CASE SERIES

The role of liver resection in the management of severe blunt liver trauma

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ABSTRACT

BACKGROUND: The management of hepatic trauma has a historical progress from mandatory operation with selective non-operative treatment, to non-operative treatment with selective operation. Liver resection (LR) seems to have a minimal role in the management of liver injury. However, surgical treatment becomes the only life-saving treatment in cases with severe liver trauma.

METHODS: It is a retrospective presentation of five cases with severe blunt liver injury whose were admitted at our center during the 8-year period.

RESULTS: The median age of patients was 30.8 (23–43). The most frequent mechanism of injury was pedestrian struck (60%). Two of five cases were transferred to our hospital from rural state hospitals after initial attempt to achieving hemostasis. The majority of liver injury was grade V (80%). The right lobe of the liver was injured in different extensions. Major vascular injury was associated to liver injury in four of five cases. The right hepatectomy (n=1), resectional debridement of segments 5, 6, and 7 (n=1), posterior sectorectomy (n=2), and segment 7 resection (n=1) were performed for hemostasis. Vascular injuries in the junction of inferior vena cava and right hepatic vein (n=1), the anterior surface of the right hepatic vein (n=1), the junction of segment 7 hepatic vein and right hepatic vein (n=1), the main portal vein (n=1), and the right renal vein (n=1) were repaired. Median operation time was 162 min (120–180 min). Operative mortality was 20%. Reoperation was needed in three of four survived cases. In-hospital complications were observed in two of four survived cases. Median stay in intensive care unit and hospital was 12.4 days (1–48 days) and 28.2 days (1–65 days), respectively.

CONCLUSION: When a severe liver injury is unresponsive to packing, the surgeon must always keep in mind that extensive maneuvers for vascular control and LR are required for bleeding control.

Keywords: Blunt trauma; liver injury; liver resection.

INTRODUCTION

The management of major liver injuries has always been one of the most demanding aspects of trauma surgery. Since the early 1990s, standard principles of damage control surgery have been widely adopted with the hope of better understanding of the injured patient's physiology. Especially, liver injuries in hemodynamically stable patients have managed non-operatively with the guidance of modern imaging and minimally invasive technologies.[1,2] However, patients with severe liver injuries (Grade III, IV, or V) generally arrive to the hospital with hemodynamically stable but deteriorating state, or initially unstable state. The patient in shock with hemoperitoneum requires immediate laparotomy to control the bleeding regardless of the injury mechanism. The only major goal of the operation is to achieve hemostasis as rapidly as possible before the onset of hypothermia, acidosis, and coagulopathy. Packing is especially useful for high-grade lacerations or parenchymal disruptions that are not amenable to local hemostatic techniques including suture

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ligation, application of topical hemostatic agents, argon beam coagulation, or electrocautery coagulation.[3] In addition to operative packing, utilization of interventional radiology, such as angiography and embolization, is recommended for achieving hemostasis.[4] Bleeding from the liver may not stop with packing, especially in the presence of extensive destruction of the periphery of the liver or bleeding from the hepatic veins and juxtahepatic inferior vena cava (IVC). Under these circumstances, partial hepatectomy and selective vascular ligation under inflow or inflow and outflow occlusion may be required for achieving hemostasis.

We present here the clinical course of five patients with severe blunt liver trauma. The role of liver resection (LR) in the management of blunt liver trauma is discussed.

MATERIALS AND METHODS

The following is a retrospective evaluation of five patients with severe liver injuries secondary to blunt abdominal trauma who were admitted and treated by the same surgical team at the Karadeniz Technical University, Farabi Hospital from January 2012 and December 2020. Informed consent was received from survived patients and the relatives of deceased patients. Collected data included patient demographics, mechanism of injury, injury severity score (ISS),[5] revised trauma score (RTS),[6] acute physiology and chronic health evaluation score (APACHE-II),[7] hemoglobin level, and transfusion requirement before our operation and the interval period between the time of injury and laparotomies. The severity of liver injury is reported using the organ injury scale proposed by the American Association for Surgery of Trauma and is graded as I-VI based on abdominal computed tomography (CT) scan and/or intraoperative findings.[8] Associated injuries of the patients were also collected. The abdomen was explored with midline abdominal incision with the right transverse extension above umbilicus. The abdomen was packed in the first exploration and massive transfusion protocol was initiated. Portal triad clamping (PTC) was performed in all patients with Rummel tourniquets. A conventional technique including intermittent PTC in 15/5 min cycles of clamp/unclamp times was applied. The liver was transected through clamp crushing and a vessel sealing device (LigaSureTM, Medtronic, 710 Medtronic Parkway, Minneapolis, MN 55432-5604, USA). Closed-suction drainage was used routinely. Operative variables including type and duration of operation, PTC period, transfusion requirement during operation, and requirement of reoperation were recorded. Outcome measures were included length of intensive care unit (ICU) and hospital stay, complications, and mortality. All patients were resuscitated according to the advanced trauma life support guidelines.[9] Focused assessment with sonography for trauma (FAST) was utilized in the early assessment of all patients to detect the presence or absence of hemoperitoneum. CT scan of the abdomen and thorax was performed in 4 of 5 patients before operation for assessment of injury severity.

Statistical Analysis

The data were expressed as median (minimum-maximum) and per cent to its necessity. Small sample size impeded healthy comparison of parameters; therefore, there was no comparative analysis performed with the data.

RESULTS

Patients' Demographics and Clinical Characteristics

The median age of patients was 30.8 (23–43). The most frequent mechanism of injury was pedestrian struck by vehicle (60%), followed by fall from height (20%) and motor vehicle collisions (20%). The median period between the injury and initial operation was 84 min (30–120 min.). The extra-abdominal injuries of patients were chest (80%), extremity (40%), head (20%), and thoracolumbar spine (20%). The associated abdominal injuries were spleen (20%), kidney (20%), and retroperitoneal hematoma (20%). The median ISS, RTS, and APACHE II scores were 40.4 (33–50), 5.76 (5–7.8), and 26.8 (11–35), respectively (Table 1). Blood transfusion was started preoperatively in 80% of cases. Two of five cases were transferred to our hospital from rural state hospitals after initial attempt to achieving hemostasis. Packing was performed in both operations. It was successful in Case-1 and, hence, the patient was managed with minimal transfusion requirement before and during the reoperation (36 h after initial operation). Packing did not stop the bleeding from liver in Case – 5. Therefore, the patient was reoperated 12 h after initial operation with massive transfusion requirement. Other patients (n=3) arrived to our hospital with unstable hemodynamic state. CT scan findings indicated severe right liver lobe injury and extensive intraperitoneal blood in Cases 2 and 4 (Figs. 1 and 2). Only FAST was performed preoperatively in Case – 3 due to rapid deterioration of hemodynamic state. Median erythrocyte suspension (ES) transfusion during operation was 7.2 unites (1–12 unites). Massive transfusion defined by transfusion of more than 10 units of ES within the 24 h period was required in 60% of patients.

Operative Management

If the spleen was injured (as in Case – 3), it was removed immediately. In the referred cases (n=2), previously packed compresses were gently removed with warm saline pouring. The majority of liver injury was grade V (80%). Operative findings revealed that the right lobe of the liver was injured in different extensions (Table 1 and Fig. 3). The so-called "bear claw" injury of the liver parenchyma was observed in all cases. Associated vascular injuries were detected in the junction of IVC and right hepatic vein (n=1), the anterior surface of the right hepatic vein (n=1), the junction of segment 7 hepatic vein and right hepatic vein (n=1), the main portal vein (n=1), and the right renal vein (n=1). The median PTC time was 32 min (20–45 min.). The PTC maneuver failed to stop the bleeding in the liver in four of five patients. It successfully

Table 1. Demographics, clinical presentation, management and complications of patients

Parameters	Case-1	Case-2	Case-3	Case-4	Case-5
Age (years)	30	27	31	43	23
Gender	Male	Female	Female	Male	Male
Mechanism of injury	Fall from height	Pedestrian struck	Motor vehicle collisions	Pedestrian struck	Pedestrian struck
ISS	33	50	45	36	38
RTS	7,8	5	5,5	5,5	5
APACHE II	11	33	35	27	28
Preoperative hemoglobin (g/dl)	11,9	6	4,5	8	5
Preoperative transfusion (unite)	3 ES	1 ES	none	1 ES	5 ES 4 FFP
Period between injury and initial operation (min)	120	90	30	60	120
Liver injury scale	4	5	5	5	5
Period between initial operation and re-operation for hemostasis (h)	36	8	none	none	12
Associated injuries	Right hemothorax and transverse process fracture of 1st thoracal vertebrae	Right hemothorax, multiple fractures in the right and left orbital spaces, left mandibula,the posterior wall of left maxillary sinus, the distal part of the left femoral shaft, the left pelvic ramus and the left forehand	Right hemothorax, left pneumothorax, spleen laceration and retroperitoneal hematoma	Plulmonary contusion, right pneumothorax right renal vein injury and fracture of right clavicula	Right hemothorax and left pneumothorax
Operative management	Segment 7 resection and multiple repairs of right hepatic vein	Right hepatectomy, cholecystectomy, and repair of main portal vein trunk	Splenectomy and resectional debridement of segments 6 and 7	Resectional debridement of segments 5, 6 and 7, cholecystectomy, repair of right renal vein	Repair of vena cava and resectional debridement of segments 6 and 7
Operation time (min)	120	180	180	150	180
PTC time (min)	20	30	45	40	25
Intraoperative transfusion (unite)	1 ES 1 FFP	6 ES 8 FFP	18 ES 19 FFP	9 ES 7 FFP	8 ES 8 FFP
Postoperative transfusion (unite)	2 FFP	8 ES 94 FFP 6 TS	2 ES 1 FFP	16 ES 50 FFP	7 ES 18 FFP 2 TS
Re-operation for additional reasons	None	Stabilization of left femoral shaft fracture in 13 PODs	none	none	Take out the forgotten pad in 11 PODs
Morbidity	None	Postoperative bleeding, POHF, biliary obstruction		Pneumoniae, Pulmonary effusion, tracheal stricture secondary to tracheostomy, hand and knee contractures related to long ICU stay	None
Mortality	None	None	Died related to unresponsive hemodynamic shock	None	None
ICU stay (day)	1	8	1	48	4
Extubation time (day)	At the operating room	7 PODs	–	Tracheostomy in 19 PODs, MV support ceased in 36 PODs	1 POD
Hospital stay (day)	7	49	1	65	19

ISS: Injury Severity Score; RTS: Revised Trauma Score; APACHE: Acute Physiology and Chronic Health Evaluation Score; ES: Erythrocyte suspension; FFP: Fresh frozen plasma; TS: Thrombocyte suspension; PTC: Portal triad clamping; POD: Postoperative day; POHF: Postoperative hepatic failure; ICU: Intensive care unit; MV: Mechanical ventilation.

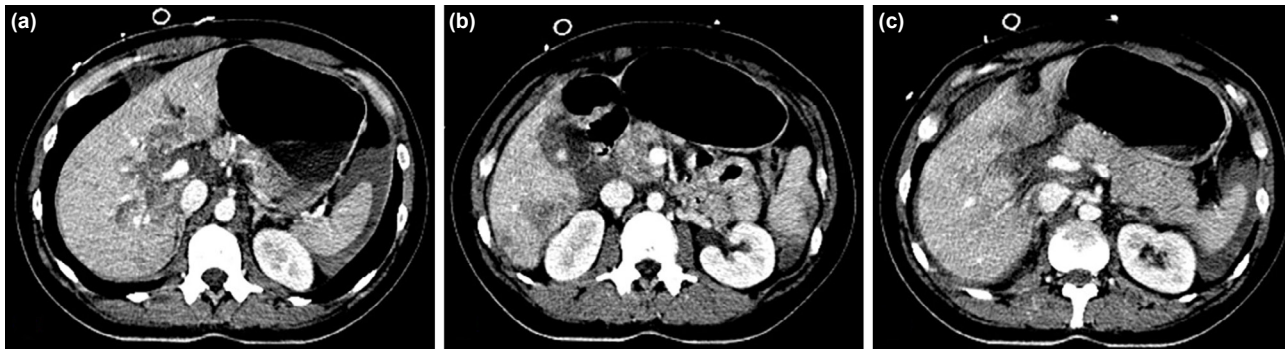

Figure 1. Axial contrast-enhanced computed tomography images showing hypodense areas in segments 5, 6, 7, and 8 of the liver **(a-c)** indicating grade V liver injury.

ceased bleeding from the liver in Case – 4. The right lobe of the liver was quickly mobilized in all patients. Gentle compression was applied to the injury site. The separated fragments of liver and clots were removed. To access bleeding vessels, irregular margins of traumatized liver were straightened with partial LRs. With the help of segment 7 resection, bleeding from the anterior surface of the right hepatic vein and the junction of segment 7 hepatic vein and the right hepatic vein were controlled with vascular sutures in Case – 1 (Fig. 3). The outflow stream of the remnant right hepatic vein was protected. Bleeding from superficial laceration in segment 5 was ceased with compression in that case. Right hepatectomy was performed to control bleeding from huge laceration of the right liver lobe in Case – 2 (Fig. 3). Partial injury of the main portal vein trunk was also repaired under inflow control. The resectional debridement of fragmented segments 6 and 7 was performed after splenectomy for bleeding control in Case – 3 (Fig. 3). However, hemodynamic stability was not achieved and cardiopulmonary resuscitation was required during operation. The irregular surface of the injury site was straightened with removal of fragmented segments of 5, 6, and 7 in Case – 4 (Fig. 3). After the control of bleeding from raw liver surface, oozing from the right kidney was detected. The source of bleeding was the anterior surface of the right renal vein and the injury site was repaired with vascular sutures. After gentle removal of pads previously placed over the right liver lobe, profuse bleeding from the junction of the right hepatic vein and the IVC was detected in addition to fragmented segments of 6 and 7 in

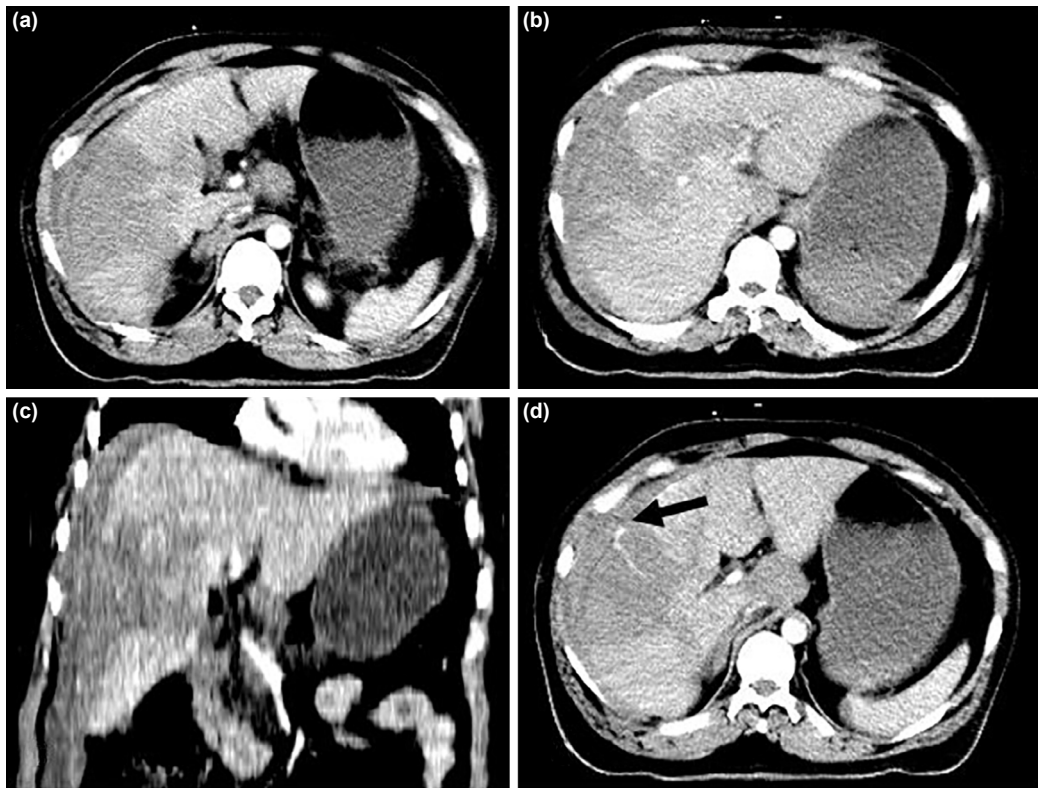

Figure 2. In the portal phase liver computed tomography images, hypodense parenchymal areas representing Grade V liver injury were observed in segments 5, 6, and 7 of the right liver lobe **(a-c)**. Active extravasation from the posterior branch of right portal vein was marked with arrow **(d)**.

Case – 5 (Fig. 3). Complete avulsion of the right hepatic vein from the IVC was observed. Immediate control of the opening on the IVC was achieved by side clamping with the Satinsky clamp and the injury site was repaired with vascular sutures. The resectional debridement of fragmented segments 6 and 7 was also performed for straightening the irregular surface of the injury. Bleeding from the trace of the remnant right hepatic vein was controlled with suturing and electrocautery coagulation. Median operation time was 162 min (120–180 min).

In-hospital Complications and Outcomes

Reoperation was needed to control post-operative bleeding from raw liver surface (n=1), to take out a forgotten pad left behind due to insufficient communication with the surgical team of the initial operation in rural state hospital (n=1), and to stabilize the fracture of the femoral shaft (n=1). In-hospital complications were observed in two of four survived cases. Post-hepatectomy liver failure (PHLF) was observed after right hepatectomy in Case – 2. Plasma exchange treatment (with 10 units of fresh frozen plasma per day) was applied for the treatment of PHLF between post-operative days (PODs) 4 and 12. Partial biliary tract obstruction was relieved with percutaneous biliary drainage catheter in 14 PODs. Intensive pulmonary care was required for massive pulmonary contusion and related complications in Case – 4. Despite our aggressive operative and early post-operative efforts, the state of hypovolemic shock was not stabilized in Case – 3. The patient died hours after operation in the ICU. Median stay in the ICU and hospital were 12.4 days (1–48 days) and 28.2 days (1–65 days), respectively.

DISCUSSION

The right lobe of the liver is very susceptible to compression by the lateral ribs in blunt trauma. The mechanism of liver of injury may be classified as vertical movements such as a fall from height, anteroposterior strike such as head-on collision, and right lateral strikes such as a T-bone crash from passenger side. Vertical movements can damage the hepatic round ligament and the triangular ligament. In the anteroposterior movements, the liver moves forward with the triangular ligament as a fulcrum. Direct compression of the lateral ribs can cause liver damage in a right lateral strike.[1,8,10] In laparotomy, surgeons generally face typical curvilinear lacerations across the dome and anterior surface of the right lobe, the so-called "bear claw" injury.[1] Fragmentation of liver parenchyma may be observed depending on the velocity or force of the strike. Eighty percentages of our patients presented with different grades of fragmentation in the right liver lobe. Run over by truck (in Cases – 2 and 5) and car crash (in Case – 4) were causes of pedestrian collision injury. Case – 4 was dragged by a car for a while, squeezed between the car and the wall until the car was stopped. Above-mentioned histories of the injury were received by eyewitnesses and indicated the violence of the event. Different mechanisms may induce liver injury within the same event. Therefore, the impact of injury should also be taken into consideration when determining of the severity of liver damage.

Packing is a lifesaving surgical maneuver for hepatic trauma, especially for unexperienced surgeons. It is important to note that packing is most effective for venous injuries. The goal of

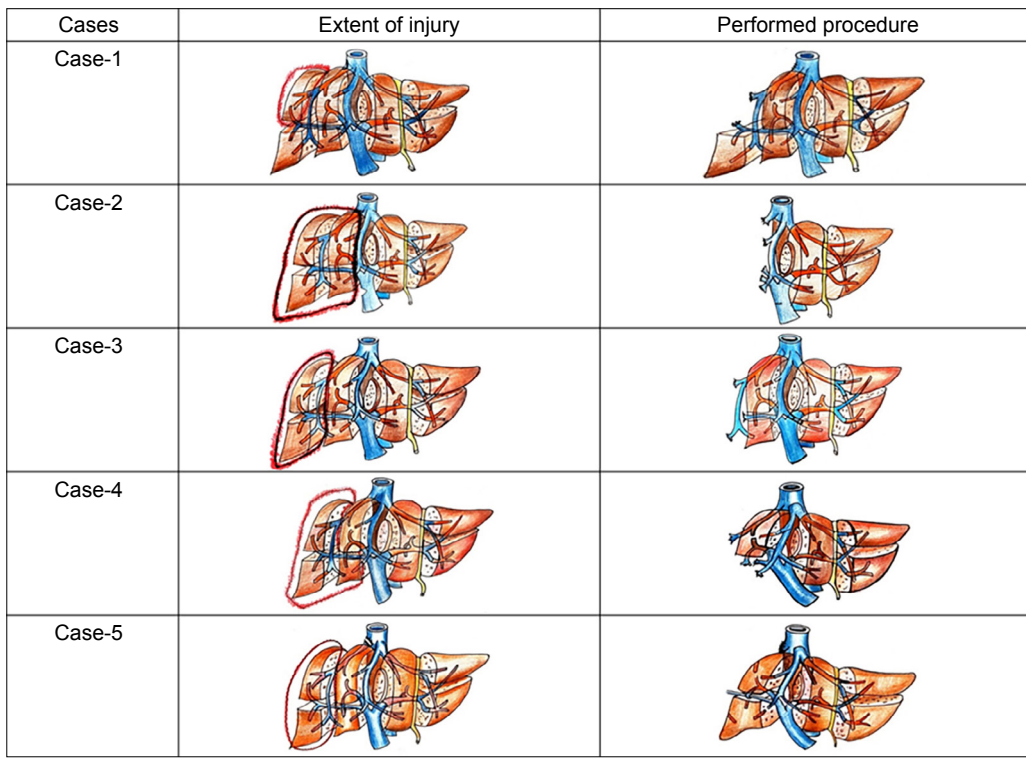

Figure 3. Schematic presentation of injury extent and performed procedure.

the technique is to achieve hemostasis by compressing the bleeding parenchyma between packs placed above and below it.[11] The hemostatic effect of packing is easily checked in the operation room. It is rational to wait few minutes after application of the laparotomy pads before closing the abdomen. If the patient is transferred to a different hospital after packing, the number of applied pads and zones of application should be noted and shared with the surgical team of tertiary trauma center. Close communication between surgical teams is crucial in the prevention of unnecessary reoperations for forgotten pads.

In high-grade liver injuries with arterial hemorrhage that cannot be directly controlled by suture-ligation of the bleeders, immediate angiography with selective embolization is suggested after packing.[4] However, selective embolization is incapable of controlling venous bleeding from the liver. The absence of a venous valve and the low contractility of hepatic veins are main factors for severe bleeding from venous injuries of the liver.[10] More than 60% of fatalities from the liver injury occur due to the uncontrollable bleeding.[12] In the event that packing fails, operative control of major venous bleeding from the liver should be obtained.

Inflow occlusion of the liver is the next step.[11] There are no available data presented to define the safe duration of hepatic inflow occlusion in trauma patients. Intermittent occlusion of inflow also facilitates determination of the injury site in the contents of hepatoduodenal ligament. The vessel should be liberated below and above the injury site before repairing of the hepatic artery or the portal vein. The surgeon must urgently consider more extensive procedures for bleeding control during inflow occlusion. This requires mobilizing the liver, initially the right lobe, and occasionally the left lobe. Compression of the injured liver during mobilization is an important detail and it should be carried out by the assistant surgeon or by the left hand of the senior surgeon. Vascular isolation of the liver is a more sophisticated procedure and it requires an expertise on the era of hepatobiliary surgery or transplant surgery. If the extensive destruction or fragmentation of the periphery of the liver has occurred, the resectional debridement of injured tissue is an important option.[1,11] It reveals regular remnant liver surface for detection of the bleeding origin thorough the liver. In contrast to bleeding from parenchyma, major vascular injury is not controlled with the application of topical hemostatic agents, argon beam coagulation, or electrocautery coagulation. The site of vascular injury should be repaired by suturing. Hepato-caval junction and retrohepatic IVC are critical origins of massive venous bleeding from the liver trauma. Surgeons should be aware of the possible anatomical variations between the liver and the IVC.[13] If suspensory ligaments are injured, bleeding from the retrohepatic IVC or the major hepatic veins is manifested by blood leakage around the liver. In the presence of intact suspensory ligaments after trauma, bleeding from the retrohepatic IVC or the major hepatic veins is manifested by blood leakage through a hole in the liver.[14] The infrahepatic IVC can usually be controlled relatively quickly after a Kocher maneuver. However, dissection of the infradiaphragmatic suprahepatic IVC is difficult and should be started from the left side of the hepato-caval junction. Both of these intra-abdominal maneuvers are required for complete hepatic vascular isolation.[1,11,14] The risk of hypovolemic arrest after IVC occlusion in trauma patients is seriously high. Simultaneous aortic cross-clamping with IVC occlusion, or use of a centrifugal pump to return blood to the heart have been used to reduce the risk of cardiac arrest.[15,16] Another option for achieving outflow control is the atriocaval shunt; however, application of the shunt requires median sternotomy in addition to laparotomy.[17] The most aggressive and advanced surgical technique for hemostasis are hepatic explantation and back-table repair of the hepatic vein avulsion followed by hepatic autotransplantation.[18]

Rapid hemodynamic deterioration of patients during exposure of the injury site is inevitable. Hollands and Little reported a low survival rate (20%) in patients with the right hepatic vein avulsion from the IVC.[19] Therefore, close dialogue between surgical and anesthetic teams should be established before starting dissection. Delayed action ensures failure and patient death as a result of continued massive blood loss. In addition to standard monitoring such as ECG, blood pressure, body temperature, peripheral oxygen saturation, and urine output; close hemodynamic follow-up should be performed by invasive arterial monitoring with central venous blood pressure catheterization (CVP).[20] Blood sugar and electrolyte levels and coagulation parameters should be closely monitored during replacement of fluid, blood, and blood products.[21] PTC increases systematic vascular resistance by up to 40% and reduces cardiac output by 10%. Mean arterial pressure increases about 15%. Whereas, cross-clamping of the IVC and portal vein result in a 40–60% reduction of venous return and cardiac output, with a compensatory 80% increase in systemic vascular resistance and a 50% increase in heart rate.[21] Unclamping is followed by an increase in cardiac index and a significant reduction in systemic vascular resistance. Therefore, the anesthetist should manage the preload reduction and the sudden decrease in cardiac output evoked by clamping of the IVC and portal vein. It should be noted that air embolism might develop from injured hepatic veins and they should be closely monitored and treated.[22]

The primary goal of the surgeon is to reduce fatality, but various types of complications should continue to be monitored for and treated in survived patients. Strong and associates reported that 60% of survived patients after LR for severe liver trauma faced with complications.[23] Pulmonary complications are the leading causes of morbidity. Intra-abdominal bleeding, biliary leak or obstruction, wound infection, and POHF are other common causes of morbidity that should be managed once detected.[1,12,23–25] Long ICU stay and hospitalization are generally indicated in the treatment of associated injuries and morbidities.

Conclusion

The aim of operative management of blunt liver trauma is obtaining hemostasis, as exsanguination is the most immediate risk for the patient. The methods used for bleeding control directly related with surgical expertise and they should be appropriate for the injury, the patient, and the support facilities. When a severe liver injury is unresponsive to packing, the surgeon must always keep in mind that extensive maneuvers for vascular control and LR are required for bleeding control. Especially in hepatocaval junction trauma, this aggressive approach should be performed for the repair of the injury site even after a successful packing attempt.

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OLGU SERİSİ - *ÖZ*

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AMAÇ: Karaciğer travmasına yaklaşımın tarihsel gelişimine bakıldığında ameliyatın zorunlu, ameliyat dışı tedavinin ise seçilerek uygulandığı bir dönemden günümüzde ameliyat dışı tedavinin yaygın uygulandığı ve ameliyatın seçilerek uygulandığı bir döneme doğru ilerleme olduğu görülmektedir. Karaciğer travmasının tedavisinde karaciğer rezeksiyonunun kısıtlı bir rolü bulunmaktadır. Ancak, ağır karaciğer travmasında cerrahi tedavi hayat kurtarmak için tek seçenektir.

GEREÇ VE YÖNTEM: Sekiz yıllık süre zarfında merkezimizde tedavi edilen ağır seviyedeki beş künt karaciğer yaralanması olgusunun verileri geriye dönük olarak sunuldu.

BULGULAR: Hastaların ortanca yaşı 30.8 (23–43), en sık yaralanma mekanizması ise aracın yayaya çarpmasıydı (%60). İki hasta merkezimize başka merkezlerde kanama kontrolüne yönelik yapılan ameliyat sonrasında transfer edildi. Karaciğer hasarının derecesi çoğunlukla V. dereceydi (%80). Tüm olgularda karaciğer sağ lobda değişen genişlikte hasar olduğu gözlemlendi. Dört hastada eşlik eden büyük damar yaralanması saptandı. Hemostazı sağlamak için sağ hepatektomi (n=1), segment 5, 6 ve 7'nin rezeksiyon yolu ile debritmanı (n=1), posterior sektörektomi (n=2) ve segment 7 rezeksiyonu (n=1) uygulandı. İnferior vena kava ile sağ hepatik ven bileşkesi (n=1), sağ hepatik venin ön yüzeyi (n=1), segment 7'nin hepatik veninin sağ hepatik vene açıldığı bölge (n=1), ana portal ven (n=1) ve sağ renal ven (n=1) yaralanmaları vasküler teknikle onarıldı. Ortanca ameliyat süresi 162 dakikaydı (120–180 dk). Ameliyat mortalite oranı %20 bulundu. Yaşayan dört hastada üçünde tekrar ameliyata gerek duyuldu. Dört hastanın ikisinde komplikasyonlar görüldü. Yoğun bakım ve hastanede kalış ortanca süreleri sırası ile 12.4 gün (1 ile 48 gün arası) ve 28.2 gündü (1 ile 65 gün arası).

TARTIŞMA: Paketleme (packing) uygulamasının hemostazı sağlayamadığı ağır karaciğer yaralanması varlığında cerrah, kanamanın ancak vasküler kontrol manevraları ve karaciğer rezeksiyonu ile durdurulabileceğini aklından çıkarmamalıdır.

Anahtar sözcükler: Karaciğer rezeksiyonu; karaciğer yaralanması; künt yaralanma.

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