quickly, perihepatic packing will be the right choice (19).

Mesh wrapping is ineffective and not recommended in cases of injuries of the retrohepatic inferior vena cava or hepatic veins, because those areas are excluded from compression (2, 3, 19). Reed et al. used this technique in 14 patients with liver injuries and it was efficient in all cases when other techniques had failed, except in cases of injuries of the retrohepatic inferior vena cava or hepatic veins and they did not notice problems with liver function after the operation (3). In our department there is no experience with using the mesh and the authors are sceptical about the possibility of its successful use.

Omental pack inserted into the area of liver injury

Packing with the omental pack has the ability to tamponade deep intrahepatic venous bleeding, local oozing from the sides of parenchymal lacerations or hepatotomy sites and small bile leaks (10, 19). This strategy may be used in patients with deep lacerations, stellate fractures and burst injuries of the liver (12). The viable omental pack, inserted into the area of liver injury, has two important roles: eliminates „dead space” and tamponades venous oozing from the hepatic parenchyma (10). It also fills dead space within the liver with a viable tissue (11, 19). It also allows to close lobar lacerations or hepatotomy sites without passing mattress sutures able to cause parenchymal necrosis (7). The omental pack has also a significant advantage because as an autogenous and viable tissue does not require removal during a relaparotomy (12). Use of omental packing is concerned with the decreased incidence of sepsis, abscesses and mortality in the postoperative period (7, 10, 12). Fabian et al. after use of the omental packing noticed the significantly lower incidence of septic complications and mortality rate than after use of perihepatic gauze packing (12).

Before placing the omentum, meticulous hemostasis and adequate debridement of all necrotic tissue must be performed to avoid perihepatic and intrahepatic abscesses (11, 22). Adequate debridement often results in oozing from the liver parenchyma and large
areas of dead space, so an autologous omental pack may be inserted into the area of injury (22).

After individual ligation of all bleeding vessels, the omentum is inserted into the area of the liver defect after mobilization of the transverse colon (10, 11, 12, 22). The omental pedicle can be based on either the right or the left gastroepiploic vessels (22). The omentum must be cut from the left or the right, beneath the large gastric curve, parallelly to it and between it and the gastroepiploic vessels (22). The omental pedicle is placed within the hepatic parenchyma defect and the edges of the liver are loosely approximated around the pedicle with interrupted sutures applied at least 2.5 cm from each liver edge, lying below the pedicle and holding it in place (10, 19, 22). Currently absorbable sutures are recommended (2, 19). Care must be taken so as not to pass the sutures through the pedicle due to a possibility of an inadvertent laceration of the gastroepiploic vessels leading to hemorrhage and the impaired viability of the pedicle (12, 22).

Indications for intraoperative management

In patients with abdominal trauma who did not undergo diagnostic radiologic procedures due to hemodynamic instability, the most reasonable decision is a midline abdominal incision which in case of hepatic and splenic injuries may be extended bilaterally. In patients with radiologically confirmed liver trauma requiring surgical treatment, a right subcostal incision or a bilateral subcostal incision ensuring surgical access to the spleen are recommended. If the indication for operation is an obvious penetrating through-and-through liver injury, a bilateral subcostal incision will be a useful strategy (2).

The surgeon’s essential aim is to arrest hemorrhage (17). The falciform ligament is cut to inspect the anterior surface of the liver (12). After opening the abdomen all four quadrants should be packed to enable replacement of intravascular volume and control of venous hemorrhage (7, 15, 17). The packs in the two lower quadrants ought to be removed first and the control of any fecal contamination is necessary (15, 17). Then the packs in the left upper quadrant are removed and in case of injury of the spleen it must be removed (15, 17). In case of the presence of primarily venous bleeding the liver should be packed and compressed manually for a minimum of 15 minutes (17). It is necessary to remember that initial control of bleeding can be achieved by bimanual compression of the liver (10, 11, 20). This manoeuvre usually arrests bleeding temporarily and allows for replacement of blood volume and correction of acidosis (10, 11). After removal the packs from the right upper quadrant injuries and bleeding intensity are evaluated (17). If compression applied for 15-20 minutes controls hemorrhage, the omentum may be inserted into the area of injury (17). Hemostatic agents have adjunctive roles during treatment of liver injuries (17). If hemorrhage continues, the surgeon must consider more extensive procedures (17). If he is not experienced in liver surgery, he should perform perihepatic packing at this moment, close the abdomen and transfer the patient to the liver surgery center (15, 17).

Major procedures, necessary if bleeding continues, require mobilizing the right lobe and more rarely the left lobe (17). Both liver lobes are mobilized by dividing their triangular and coronary ligaments (12, 17). If the injury is localized high in the dome of the liver, the right lobe must be also mobilized (17). If hemorrhage continues, Pringle manoeuvre should be performed with a soft clamp or Rumel tourniquet (17). If this controls hemorrhage, the injury is either to a branch of the portal vein, or in some cases, the hepatic artery (17). In this moment opening the liver wound to control the bleeding vessels with 3-0 or 4-0 nonabsorbable ligatures should be considered (17). If there is a blood clot in the fracture fissure and there is no active bleeding, the clot must not be removed (14). In case of the liver parenchyma fragmentation with the presence of nonviable tissue, due to either a gunshot wounds or blunt trauma, all necrotic portions must be removed (resectional debridement) and bleeding vessels should be ligated or clipped (7, 14). Placing a Satinsky clamp across the inferior vena cava suprahepatically and suprarenally and the Rumel tourniquet around the porta hepatitis may be an alternative strategy and during this procedure resectional debridement and liver resection can be performed with minimal blood loss (17). However, it is necessary to remember that total vascular isolation of the liver, when venous return through the inferior vena cava is occluded,
leads to hemodynamic disorders in hypovolemic patients. Generally, control of parenchymal bleeding can be achieved with a combination of suture ligation of bleeding vessels, electrocautery and the argon beam coagulator (17). In case of gunshot wounds, all foreign bodies must be removed, especially the plastic wadding or clothing that may be blown into the liver (17). After resectional debridement or liver resection, a drain may be placed near the raw liver surface due to possible bile leak (17).

Very seldom a major segmental bile duct may be disrupted without laceration of the accompanying vessel ensuring blood supply to that segment (2). In this case, if the patient is in good general condition, the involved liver parenchyma should be resected, even if it is still vascularized and viable, in order to avoid biliary fistula (2). It is necessary to remember that during the operation manual compression of the liver can control bleeding and enables replacement of blood and clotting factors, then bleeding vessels can be identified and ligated (12, 14). If the patient becomes coagulopathic, hypothermic or acidotic at any time, any arterial bleeding must be controlled, perihepatic packing should be performed and the patient ought to be taken to the Intensive Care Unit to correct those three disorders (17). During the relaparotomy venous bleeding is controlled and bile leaks are ligated with sutures (17). Resectional debridement or liver resection may be necessary (17). Another possible solution after correction of coagulopathy, hypothermy and acidosis is angiography before the patient’s return to the operating room (17).

Drainage after blunt hepatic trauma seems to be not always necessary, contrary to penetrating trauma when the operative field is contaminated (14).

COMPLICATIONS AFTER SURGICAL MANAGEMENT OF LIVER TRAUMA

Bleeding

Rebleeding from the liver is the most dangerous complication for a patient in the postoperative period (22). It can be caused by coagulopathy, an inadequate surgical repair and missed juxtahepatic venous injuries (2). If the patient is hemodynamically unstable, the reoperation must be performed in order to arrest bleeding (22). In hemodynamically stable patients angiography may be considered and after identification of the bleeding site embolization may be performed (19, 22). Confirmed coagulation defects ought to be corrected as soon as possible with fresh frozen plasma and platelet transfusions (2).

Bile collections (bilomas)

Bilomas are intraabdominal bile collections which should be treated by percutaneous drainage and in case of its failure by surgical drainage (2, 21, 22, 25).

Biliary fistula

Factors associated with prolonged bile drainage are the presence of biliary tract obstruction, infection, the presence of foreign body or a laceration of a major duct (2, 22). In references various definitions of biliary fistula are reported – for example persistent bile leak that lasts longer than 10 days (21) or drainage greater than 50 mL of bile per day after 14 days (9). ERCP can determine whether the site of bile leak is localized in either a peripheral biliary radical or a main branch of one of the major hepatic ducts (9, 16). ERCP and sphincterotomy alone or in conjunction with the insertion of an endostent bridging the laceration and leading to healing of all fistulas, confirmed by ERCP before the stent removal, is usually an effective strategy (9, 16, 22). Partial lacerations of major ducts may by treated with the insertion of the stents to bridge the gap until spontaneous healing is present and complete laceration of major biliary ducts may require operative treatment, but that situation occurs very seldom (22).

Intraabdominal and liver abscess

Intra-abdominal abscess is a purulent, culture-positive fluid collection localized in the right subphrenic space, subhepatic space or within the liver parenchyma (12, 21). Intra-abdominal abscess formation is the most common complication after major hepatic trauma (7). Infectious complications are caused by retained necrotic tissue or by collections of bile or blood (3). Percutaneous drainage is widely accepted and effective treatment of intra-abdominal abscesses (9, 16, 22). It has revolution-
ized management of postoperative abscesses and has contributed to a drop of morbidity and mortality rates (2). Appropriate intravenous antibiotic administration should be applied additionally (2). However, percutaneous drainage not always allows to avoid surgical drainage (25). Operative management may be indicated if there is a liver sequestrum or if percutaneous drainage is ineffective (2). Patients with a well organized intrahepatic abscess may be treated by percutaneous drainage, but if there is no improvement or fungi are isolated from the blood or the abscess site, surgical management must be considered (27).

Haemobilia

Haemobilia is a complication that occurs very seldom after liver injuries and is caused by an extravasation of the arterial blood in a biliary duct due to the communication between the biliary tract and blood vessels (25, 27). Typical symptoms are: right upper quadrant colicky pain, jaundice and the symptoms of upper gastrointestinal bleeding such as blood in either stool or vomitus (15, 25, 27). Haemobilia is treated by embolization of the injured vessel or liver resection (12, 15, 27).

Bilhaemia

Bilhaemia is a very rare complication of severe liver injuries caused by deceleration, in which the hepatic venules and the intrahepatic bile ducts have been ruptured (27). This is followed by the formation of an intraparenchymal biliovenous fistula and the main symptom is jaundice secondary to the presence of the bile in the blood (25, 27). Bilhaemia is treated by sphincterotomy with stenting or more rarely by liver resection.

SUMMARY

Intraoperative treatment of severe liver injuries remains a formidable challenge for the surgeon (2). The recommended operative strategies are hepatotomy with direct suture ligation, resectional debridement and perihepatic packing (2). The majority of surgeons facing severe liver injuries are advised to consider perihepatic packing to control hemorrhage and to transfer a patient to a regional liver surgery center for definitive treatment (2). It is necessary to remember that successful management of liver trauma requires not only indispensable experience in liver surgery, but also specialistic devices that allow to perform efficient parenchymal resection with minimal blood loss. Deep parenchymal sutures, anatomic resections, hepatic artery ligation and retrohepatic caval shunts are limited options, reserved for selected injuries (2). Pachter et al. advise to perform sequential steps to avoid postoperative complications after stabilizing the patient hemodynamically (for example by manual compression and fluid resuscitation): Pringle manoeuvre, rapid hepatotomy to the site of injury with the control of injured vessels and bile ducts, debridement of necrotic tissue, placement the omental pedicle to the injury site and closed suction drainage in case of grade III to V injuries (11, 22, 23). Better knowledge of liver pathophysiology and anatomy and progress in resuscitation, anesthesia and intensive care have contributed to decreasing a mortality rate after hepatic trauma during the past years (2). Emphasis placed on the importance of recognition and avoidance of shock, hypothermia, coagulopathy and acidosis has improved the results of management (2). Aggressive resuscitation allows to stabilize the patient, correct coagulation disorders, acidosis and shock in order to perform surgical treatment at the appropriate moment, when the patient is able to survive even the major surgical operation.

Hemorrhage and sepsis are the most frequent causes of liver-related deaths after liver trauma, so aggressive resuscitation with immediate and expeditious hemostasis and early control of infection are the most important aims (2). Modern treatment of the majority of the complications after liver trauma requires multidisciplinary approach, involving the activity of experienced interventional radiologists, endoscopists and surgeons (2).
REFERENCES


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