

Definitive Surgery for Liver Trauma in a Tertiary HPB Center (with video)

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Rezumat

Tratamentul chirurgical definitiv pentru traumatisme hepatice într-un centru terțiar HPB

Introducere: Chirurgia în traumatismele hepatice severe rămâne o provocare chiar și pentru chirurgii HPB, în principal din cauza instabilității hemodinamice a pacienților, a implicării elementelor vasculare și biliare majore, a calității parenchimului hepatic și a variantelor anatomice frecvente. În acest context, în ciuda politicii conservatoare, rezecția hepatică majoră este încă necesară în cazuri selecționate. De asemenea, poate fi necesar transplantul hepatic ca ultimă măsură terapeutică. Studiul nostru își propune să analizeze rezultatele tratamentului chirurgical definitiv pentru traumatismele hepatice (TH) într-un centru terțiar HBP.

Metode: Șaizeci și șase de pacienți cu TH au fost internați și tratați în centrul nostru între iunie 2000 și iunie 2021. Vârsta medie a fost de 29 de ani (media 35, interval 10-76). Raportul bărbați/femei a fost de 50/16. Conform sistemului American Association for the Surgery of Trauma (AAST), TH au fost de gradul II la un pacient (1,5%), gradul III la 11 pacienți (16,7%), gradul IV la 25 de pacienți (37,9%) și gradul V în 29 puncte (43,9%); niciun pacient nu a avut TH de gradul I sau VI.

Rezultate: Cincizeci și doi de pacienți (78,8%) au beneficiat de intervenție chirurgicală și 14 pacienți (21,2%) de tratament non-operator (TN). Packing-ul perihepatic a fost efectuat anterior la 38

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pacienți (73,1%). Chirurgia a constat în rezecții hepatice (RH) la 51 de pacienți (77,3%) și transplant de ficat la un pacient (1,5%). Rata de RH majore a fost de 51,9% (27 HR). Ratele generale morbiditate majoră și mortalitate au fost de 33,3% (20 pacienți) și, respectiv, de 13,6% (9 pacienți). Pentru intervențiile chirurgicale, rata complicațiilor majore a fost de 35,3% (18 pacienți), în timp ce pentru RH majoră și minoră a fost de 40,7% (11 pacienți) și, respectiv, 29,2% (7 pacienți); rata de mortalitate a fost de 15,7% (8 pacienți). După TN, ratele majore de morbiditate și mortalitate au fost de 14,3% (2 pacienți) și, respectiv, 7,1% (1 pacient).

Concluzii: Rezecțiile hepatice, în special cele majore și/sau care implică reconstrucții vasculare și biliare, precum și tratamentul nonoperator al leziunilor hepatice severe sunt optim efectuate în centrele de HBP terțiare, reducând astfel ratele de morbiditate și mortalitate, având în același timp transplantul hepatic ca ultimă opțiune terapeutică.

Cuvinte cheie: traumatism hepatic, leziuni hepatice de grad înalt, rezecție hepatică majoră, tratament neoperator, centru terțiar HBP

Abstract

Background: Surgery for severe liver trauma remains challenging even for HPB surgeons, mainly due the hemodynamical instability, involvement of major vascular and biliary elements, impaired background liver and frequent anatomical variants. In this setting, despite conservative policy, major liver resection is still required in selected cases. Also salvage liver transplantation may be needed. Our study aims to analyze the results after definitive surgery for hepatic injury (HI) in a tertiary HPB center.

Methods: Sixty-six patients with HI were admitted and treated in our center between June 2000 and June 2021. The median age was 29 years (mean 35, range 10-76). The male/female ratio was 50/16. According to the American Association for the Surgery of Trauma (AAST) system, HIs were grade II in one patient (1.5%), grade III in 11 pts (16.7%), grade IV in 25 pts (37.9%), and grade V in 29 pts (43.9%); no patient had grade I or VI HI.

Results: Fifty-two pts (78.8%) benefitted from surgery and 14 pts (21.2%) from non-operative treatment (NOT). Perihepatic packing was previously performed in 38 pts (73.1%). Surgery consisted in hepatic resections (HR) in 51 pts (77.3%) and liver transplantation in one patient (1.5%). The rate of major HR was 51.9% (27 HRs). The overall major morbidity and mortality rates were 33.3% (20 pts) and 13.6% (9 pts), respectively. For surgery, the major complication rate was 35.3% (18 pts), while for major and minor HR were 40.7% (11 pts) and 29.2% (7 pts), respectively; the mortality rate was 15.7% (8 pts). After NOT, the major morbidity and mortality rates were 14.3% (2 pts) and 7.1% (1 pt), respectively.

Conclusions: Hepatic resections, especially major ones and/or involving vascular and biliary reconstructions, as well as non-operative treatment for severe hepatic injuries, are to be carried out in tertiary HPB centers, thus minimizing the morbidity and mortality rates, while having the liver transplantation as salvage option.

Key words: hepatic trauma, high-grade hepatic injuries, major liver resection, non operative treatment, tertiary HPB center

Introduction

Abdominal trauma can cause significant damage to the abdominal organs, liver trauma

representing the most frequent type of injury. In 80% of the cases, it can be accompanied by injury of other viscus, in which case the morbidity and mortality rates are high (1).

The liver is most affected by blunt and penetrating traumas. Blunt traumas are mostly caused by car accidents (2), while lesions determined by knives and guns predominate in penetrating traumas. The ratio between liver injuries caused by blunt traumas and those caused by penetrating traumas, differs around the globe. While in the UK, the number of injuries caused by blunt traumas is double compared to the ones from penetrating traumas (3), in South Africa and North America, most of these injuries are the result of penetrating traumas (66% in South Africa and 86% in North America) (4, 5). In Romania, blunt trauma is a national health issue, as continues to have the highest incidence among the European countries, with a value of 85/1.000.000 (6). Consequently, treatment of liver trauma remains of utmost importance. Liver trauma, as all traumas, is referred to the closest Emergency Hospital, which, in absence of HPB expertise, refers the patient to a tertiary HPB center. Currently, liver trauma in stable patients is based on non-operative treatment (NOT), consisting in careful monitoring, intensive care support and interventional treatment in a specialized center, thus significantly improving both morbidity and mortality rates (1). However, in unstable patients, surgery for severe HI remains challenging even for HPB surgeons, mainly due the hemodynamical instability, involvement of major vascular and biliary elements, impaired background liver and frequent anatomical variants. In this setting, despite conservative policy, major liver resection is still required in selected cases. Also salvage liver transplantation may be needed. Our study aims to analyze the results after definitive surgery for trauma in a tertiary HPB center.

Materials and Methods

Study Group

Sixty-six patients with HI were admitted and treated in our center between June 2000 and

June 2021. The median age was 29 years (mean 35, range 10-76). The male/female ratio was 50/16. HIs were in the right hemiliver in 41 pts (62.1%), left hemiliver in 17 pts (25.8%), bilobar in 7 pts (10.6%), and in segment 1 alone in one patient (1.5%).

According to the American Association for the Surgery of Trauma (AAST) system, HIs were grade II in one patient (1.5%), grade III in 11 pts (16.7%), grade IV in 25 pts (37.9%), and grade V in 29 pts (43.9%); no patient had grade I or VI HI. Almost all patients had blunt trauma (63 pts, representing 95.5%), except 3 with stab wound (4.5%).

Associated traumas were encountered in 22 pts (33.3%): other abdominal and pelvic structures in 18 pts (27.3%), thorax in 17 pts (25.8%), head in 7 pts (10.6%), and/or limbs or vertebral column in 6 pts (9.1%).

Analyzed Data

Patient demographics, preoperative data (anamnesis, hemodynamic stability, type of hepatic trauma, associated trauma, imaging data), information from surgery (type of HI, surgical technique used, type of hepatic resection, use of Pringle maneuver and/or vascular exclusion, associated surgical procedures, blood loss, blood transfusion requirements, duration of surgery), and postoperative data (90-day complications and mortality) were gathered in a database and analysed.

The primary end-point was the short-term results after major liver resection, based on the postoperative morbidity and mortality. All postoperative complications for 90 days after trauma were recorded and classified according to Dindo-Clavien classification et al (7). At least grade IIIB complications were considered life-threatening and defined as major complications. Complications related with the liver, such as hemoperitoneum, hematoma, abscess, bile leak, and/or liver failure were defined as liver-related complications. Operative mortality was considered death occurring within the 90 postoperative days after trauma. Long-term follow-up was considered not relevant for the study.

Diagnostic and Treatment

All patients with HI were evaluated based on anamnesis, clinical exam, vital parameters and its variations, lab tests, imaging (ultrasound, CT scan). Particularly, CT scan was used to classify the HI according to the American Association for the Surgery of Trauma (AAST) system (8). Furthermore, to correlate the HI grade with the hemodynamic status, we also used the classification according to the World Society of Emergency Surgery (WSES) (9).

Patients admitted after being already operated in other centers for temporary haemostasis with liver packing were offered surgery for definitive haemostasis after 48 to 72 hours from the first operation. This period of time was used for completion of diagnosis, medical treatment and careful monitoring.

Patients with HI directly referred to us were evaluated for non-operative treatment (NOT), indicated in case of in case of hemodynamically unstable patient after intensive care support, or in hemodynamically stable patients who presented with peritonitis and/or with associated severe head trauma (10). NOT consisted in careful monitoring, intensive care support, and repeated CT-scans; in selected cases, arterial embolization was used. NOT was considered ineffective and the patient was referred to emergency surgery in case of active bleeding showed at CT scan, and/or massive fluid resuscitation or transfusion of more than 3 units of blood transfusion, or hemodynamic instability despite NOT; any other intra-abdominal injury diagnosed during NOT that required surgery (11,12).

Open approach was used in all patients referred to surgery, using a large incision to have the optimal access to the entire liver and its main vessels. Major HR was defined as the removal of at least three segments. All established surgical techniques were deployed: anatomic/non-anatomic, major/minor resections; with/without prior liver mobilization approaches.

Complete and fast liver mobilization was

useful. Otherwise, the HI may not be had been accessible, and even may had worsen due to excessive traction for exposure.

Superficial lacerations usually responded to conservative techniques such as manual compression Pringle maneuver, use of cautery, argon beam coagulation, and or energy-devices, topical haemostatic agents. Perihepatic packing was used in case of failure of the aforementioned procedures; this could be removed intraoperatively, if haemostasis was obtained, or during the following operation. HIs with deep lacerations and/or avulsions typically required ligation/suture of bleeding vessels, direct liver suturing, and even hepatic resection (debridement or anatomic resection) (13). In case of deep and narrow HI, a balloon tamponade could be used. Auto-transfusion was used whenever feasible.

The removal of the perihepatic pack was performed 48-72 hours after the initial operation. When the initial procedure was carried out in other hospital, the patient was transferred only when hemodynamically stable. Otherwise, prior to transfer any active bleeding had to be controlled, even by repacking. The preferred technique for hepatic transection was the clamp crushing method (Kelly-clasia). Vascular control using Pringle maneuver and/or total vascular exclusion was always used to control excessive bleeding. Haemostasis on the hepatic cut surface was performed using the standard method, such as ligatures, sutures, electro-coagulation, and haemostatic agents. In case of necrosis, resectional debridement and even upfront anatomical resection (for extensive necrosis) were performed (14). When HI led to liver failure, liver transplantation was considered.

Grade V HIs involving the vena cava and/or main hepatic veins were challenging due to severe bleeding and difficult access; in these cases, total vascular exclusion was often used.

Transplantation was required when the extensive parenchymal necrosis led to liver failure (15). Associated injuries of other organs were also explored and treated.

Results

Out of the 66 pts, 52 pts (78.8%) benefitted from surgery and 14 pts (21.2%) from NOT. The overall major morbidity and mortality rates were 33.3% (20 pts) and 13.6% (9 pts), respectively.

Surgery consisted in hepatic resections (HR) in 51 pts (77.3%) and liver transplantation in one patient (1.5%). One patient from the liver resection subgroup underwent two consequent hepatic resections; therefore, a total of 52 HR were recorded. Prior perihepatic packing was performed in 39 pts (76.5%), while 12 pts (23.5%) were hemodynamically unstable. The types of HR are depicted in *Table 1*. According to our policy, major HR was avoided whenever feasible and was replaced with minor HR (*Figs. 1 and 2 Supplemental video, <https://www.revistachirurgia.ro/pdfs/?art=2021-6-678.pdf&EntryID=922950>*). The rate of major HR was 51.9% (27 out of 52 HRs). Perihepatic packing was previously performed in 38 pts (73.1%). After surgery, the major complication rate was 35.3% (18 out of 51 pts). The reintervention rate was 11.8% (6 pts). The major complication rate for major and minor HR were 40.7% (11 out of 27 pts) and 29.2% (7 out of 24 pts), respectively. The mortality rate was 15.7% (8 pts).

Vascular or biliary reconstructions were performed in 5 pts (9.8%) and 6 pts (11.8%), respectively. Vascular reconstruction for hepatic artery, portal vein, and hepatic veins was carried out in 1, 2, and 2 patients, respectively. High output bile leaks due to trauma were recorded in 15 pts (29.4%) and were treated with anatomic HR (of the territory that was excluded from the biliary tree) in 9 pts (17.6%), or with biliary reconstruction with cholangio/hepatico-jejunostomy with a Roux-en-Y loop in 6 pts (11.8%).

The median operative time was 180 minutes (mean 210; range 140-420). The median blood loss was 800 ml (mean 980; range 500-6500).

The details of the patient that needed liver transplantation were already reported (16).

Patients that benefitted from NOT are presented in *Table 2*. Major morbidity and

Table 1. Type of hepatic resection (HR) involved in the management of the hepatic injuries (HIs)

Type of hepatic resection	No of pts	%
Major resections	27	51.9
Right hemihepatectomy	19	36.5
Left hemihepatectomy	2	3.8
Extended right hemihepatectomy	4	7.7
Extended left hemihepatectomy	2	3.8
Minor resections	25	48.1
Left lateral sectionectomy	11	21.2
Posterior right sectionectomy	3	5.8
Extended posterior right sectionectomy	1	1.9
Extended left lateral sectionectomy	2	3.8
Central LR (non-anatomic)	2	3.8
Limited non-anatomic resection	6	11.5
Anatomic resections	35	67.3
Non-anatomic resections	17	32.7

mortality rates were 14.3% (2 out of 14 pts) and 7.1% (1 patient), respectively. The death recorded during NOT was related to associated thoracic trauma.

Discussion

Liver trauma remains challenging in terms of diagnosis and treatment. To optimize them, the trauma mechanism must be thoroughly evaluated. Blunt hepatic injuries (HI) may be due to crush and/or deceleration. Deceleration determines parenchymal injury along the right portal fissure, while crush determines injury on the central part of the liver, and if there is any compression, it can cause haemorrhage of the segment 1. The hepatic veins and inferior vena cava may also be injured in these patients. Interestingly, we had a patient

Table 2. The hepatic injuries (HIs) according to the American Association for the Surgery of Trauma (AAST) system and therapy

AAST grade	Surgery		Nonoperative treatment	
	No of pts	%	No of pts	%
I	-	-	-	-
II	0	0.0	1	1.5
III	2	3.0	9	13.6
IV	21	31.8	4	6.1
V	29	43.9	0	0.0
VI	-	-	-	-
Total	52	78.8	14	21.2

Figure 1. Enhanced CT-scan for a crushing trauma (landslide) in a 16-year-old male patient, referred from a paediatric hospital for grade V liver laceration with active bleeding from the right hepatic vein (arrow) and large amount of peritoneal fluid. The patient also had kidney contusion with subcapsular and perirenal hematoma, and thoracic contusion. For further details see the Supplemental Video

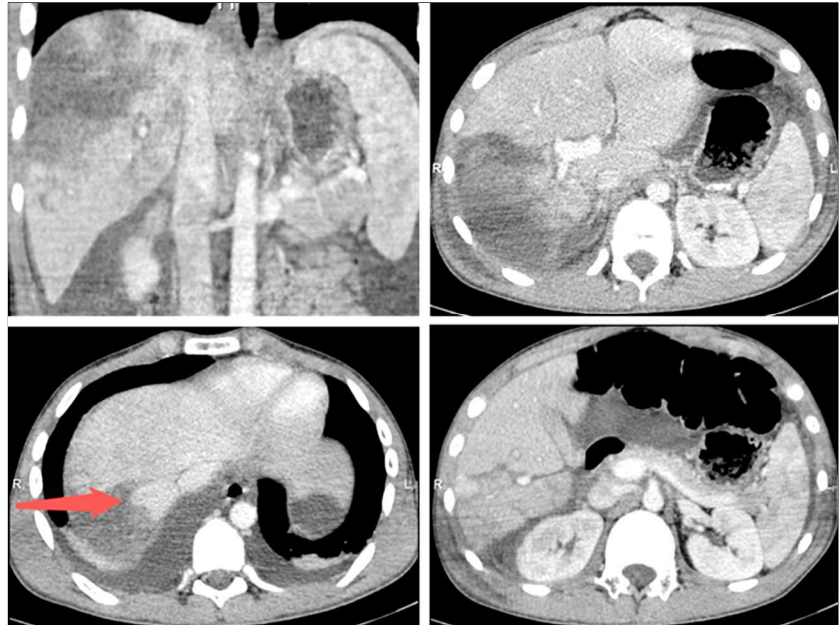
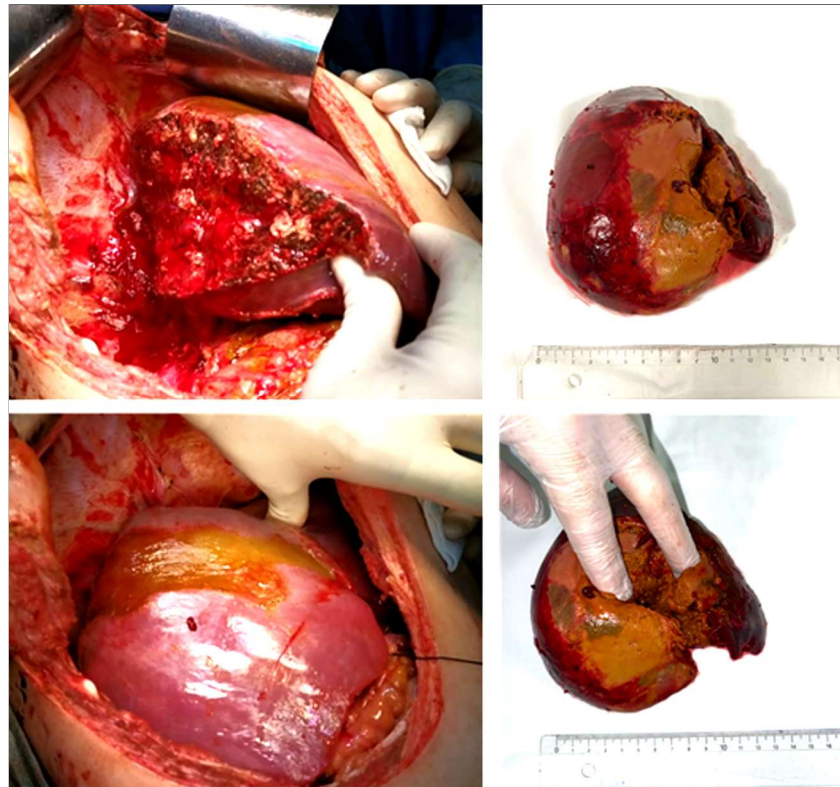


Figure 2. Intraoperative aspects after hepatic resection and the surgical specimen (same patient as in Fig. 1). Even though the patient was stable, he presented with signs of peritonitis that required surgery. Intraoperatively, a massive hemocholeperitoneum was found due to laceration of segments 6 and 7 involving the right hepatic vein, with high-output bile leak and hepatic necrosis of segment 7. Therefore, non-anatomic ultrasound-guided hepatic resection of segment 7 extended to segment 6 and 1, along with the right hepatic vein and the rupture bile duct was performed. The postoperative course was uneventful, and the patient was transferred back to the paediatric hospital in the second postoperative day. For further details see the Supplemental Video



with trauma limited to segment 1 alone, associated with injury of the inferior vena cava and high-output bile leak, who was treated with left hemihepatectomy after failed suture

of the injured bile duct of S1.

In case of a hemodynamically stable patient, a rigorous assessment should be carried out, including a comprehensive clinical

history, physical examination, laboratory and imagistic investigations.

If the patient is unstable, unresponsive to treatment, and/or shows signs of peritonitis, then an emergent laparotomy should be performed.

Contrast-enhanced CT-scan is the investigation of choice when assessing liver trauma, establishing the HI grade according to AAST classification. The active hepatic bleeding is demonstrated by the pooling of contrast material (17). The presence of blood in the Glissonean sheath, appearing as a low density area surrounding the portal triad ("periportal tracking") is frequently associated with biliary injury; if observed in the periphery, it may indicate a bile leak (18).

In stable patients with active arterial bleeding, angiography is the main choice, due to its capacity to perform haemostasis through arterial embolization, avoiding surgery in a significant number of patients (10, 19-22). Also in stable patients, MRI is recommended for assessing bile ducts injury (1). However, it is time consuming, making it suboptimal in emergency settings. ERCP can also be used in these situations, being able to treat a bile leak by trans-papillary stenting (23). In case of dubious diagnosis, laparoscopy may provide favourable results.

Non-operative treatment (NOT) is based on the ability of liver to induce spontaneous haemostasis in more than half of patients. The selecting criteria for NOT is based on hemodynamic stability (independently of hemoperitoneum volume), absence of signs of peritonitis, availability of intensive care monitoring, experienced surgeons and immediate access to operating room in case of NOT failure (24-26). However, patients with continued active bleeding and coagulopathy, even if hemodynamically stable during NOT, should be re-evaluated for surgery.

Whenever feasible, NOT should be the first choice in the management of liver trauma. NOT is most effective in HI with low AAST grade (I to III), which are the most frequent HI (up to 67% of patients) (2). Also, HI with higher AAST grade (IV or V) occurred in a

stable patient may benefit from NOT. HI with AAST Grade VI is always referred to urgent surgery, as it presents with haemorrhagic shock. It is also associated with very high mortality, and death usually occurs prior to hospital admission.

NOT is used in over 80% of blunt HIs, being successful in more than 90% of these cases (27). When feasible, it provides improved overall survival when compared with surgery, with reduced costs (28). NOT is successful due to the developments in imaging, intensive care monitoring and support, and in interventional treatment (29).

Angioembolization is effective in controlling bleeding in stable patients, and up to 5% of patients with NOT may require this procedure (30). Furthermore, it may also treat posttraumatic complications, such as pseudoaneurysm, intrahepatic arterio-venous fistula, haemobilia. The success rate may be more than 90% (14). It can also be used for controlling bleeding after surgery in 12-28% of patients (30). In our study group, arterial embolization was performed in one case. The low rate of angioembolization may be due to the fact that most liver traumas were high grade HI, with complex vascular and biliary injuries. Percutaneous drainage may be used for treating symptomatic biloma and abscesses (31).

However, complications during NOT may occur. For example, bile leaks may occur in up to 21% (21,32-34). Also, abscesses can form, requiring fast diagnosis, antibiotic therapy and drainage, but also surgery if these methods fail (35). Moreover, the probability of NOT failure increases with the severity of liver trauma.

Therefore, surgery still plays an important role in treating complex HIs. In unstable patient, emergency surgery is mandatory. In stab wounds, besides the guidelines used for blunt trauma, the topography, angle of entrance and deepness (beyond the peritoneum or not) must be taken into consideration. In gunshot wounds, the standard approach is immediate laparotomy (36); however, some authors advocate for NOT in

selected hemodynamically stable patients. Nevertheless, this approach is recommended in experienced centers because injuries are frequently not properly diagnosed, leading to complications and death that would have been avoided in case of upfront surgery (37,38). However, NOT is unsuccessful in approximately 33% of these patients (39-42).

Operative treatment is deployed in around 15-20% of the cases with liver trauma (1,2). In our experience, the rate was significantly higher (78.8%) because of the severity of the treated HI, as most of our patients had AAST high-grade lesions, IV and V grades (81.8%). Moreover, most of our patients were referred after perihepatic packing (73.1%). The standard surgical approach is open. Incisions depend on the approach; for example, a midline incision may be initially used, which can be subsequently extended to insure proper liver exposure. Controlling the bleeding should be the first priority (43), while intraoperative exploration of all intrabdominal organs is mandatory to identify all injuries. In case of massive hepatic bleeding, the use of packs is the first choice; if unsuccessful, other methods should be used, such as the vascular control via Pringle maneuver or even total vascular exclusion, and/or direct compression. Intraoperative ultrasound is very useful for assessing both parenchymal and vascular injuries (44).

The current surgical policy is conservative, aiming to avoid parenchymal sacrifice whenever feasible. Moreover, when hepatic resection is needed, efforts should be made to avoid major resections (35). In this sense, direct suture/ligation of the intra-parenchymal bleeding vessel, repair of vessel injury under vascular control (Pringle maneuver or total vascular exclusion). If the vessels are injured beyond repair, then the resection of the corresponding territory is mandatory. However, main hepatic vessel repair and/or complex hepatic resections should be carried out in tertiary HPB centers. When performed in this setting, HR for HI provides low morbidity and mortality rates, of 17-30% and 2-9%, respectively (45,46). Hepatic sutures should be used

with caution, as they may increase the bleeding, induce hematomas and/or ischemia, and cause biliary injury. A good choice for stopping diffuse bleeding is diathermy coagulation, bipolar coagulation, or argon beam coagulator. Use of haemostatic material is recommended (fibrin glue, patches, etc).

When the haemorrhage cannot be controlled, perihepatic packing is the best choice, as it offers time to stabilize the patient and undergo surgery in better conditions (47). Complications after packing can be immediate, such as the inability to control the bleeding, or late, such as infection, sepsis, and multiple system and organ failure (MSOF). After perihepatic packing, definitive surgery should be performed after 24-48 hours (48). However, in our experience, whenever considered useful and in absence of significant inflammatory response, we extended the period to 72 hours without any related complications.

Whenever in unfavourable setting, the strategy of temporary haemostasis, based on perihepatic packing, is always recommended in severe HI, offering the patient the best chance of survival. This allows the definitive surgical treatment to be carried out in a referral HPB center, as scheduled surgery, providing the best chance for cure with reduce complication and mortality rates (49).

Resectional debridement is a common surgical procedure (50). Anatomic liver resections should be performed only when all the other methods failed and cannot be replaced with minor resection. This type of resection is usually indicated in traumatic sectioning of the main liver vessels, such as main portal pedicles and/or hepatic veins (43). Authors report that satisfactory results can be achieved only in tertiary HPB centers (51).

Injuries of the hepatic veins and/or adjacent inferior vena cava may occur in approximately 10% of the patients with liver trauma (*Figs. 1 and 2; Supplemental Video, <https://www.revistachirurgia.ro/pdfs/?art=2021-6-678.pdf&EntryID=922950>*). These injuries are severe (AAST grade V) and difficult to treat, being associated with very high mortality rate to up to 77% (43,52). For

this reason, particular care must be paid during reintervention when removing the packs in vicinity of the hepatocaval confluence and inferior vena cava, as massive bleeding may occur from a venous lesion that was temporary controlled by packing. In our experience, this happened in one patient, who had an unknown large lesion of the left hepatic vein at the hepatocaval confluence, that produced important bleeding after packing removal.

In complex venous injuries with massive bleeding, total vascular exclusion is recommended. If the venous return is to be preserved, a veno-venous or an atriocaval shunt may be used (53). However, it carries a high risk of vital complications (e.g. thrombosis and air embolism) (43). In our experience, vascular or biliary reconstructions were performed in 11.1% and 13.5%, respectively.

Bile leaks are difficult to diagnose preoperatively and they are usually discovered during surgery. Males are 5 times more exposed to this type of injury than women. The median age of these patient is 30 years, many of these being children (54). In blunt traumas, injuries of the common bile duct are relatively rare (5%), but usually are associated with severe liver trauma, frequently involving the hepatic artery and/or portal vein (55), with a high risk of intraoperative death due to bleeding (56). Of note, we had in our experience on such patient, with a severe laceration of the right hemiliver associated with the avulsion of the right portal vein and complete transection of the common bile duct, who was referred to our center after periliver packing; surgery consisted in right hepatectomy and Roux-en-Y cholangiojejunostomy (16). Gallbladder injury also frequently occurs in such patients (57). The most common immediate complications after biliary trauma are bile leak and sepsis, with a mortality rate of about 10% (54). As late complications, some of the patients may develop biliary stenosis.

The most common complications after surgery for liver trauma include re-bleeding, bile leak, intrahepatic arterioportal fistulas, abscesses, liver failure and sepsis.

Haemorrhage can also occur later, through haemobilia (58). High grade HI have high morbidity and mortality rates, depending on the trauma severity, due to haemorrhagic shock, high risk of rebleeding despite surgery, hematoma, biloma, bile leak, liver necrosis, sepsis and MSOF.

The morbidity after liver trauma is dependent on the AAST grade varying from 5%, in case of grade III, to over 50%, in case of grade V (35,59). Consequently, mortality increases in high-grade HIs (IV and V) (60). Following hepatic trauma, the overall mortality rate is 10-15%. Death is usually provoked by bleeding or by septic complications. Blunt HI have higher mortality rate (10-30%) when compared to penetrating HI (0-10%).

NOT and perihepatic packing are successful in reducing the mortality rate even in severe HI (28,59,61). Even more, NOT is successful in many of these cases, leading to low mortality rates that vary between 0 and 8% (25,27,30, 52, 62-69). In our study, the mortality after NOT was in accordance with the literature (7.1%). It is worth mentioning that we had few cases with NOT because of the severity of the liver trauma referred to our center, and the fact that most patients arrived after initial surgery performed elsewhere. Moreover, the one death occurred in this subgroup of patients was unrelated to HI. Clearly, the mortality rate is significantly higher in case of high-grade HI requiring surgery, ranging from 30 to 68%. Importantly, in these cases the mortality was not influenced by initially attempted of NOT (49). Of note, the mortality raises to up to 77% in case of injury of the liver hilum and/or inferior vena cava (52). In our study, surgery for high-grade HIs had a significantly lower mortality rate (15.7%) when compared to the literature. After surgery, complications requiring reinterventions occur in up to 50% of cases (70). However, in our experience, the reintervention rate was significantly low (11.8%).

Total hepatectomy followed by liver transplantation may be required in selected patients with liver failure after complex trauma (71). Despite a high retransplantation

rate, the long-term survival is similar to other benign indications for LT (72). In our study, we had one patient which required transplantation, a 22-year-old female with liver failure after extensive multiple bilobar lacerations (16); the patient is currently alive with no complications at 6 year after transplantation.

Therefore, for best results, we recommend that liver resections, especially major HR and/or vascular and biliary reconstructions, should be performed in a high-volume HPB center, reducing the morbidity and mortality rates, while having the liver transplantation as a salvage solution. With around 4000 liver resections and 1250 LTs, our hospital is an established national referral center for liver surgery.

Conclusion

Hepatic resections, especially major ones and/or involving vascular and biliary reconstructions, as well as non-operative treatment for severe hepatic injuries, are to be carried out in tertiary HPB centers, thus minimizing the morbidity and mortality rates, while having the liver transplantation as salvage option.

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Conflicts of Interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript

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Ethical Statement

For performing this study ethical approval was obtained.

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