Indian Journal of Surgery (April 2021) 83(Suppl1):S149 –S154
https://doi.org/10.1007/s12262-021-02727-z

ORIGINAL ARTICLE

The Operative Management for Gunshot Liver Injuries: an Experience of Seventy-One Patients in 5 Years

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Received: 14 July 2020 / Accepted: 7 January 2021 / Published online: 11 January 2021

Abstract

Abdominal gunshot wounds have become a major problem globally, and it is commonly associated with liver injury. The aim of this study is to review our experience and outcomes of operative management of gunshot liver injures. A case series analysis reviewed all patients who underwent emergency laparotomy following liver gunshot injuries from January 1, 2011, to December 31, 2016. The collected data included age, gender, vital signs on admission, blood transfusion, grade of liver injury, associated intra-abdominal injuries, surgical procedures performed and re-operations, morbidity, and mortality rate. During the study period, we have done 71 operations for gunshot liver injured patients. The mean age was 28.5 years. There were 68 men and three women. There were 56 patients who had multi-organ injuries, while 64 patients were in shock. Liver injury grade I was occurred in two patients, while grades II, III, IV, and V have occurred in 10, 34, 19, and 6 patients, respectively. Liver tissue hemostasis was done in seven patients, 25 underwent liver tissue primary repair, 15 had direct blood vessel ligation, 21 were treated with perihepatic packing as part of damage control surgery, and three patients had a non-anatomical liver resection. Postoperative liver-related complications occurred in 15 patients, bleeding occurred in nine patients, the biliary leak in five, and hepatic abscess with septicemia in one patient. Despite the acceptance of selective non-operative management like hepatic angioembolization with its high success rate, expeditious exploratory laparotomy still has an effective role in the treatment of gunshot wounds of the liver with advanced grade penetrating injuries with acceptable morbidity and mortality.

Keywords Gunshot injury · Penetrating liver injury · Liver trauma

Introduction

The liver is the largest solid intra-abdominal organ, has a thin, friable capsule, and is very vascular. Anatomically, the liver is located on the right side of the upper abdomen, and it is divided into a large right and a small left lobe by the falciform ligament. From a surgical point of view, the liver is divided into eight segments based upon the vascular and bile duct distribution. Despite its anatomical location that offered a type of protection by the lower thoracic cage, its site and size still make it vulnerable to injury.

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Trauma is the main cause leading to death in the first four decades of life in developed countries [1]. In the presence of multiple conflict hotspots internationally as well as the growing civilian usage of weapons, gunshot injuries are a common surgical case and have become a major problem globally [2]. Even in a post-conflict setting, the mere presence of firearms in society produces a constant number of injured somewhat similar to an endemic state [3].

The liver is the most commonly injured solid organ in the patient with abdominal gunshot wounds [4]; penetrating liver injuries can range from a superficial parenchymal wound to major vascular laceration [5]. Based on the use of the Focused Assessment with Sonography in Trauma (FAST) exam, the positive FAST is suggestive of intra-abdominal free fluid in hemodynamically unstable injured patients, while in hemodynamically stable patients, intravenous contrast-enhanced computed tomography of the abdomen is the best diagnostic modality [6].

In the past, all-penetrating liver injuries were managed by mandatory laparotomy. Operative management can range from the application of topical hemostatic or simple primary

repair to the more complicated techniques such as a direct ligation of bleeding vessels, major non-anatomic liver resections with or without hepatic tissue debridement, and damage control surgical techniques. In the past two decades, stable patients with isolated liver injuries have been managed non-operatively with angioembolization techniques.

Our message in this article is to review and present our experience and analyze the outcomes of the operative management of gunshot liver injuries in a large volume trauma center in eastern Libya.

Patients and Methods

A case series analysis reviewed all patients who treated with urgent laparotomy due to liver gunshot injuries within the period from January 1, 2011, to December 31, 2016, in our department. The collected data included age, gender, vital signs on admission, blood transfusion, grade of liver injury according to the American Association for the Surgery of Trauma (AAST Hepatic injury scale), associated intra-abdominal injuries, surgical procedures performed and re-operations, morbidity, and mortality rate. All patients were resuscitated by a trauma team following the protocols of the Advanced Trauma Life Support of the American College of Surgeons. Urgent computed tomography was only done in hemodynamically stable patients in order to confirm the hepatic injury and detect other associated organ injuries. Operative procedures that were performed after initial resuscitation included exploratory laparotomy followed by hepatic tissue hemostasis, primary repair of liver laceration, emergency non-anatomical hepatectomy, and perihepatic packing as part of damage control surgery.

In this study, we have included all cases who had operations due to abdominal gunshot wounds with penetrating liver injuries, while we have excluded all cases of liver injuries that were treated conservatively or with non-operative management. In statistical analysis, all continuous variables were expressed as mean ± standard deviation (SD). The categorical data were expressed as frequency and percentage. Comparisons between groups were made using the X^2 test or Fisher exact test for categorical variables as appropriate. Statistical analyses were performed using the SPSS v21 statistical software, and P values of less than 0.05 were considered statistically significant.

Results

During the study period, we have done 71 operations in our department, for patients who suffered from gunshot liver injuries. The mean age of these patients was 28.5 years (SD = 8.7). There were 68 men and three women. Isolated liver injury has occurred in 15 (21%) patients, while 56 (79%) patients had multi-organ injuries. The colon, diaphragm, and small bowel were the more frequently injured organs in association with the liver (34%, 21%, and 20%, respectively). At admission time, 64 (90%) patients were in shock and seven (10%) patients were stable. Liver injury grade I has occurred in two patients (3%) who have had operations because of colonic injuries, while grades II, III, IV, and V have occurred in 10 (14%), 34 (48%), 19 (27%), and 6 (8%) patients, respectively.

The aim in all patients who underwent emergency laparotomy was to control bleeding while preserving liver tissue. Liver tissue hemostasis was done in seven (10%) cases, three were with electrosurgical hemostasis and four cases with application of topical hemostatic agent; 25 (35%) cases underwent liver tissue primary repair; 15 (21%) patients had direct blood vessel ligation with liver tissue primary repair; 21 (30%) patients had perihepatic packing as part of damage control surgery; and three (4%) patients had necrotic tissue debridement with non-anatomical liver resection. Table 1 shows the frequency of each operative procedure with its outcomes.

Postoperative complications occurred in 38 (53.5%) patients, and 14 (19.7%) of them had a liver-related complication. Bleeding was the most frequent liver-related complications that occurred in eight (11.2%) patients, biliary leak in five (7%) patients, and hepatic abscess with septicemia in one (1.5%) patient. Table 2 shows types of postoperative complications and its mortality sequels. Second-look laparotomy was necessary for 20 patients (28%). Of those, 17 had the packs removed during surgery on average after the second postoperative day. The remaining three patients were re-explored for the biliary leak, colonic leak, and missed gastric injury. The mortality was in 14 (19.7%) patients, with the cause of death being hypovolemic shock due to intraoperative massive bleeding in ten patients, seven of them due to hepatic bleeding while the rest three die due to extra hepatic bleeding. The postoperative mortality occurred in four patients (6%); the first patient died due to postoperative hepatic bleeding, while sepsis with multiple organ failure occurred in second patient, and aspiration pneumonia in the third patient and pulmonary embolism in the last patient.

Discussion

Similar to Nigeria, the incidence of abdominal gunshot injuries is on the rise in our community [7], while on the other side of the world, some series have reported that this incidence has decreased in the last two decades, as in Brazil [8]. The severity of gunshot hepatic injury depends upon the blood vessels that are involved, which may diminish normal hepatic tissue perfusion [9]. Gunshot liver injuries have a high risk of

Table 1 The frequency of each operative procedure with its outcomes

Grade	Operative procedure	No	Shock	Morbidity	Re-operation	Mortality
I	Electrosurgical hemostasis	2	1 (Septic shock)	0	0	0
II	Electrosurgical hemostasis	1	1	0	0	0
	Hemostasis agent	2	2	1	0	0
	Liver tissue primary repair	6	5	2	1	0
	Direct blood vessel ligation and liver tissue primary repair	1	1	0	0	0
III	Hemostasis agent	2	2	1	0	0
	Liver tissue primary repair	19	14	5	1	1
	Direct blood vessel ligation and liver tissue primary repair	11	11	8	1	2
	Damage control surgery with perihepatic packing	2	2	1	2	0
IV	Direct blood vessel ligation and liver tissue primary repair	3	3	1	0	1
	Non-anatomical liver resection with necrotic tissue debridement	1	1	1	0	0
	Damage control surgery with perihepatic packing	15	15	13	13	6
V	Damage control surgery with perihepatic packing	4	4	3	2	2
	Non-anatomical liver resection with necrotic tissue debridement	2	2	2	0	2
Total		71	64	38	20	14

concomitant adjacent organ-associated injuries that may present in about 80% of patients. Some international studies of hepatic injury have reported that chest trauma was the most common associated injury, especially pulmonary contusion, and rib fracture, while splenic injury was the most common associated abdominal injury. However, in penetrating chest injury, the liver is the most common abdominal organ involved [10]. In our cases, 79% of patients had multiple organ injuries. The colon was the most frequently injured organ in association with liver injury. Because of its dual blood supply, gunshot liver injuries are associated with significant bleeding which is the main cause of high rates of morbidity and mortality. Therefore, the primary management strategy includes interventions and procedures aimed at controlling hepatic hemorrhage. In general, the management of liver injuries has dramatically transformed during the past three decades in the case of blunt as well as penetrating injury; it has shifted from the operative to selective non-operative management [11]. The main goal of all interventional techniques in case of gunshot liver injury is bleeding control and to conserve liver tissue as much as possible, irrespective of the grade and severity of the injury.

Despite this transformed and evidence-based approach, urgent surgical exploration is still considered the treatment of choice for hemodynamically unstable patients. The urgent surgical exploration of liver injuries can be a challenge even for experienced trauma surgeons because of its anatomical feature and dual blood supply; some studies have reported that about 14% of liver injured patients need urgent surgical exploration [12, 13]. The type of surgical technique for control of hepatic bleeding depends upon the grade of injury. In superficial liver lacerations grade, I–II in a hemodynamically stable patient with normal tissue perfusion and temperature, control of bleeding may be performed with simple techniques such as compression, topical hemostatic agents, and electrosurgical hemostasis techniques, and Argon beam coagulation can be used to control mild bleeding from the raw liver surface, all are often used together for proper bleeding control [14]. In the case of deep hepatic tissue lacerations, as in the grade III with sizeable bleeding vessels, the direct ligation of the vessels and biliary ducts has been advocated as the best hemostatic method [15]. This technique becomes more feasible with repeated application of the Pringle maneuver, once the visible vessels and bile ducts have been controlled; further hemostasis can be achieved with the application of topical hemostatic agents and electrosurgical hemostasis of the liver parenchyma. The main aim is to control ongoing hepatic raw area oozing. Some literature has reported that the deep hepatic tear, when covered with omental packing, may result in a lower incidence of ischemic and septic complications [16]. When the active bleeding is apparent from within a deep central missile tract through the liver, and the overlying liver substance is intact, a balloon tamponade technique can be used; some studies have concluded that trauma surgeons must be prepared to use intrahepatic balloon tamponade as one of the surgical techniques to control bleeding in selected patients with major hepatic injuries [17]. In case of severe liver injuries, we require more aggressive techniques for controlling the bleeding. In grade IV and V injury, the anatomical and non-anatomical liver resection and debridement of the ischemic liver tissue may offer an effective option for bleeding control with a significant rate of morbidity and mortality [18]. Damage control laparotomy was first described by Dr. Harlan Stone in 1983, while the term damage control in the trauma setting was coined by Rotondo et al. in 1993 [19]. It is considered a technique for the surgical management of

Table 2 Type of postoperative complication and mortality

No of cases	Postoperative complications	Mortality
A. Liver-related complication		
7	Hepatic bleeding	Intraoperative
1	Hepatic bleeding	Postoperative
4	Biliary leak	No
1	Biliary leak, hypoalbuminemia, postoperative ileus, burst abdomen, and incisional hernia	No
1	Liver abscess and septicemia	Postoperative
B. Associated injury-related complication		
3	Extra hepatic bleeding	Intraoperative
1	Colonic leak, septicemia, and wound infection	No
1	Pancreatic fistula	No
1	Gastric fistula (missed injury)	No
1	Gangrenous colon	No
1	Missed gauze and intra-abdominal abscess and wound infection	No
C. Surgical site-related complication		
4	Wound infection	No
4	Wound infection and incisional hernia	No
5	Incisional hernia	No
D. Organ failure-related complication		
1	Aspiration pneumonia and acute renal failure	Postoperative
1	Pneumonia and septicemia	No
1	Pulmonary embolism	Postoperative
Total 38		Total 14

severely unstable patients due to penetrating abdominal trauma. The principle is to minimize further surgical procedures to severely shocked patients in aim to prevent the development of metabolic acidosis, hypothermia, and coagulopathy. Perihepatic packing has become a part of damage control surgery for unstable patients in the case of complex liver tissue injuries with massive bleeding, which is needed in 16–19% of cases [20]. It provides a tamponade for bleeding control and offering a short operative time for adequate and proper resuscitation to the patient in the intensive care unit, followed by second-look laparotomy for re-assessment of the hemostasis, and removed of the intra-abdominal pack with around 48 h [20]; it led to lower rates of re-bleeding and reduce mortality [21].

In the last two decades, due to the advent of improved imaging technologies, advances in intensive care unit services, and the ability reach to a more accurate diagnosis, treatment of liver injuries has shifted to non-operative management techniques with angioembolization. Many international works of literature have evaluated this method and have concluded it to be a safe and effective strategy for the selected patients [22]. Therefore, recently many specialized trauma centers have adopted non-operative management of liver injuries as standard care for hemodynamically stable patients [23]. Liver-related complications of surgical management of gunshot liver injuries occur in significant incidence. Hepatic bleeding was the most frequent complication followed by the biliary leak and hepatic abscess with septicemia in our cases. Some previous studies have reported that the persistent bile leak with the formation of Biloma can occur with ranges from 0.5 to 21% [24]. Perihepatic abscess due to secondary bacterial infection of postoperative hematoma also occurs at a significant rate [25]. Hepatic necrosis commonly occurs following angioembolization for hepatic injury; it may also be seen following laparotomy [26]. In our study, there was a significant statistical difference between liver injury grade and postoperative complications ($P = 0.012$). Therefore, we concluded that the postoperative complication rates for hepatic injury are directly related to the grade of the liver injury, which was also confirmed in some previous international literature [27]. Some other international studies have concluded that the predictive factors for mortality in liver injuries are related to severe bleeding, blood transfused, hypothermia, acidosis, and dysrhythmia [28]. Mortality rates for hepatic injury have improved with the use of perihepatic packing and introduction of non-operative management strategies; it also directly related to the grade of the injury [29]. In our study, we have confirmed that the mortality rates for hepatic injury operations are directly related to the grade of the liver injury, whereas a significant statistical difference between liver injury grade and the mortality rate ($P = 0.009$). Due to the high volume of the energy and explosive gun particles, gunshot injuries can produce damage not only in the target organ but in the

neighboring organs as well; for this reason, it is difficult to predict the possible complications in patients. Therefore, gunshot abdominal wounds can be considered a multi-organ injury, and we cannot ignore the effect of associated organ injuries in the patients' outcomes. As in our study, 79% of gunshot liver injured patients had an associated organ injury, 7% of them had postoperative complications, and 4.2% of patients deceased. The international literature reveals the morbidity and mortality rate from penetrating abdominal trauma depending on how many other organs are involved. In gunshot abdominal injuries, it has been found that the presence of colon injuries has led to an increase in both morbidity and mortality rate [30].

Conclusion

Despite the acceptance of selective non-operative management like hepatic angioembolization with its high success rate, expeditious exploratory laparotomy still has an effective role in the treatment of gunshot wounds of the liver with advanced grade penetrating injuries with acceptable morbidity and mortality.

Acknowledgments The authors would like to thank the Radiology Department and Biostatistics Department, Al-Jalaa Teaching Hospital, Benghazi University, for their assistance in this research.

Data Availability The data used to support the findings of this study are restricted by the Biostatistics Department of Benghazi University, maintained by the Benghazi University Network of Trauma and acute care. Data are available from the Benghazi University Network for researchers who meet the criteria for access to confidential data.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval This study was performed in line with the principles of the Declaration of Helsinki and its later amendments or comparable ethical standards. And the study was approved by the Ethics Committee of Al-Jalaa Teaching Hospital and Benghazi University Institutional Review Board (IRB).

Informed Consent Since the hospital is a teaching university hospital, written informed consent to participate in the study was routinely signed and obtained from all admitted patients or legally authorized representatives during the hospital stay and before the studies, for all research to use patient's data including images that were taken to be published in academic activities and researches.

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