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ORIGINAL ARTICLE

EVALUATION OF MANAGEMENT OPTIONS FOR TRAUMATIC LIVER INJURIES

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Abstract

Introduction: Hepatic trauma represents a significant management challenge that requires a high index of suspicion, rapid investigation, accurate classification and well-defined management protocols.

Aim of the work: The purpose of this work is to review 0ur experience of blunt or penetrating injuries regarding the available diagnostic modalities and current management options.

Methods: This is a retrospective study included 42 consecutive patients with hepatic trauma. Patients with associated major extra-abdominal injury were excluded from the study. After aggressive initial resuscitation; all patients were subjected to full clinical examination, routine blood investigations, Plain x-rays film evaluation of the abdomen and chest, ultrasound abdomen focused for trauma and computed tomography (CT) of the abdomen / pelvis after the patients became hemodynamically stable.

Results: 32 patients with blunt liver injuries, conservative - non operative - management was done in 23 of them. Complications (five patients) were delayed hemorrhage (two cases), perihepatic abscess (one case), and biloma (two cases). The remaining 9 patients had (laparotomy and proceed). 10 patients with penetrating liver injuries, four of them were treated conservatively- non-operatively without complications. The remaining 6 patients had (laparotomy and proceed).

Conclusion: Non-operative management (NOM) of liver injury has generally become feasible treatment. The primary focus for the surgeon should be the selection of appropriate patient and early recognition of liver injury and surgical intervention when such conservative management fails.

Keywords: Liver trauma, injury severity score, non-operative management, outcome, treatment failure.

INTRODUCTION

The liver is the second most frequently injured intra-abdominal organ following either blunt or penetrating trauma. Hepatic trauma represents a significant management challenge that requires a high index of suspicion, rapid investigation, accurate classification and well-defined management protocols. The majority of these patients could be successfully treated with non-operative management (NOM), but surgeons should have a clear understanding of the indications for operative intervention.[1-3] Computed tomography (CT) scanning has revolutionized the treatment algorithm for hepatic trauma. CT-based grading system has been

adopted by the American Association for the Surgery of Trauma (AAST) for classification of blunt hepatic injury. CT classification, although reflective of the extent of parenchymal liver damage, cannot reliably predict the clinical outcome of attempted non-surgical management.[4-5]

There was a marked decline in liver-related death rates deaths to 5% from penetrating injuries and 2% from blunt injury. Deaths related to the liver injury itself were due to hemorrhage in more than 85%. Improvement in death rates clearly resulted from a decrease in deaths from hemorrhage.[6] Remarkable advances in ICU and in critical care surgery as well as the experience in hepatobiliary surgery decreased the rate of death. It is believed that the main points in the management of severe liver injuries should include the rapid control of bleeding from the liver together with aggressive resuscitation, definitive surgical procedures, dealing with associated organ injuries and supportive postoperative care.[7-8]

Aim of work: The purpose of this work is to review 0ur experience of liver injuries regarding the available diagnostic modalities and current management options.

PATIENTS AND METHODS

This is a retrospective study included 42 consecutive patients with hepatic trauma that presented at the causality unit of Kasr EL Eini Hospital from October 2008 to October 2009. After initial aggressive resuscitation; all patients were subjected to full history taking with emphasis on the mechanism of traumatic injury and a clinical examination. Routine blood investigations, Plain x-rays film evaluation of the abdomen and chest, ultrasound abdomen focused for trauma and computed tomography (CT) of the abdomen/pelvis after the patients became hemodynamically stable. Patients with associated major extra-abdominal were excluded from the study.

Ultrasonography examination (US) has been used for detecting intra-peritoneal fluid which accumulates in four acoustic windows pericardial, peri-hepatic, peri-splenic, and pelvic – the four P's of patients in the supine position, based on the assumption that all clinically significant abdominal injuries are associated with hemoperitoneum. The hemodynamically stable patient with a "positive" ultrasound then undergoes a spiral CT of the abdomen to document the presence and magnitude of injuries to the liver and other intra-abdominal viscera. Diagnostic peritoneal lavage was not performed except in instances where the urgency of the patient's condition precluded it and diagnostic laparotomy was carried out.

The liver injuries were classified according to American Association for the Surgery of Trauma (AAST).[9] It incorporates both preoperative CT scanning in liver injuries and intraoperative assessment of the extent of hepatic injury Table 1.

Table 1. American Association for the Surgery of Trauma (AAST) classification system Liver trauma.[9]

Grade I	Subcapsular hematoma< 10% surface area or laceration as a capsular tear < 1 cm parenchymal depth.
Grade II	Subcapsular hematoma 10–50% surface area, intraparenchymal hematoma- < 10 cm in diameter or laceration1–3 cm parenchymal depth, < 10 cm in length.
Grade III	Subcapsular hematoma> 50% surface area or expanding, ruptured sub-capsular or parenchymal hematoma or intraparenchymal, > 10 cm or expanding or > 3 cm parenchymal depth laceration
Grade IV	Parenchymal disruption involving 25-75% of hepatic lobe or 1-3 Couinaud's segments within a single lobe.
Grade V	Parenchymal disruption involving 75% of hepatic lobe or > 3 Couinaud's segments within a single lobe or vascular Juxtahepatic venous injuries (i.e. Retro hepatic vena cava/ central major hepatic veins).
Grade VI	Vascular hepatic avulsion.

The criteria for conservative management were blunt trauma to the abdomen without history of loss of consciousness, hemodynamic stability and/or achievement of hemodynamic stability with modest amount of I/V fluids and unsuspected associated injuries or signs of peritoneal irritation. The patients managed conservatively were observed closely in the ICU.

Criteria for discontinuing conservative management were hemodynamic instability, decreasing hemoglobin percentage attributable to the injury; despite transfusion of up to 2 units of packed red blood cells in 24 hours and/or physical signs of an acute abdomen.

Criteria for immediate laparotomy were hemodynamic instability on presentation, recurrence of instability after initial stabilization, signs of peritoneal irritation on physical examination, concomitant intra-abdominal injuries that required surgical intervention and/or penetrating injuries.

Hemodynamically unstable patients were defined with systolic arterial blood pressure lower than 90mmHg on admission in the emergency department who were unresponsive to fluid resuscitation with fast infusion of 2 liters of crystalloid solution and those who, after initial

stabilization, presented with systolic arterial blood pressure lower than 90mmHg.

At laparotomy one or more of the following procedures were done; suture hepatorraphy in clear cut injuries, non-anatomical resection and peri-hepatic packing.

The mode of management whether conservative or surgical, the type of surgery and complications, outpatient follow-up by clinical evaluation and CT of the abdomen at 8–12 weeks after injury were documented and analysed.

RESULTS

Patients included in the study were thirty-one males and eleven females. Their Mean age for males was 28.6; (range 15 to 57 years), and for females was 31.6 (range 9 to 61years). Thirty-two had blunt abdominal trauma and ten had penetrating abdominal trauma. The causes of blunt hepatic trauma were :(24) road traffic accidents, (6) falls from height, and (2) violence induced blunt trauma. Causes of penetrating liver trauma included (4) gunshot wounds, (4) stab wounds, and iatrogenic injuries inflicted by biopsy puncture in one and transhepatic percutaneous cholangiography in one patient.

Among (32) patients with blunt abdominal trauma; twelve were hemodynamically stable on arrival, with initial intention to treat non-operatively yet, two patients of them underwent explorative laparotomy after 24 and 36 hours. The remaining twenty patients were hemodynamically unstable and eight of them were in hemorrhagic shock at the time of arrival. After resuscitation, fourteen of them became hemodynamically stable with initial intention to treat non-operatively yet; seven patients who displayed hemodynamic instability with either the suspicion of associated injuries and/or clinical deterioration were treated surgically within 12-24hours. Thus, a total of nine were subjected to surgical treatment. Associated intra-abdominal injuries were present in six patients and splenic injury was the most common (five patients) Table 2. While, twenty-three of patients with blunt abdominal trauma had their non-operative management continued till hospital discharge. Plain x-rays film evaluation of the abdomen and chest and ultrasound abdomen focused for trauma could be performed for all patients while, abdominal computed tomography could be performed for twenty-six of patients [AAST classification, (13) Grade I and II, (11) grade III ,(1) grade IV, and (1) grade V]. Most liver injuries (22 cases=85%) involve segments 6, 7, and 8 of the liver. Thus; Conservative management was done in all grades I, II (thirteen cases), grade III (nine cases) and grade IV (one case) blunt liver injuries. Complications in the form; delayed hemorrhage (two cases), peri-hepatic abscess (one case) and biloma (two cases) (table 3). Direct control of bleeding vessels within the liver by the Pringle maneuver and suture hepatorraphy in three cases (Fig. 1). Surgical treatment involved damage control techniques in the form of; resection-debridement, selective hepatic artery ligation and omentum packing of the laceration with (two cases) and peri-hepatic packing in four patients were performed. These post-operative complications included hemorrhage (one case), peri-hepatic abscess (one case) and biloma (two cases). Table 4.

Among patients with penetrating abdominal trauma; four were hemodynamically stable with localized pain and tenderness around the wound on arrival (stab wounds, two and iatrogenic injuries, two patients).

Abdominal computed tomography could be performed for all of them (AAST classification were grades I and II two cases, grade III two cases. The initial intention was to treat them non-operatively. All patients had management continued till hospital discharge without complications. Six patients were hemodynamically unstable and two were in hemorrhagic shock underwent urgent explorative laparotomy after resuscitation (stab wound, two and gunshot wound, four patients). Abdominal computed tomography could be performed for two patients [AAST classification, (1) grade III and (1) grade IV]. Surgical management treatment involved suture hepatorraphy in three cases, resection-debridement in one cases (Fig. 2) and peri-hepatic packing in two cases were performed. Associated injuries found on explorative laparotomy were small bowel injury (three), right hemi diaphragm with hemothorax (two) and both injuries (one) of the cases Table 2. Post-operative complications were hepatic abscess (one case), and biloma (two cases). Table 4.

Morbidity and mortality of non-operative treatment (NOM); There was no mortality in patients in whom NOM was applied in this study. Morbidity of NOM involved five complications (18.5%) of the twenty-seven (23 blunt and4 penetrating hepatic trauma). They included delayed hemorrhage (two cases), peri-hepatic abscess (one), and biloma (two) cases. Delayed hemorrhage was suspected in patients with a drop in hemoglobin level and pain arising in the right side of the abdomen. Increased parenchymal or subcapsular hematoma was demonstrated on serial follow-up CT scans. Clinical manifestations of other complications were abdominal pain and tenderness, fever, and leukocytosis. At follow-up CT, appeared as a low-attenuation area with an air-fluid level peri-hepatic space in a case with a peri-hepatic abscess and a well-circumscribed, low-attenuation intraparenchymal collection suggested the diagnosis of biloma in other two cases. US-guided percutaneous drainage was performed for them (Fig. 3).

Of 15 patients with operative management, post-operative complications involved hemorrhage (one case), peri-hepatic abscess (two cases), and biloma (four cases) of patients with blunt (9 patients) and penetrating (6patients) hepatic trauma (46.6. %). One patient with severe grade IV liver injury (fig. 4) died because of post-operative hemorrhage with an overall mortality rate 6.6%.

Table 2. Data of patients with traumatic liver injuries.

	Blunt hepatic trauma N=32	Penetrating liver trauma N=10
AAST classification		
Grade I,II	18	*4*
Grade III	11	*3*
Grade IV	2	*2*
Grade V	1	*1*
Grade VI	0	*0*
Admission vital signs		
Stable	12	*4*
Unstable	20	*6*
Associated injuries		
Splenic injury	5	*0*
Right hemothorax	1	*2*
Small bowel injury	0	*2*
Right hemothorax+ Small bowel injury	0	*1*
Management		
Non-operative	23	*4*
Surgical treatment	9	*6*
Complications		
Non-operative	*5*	*0*
Surgical treatment	*3*	*4*

Table 3. Non-operative treatment outcome.

	Blunt hepatic trauma N=23	Penetrating liver trauma N=4
Average Blood transfusion (units)	5 ± 2	6 ± 3
Hospital stay (days)		
ICU	4 ±2	4 ±1
Surgical ward	12 ± 9	16 ± 7
Abdominal complications		
delayed hemorrhage	2	0
peri-hepatic abscess	1	0
biloma	2	0
Mortality	0	0

Table 4. Surgical treatment.

	Blunt hepatic trauma N=9	Penetrating liver trauma N=6
Surgical intervention		
Suture alone	3	3
Resection -debridement	2	1
Packing alone	4	2
Combination of methods above	0	0
Drains		
with	2	0
without	7	2
Abdominal complications		
Post-operative hemorrhage	1	0
peri-hepatic abscess	1	1
biloma	2	2
Mortality	1	0

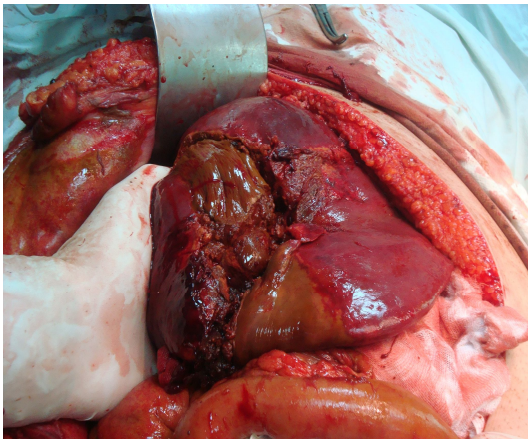

Fig 1. Exploration was done revealing shuttered liver with necrotic tissues. Non anatomical resection was done for the shuttered part of the Rt. lobe of the liver.

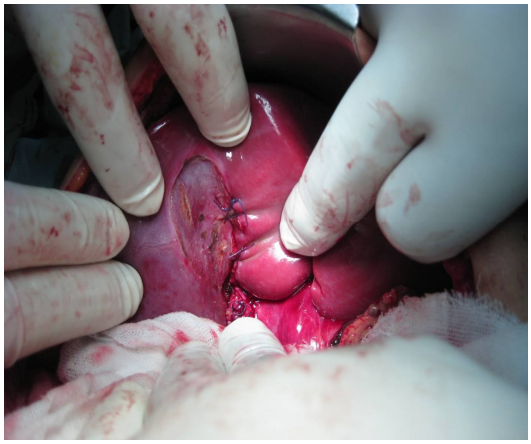

Fig 2. Exploration was done revealing liver tear on the inferior surface of the liver close to the gall bladder. Cholecystectomy was done, suture hepatorraphy was done for the liver tear.

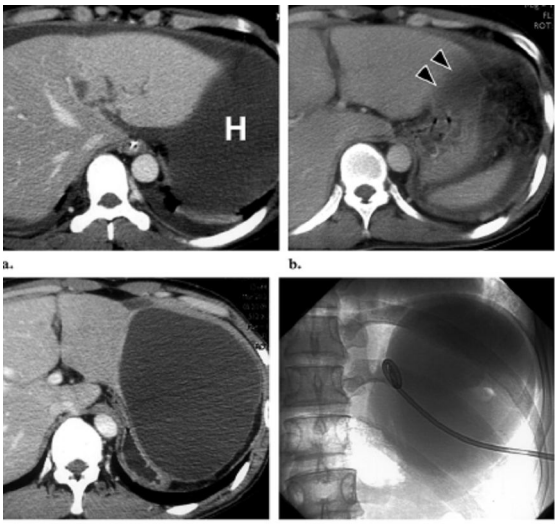

Fig 3. Biloma. (a) Initial contrast-enhanced CT scan shows lacerations in the left hepatic lobe. Note the extensive hemoperitoneum (H). (b) Follow-up contrast-enhanced CT scan obtained 1 week later reveals complete resolution of parenchymal injury. A small amount of hemoperitoneum persists in the left perihepatic space (arrowheads). The patient presented with fever and left upper quadrant pain 2 weeks after blunt liver trauma. (c) Follow-up contrast-enhanced CT scan reveals a large cystic lesion that had developed in the left upper abdominal cavity. (d) Radiograph obtained during percutaneous catheter drainage which reveals a noninfected bile collection.

Fig 4. Grade IV hepatic injury. Contrast-enhanced CT scan of the died patient shows a ruptured intraparenchymal hematoma with active bleeding in the right hepatic lobe and the associated large hemoperitoneum.

DISCUSSION

Non operative management (NOM) of liver injury has generally become the most frequent treatment. Current rates of success for NOM for blunt hepatic trauma of selected patients have been reported to be safe and efficient.[10-13] However, the trauma surgeon should be available to monitor the progress of the patient and intervention if the non-operative protocol fails. Alert Patients with persistent hemodynamic stability are ideal candidates for NOM. The Use of NOM should be exercised with caution if blood transfusion is needed, or a significant quantity of blood or fluid collection is identified on the screening ultrasonogram or CT.[14]

52.4% of our patients had grade I, II liver injury (blunt 18, penetrating 4), 33.3% had grade III (blunt 11, penetrating 3), 9.5% had grade IV (blunt 2, penetrating 2) and 4.8% of our patients had grade V (blunt 1, penetrating 1). These figures are different from other studies. A study performed on 133 patients revealed that, Patients were graded according to the severity of their liver injury as follows: 21% of patients had grade I, 37.6% of patients had grade II, 25.6% of patients had grade III, 13.5% of patients had grade IV, and 1.5% of patients had grade V. The results are different from our study because of smaller number of patients included in our study.[15]

The reported prevalence of complications during non-surgical management of blunt liver trauma ranges from 5% to 23%.[16-18] Morbidity of NOM in the patients with blunt or penetrating hepatic trauma that was found in our study involved five complications (18.5%). A carefully performed physical examination remains the most important method to determine the need for exploratory laparotomy. During the present study, which covers 12 months, we received 42 patients, 76% presented with blunt trauma while 24% presented with penetrating trauma. Similar results were found in other studies. One study which was performed on 375 patients, 71% of patients presented with blunt trauma while 29% presented with penetrating trauma.[19] The role of diagnostic peritoneal lavage (DPL) in the assessment of patients sustaining blunt abdominal trauma has been markedly diminished by the development of Ultrasonography and advanced CT scanning. In our study, CT was the main modality of diagnosis for stable patients in whom NOM was selected. However focused assessment with sonography for trauma (FAST) is the main modality of diagnosis of unstable patient with blunt trauma. This is matched with other studies. A study performed on 68 patients revealed that, CT scan with oral and intra-venous contrast were the main tools for evaluating the abdomen in haemodynamically stable patients, while FAST were done for the haemodynamically unstable patients.[20]

Surgeons should not determine on the basis of CT criteria alone whether to operate or to manage non-surgically, since even high-grade injuries may often respond favorably to conservative treatment. It has been suggested that the best predictor of the need for surgical intervention in patients with blunt liver trauma is the loss of hemodynamic stability, not the severity of injury as determined with CT.[21] The signs of failure of NOM involved a decreased hematocrit in combination with hemodynamic instability in the first 48 hours of observation; especially in the absence of orthopedic injuries, manifestations of peritoneal irritation and

expansion of subcapsular or intra-hepatic hematoma on a follow up CT. Non-operative management of liver trauma is feasible and safe in centers with a low trauma incidence because the treatment of patients with extensive liver injuries has been recommended to be reserved to specialized canters where liver surgery can readily be performed in case of 'failure' of NOM.

Alternatively, if NOM is failing in a small volume centre, damage control may be performed before referral to a specialized centre for further treatment.[11-17] Most of the local complications following non-operative management of liver injuries, such as biloma, or abscesses, can be managed with percutaneous drainage or endoscopic stenting of bile duct injuries.

Six cases were identified in our series as requiring liver packing. In all cases, this method was efficient, with no postoperative bleeding except one case. In the same time, there were specific complications such as bile leak or abdominal collections. Despite a second procedure for packs removal and the possibility for specific complications, liver packing is an efficient method for severe liver trauma or complex abdominal lesions.[22-23]

Selective NOM of stab wounds and shot gun wounds to the abdomen have become the standard treatment in the U.S.A and is evolving in Europe. However, judicious selection of patients suitable for NOM after penetrating injuries is more challenging. Requirements are: hemodynamically stable patient, awake and cooperating, with pain located exclusively around the wound. Serial (hourly), physical examination has the best sensitivity and negative predictive value of all modalities for the evaluation of penetrating abdominal trauma.[24-26] In our study, ten patients with penetrating liver injuries, four of them were hemodynamic stable so NOM was carried out for them. A study performed on 152 patients with penetrating liver trauma revealed that, 125 patients (82.2%) were operated upon due to haemodynamically instability and 27 patients (17.8%) were treated with NOM due to haemodynamic stability, all these patients were evaluated with serial physical examination and CT scan.[27] These studies support the fact that, NOM of the selected cases of penetrating liver trauma is safe especially if the patient was haemodynamically stable.

The optimal time frame for follow-up CT in patients with high-grade injuries appears to be between 7 and 10 days from the original injury. The physiologic characteristics of hepatic repair after blunt injury progress in a predictable fashion, resulting in virtually complete restoration of hepatic integrity at the end of 3 months. Follow-up CT can document the tissue healing process: The healing time increased along with the grade of liver injury.[28]

In conclusion Non operative management (NOM) of both blunt and penetrating liver injury has generally become feasible treatment. The primary focus for the surgeon should be the selection of appropriate patient and early recognition and surgical intervention when such management fails. Immediate assessment with ultrasound has replaced diagnostic peritoneal lavage in the resuscitation room, but computerized tomography remains the gold standard investigation.

REFERENCES

1. Chiara O, Cimbanassi S, Bini R, Pavesi L, Rampoldi A, Colombo F, Sansonna F.. Nonoperative management of traumatic liver injuries. Ann Ital Chir. 2005;76:161-5.

2. Badger SA, Barclay R, Campbell P, Mole DJ, Diamond T. Management of liver trauma. World J Surg. 2009;33:2522-37.

3. Van Vugt R, Bosscha K, Olsman J, Jager GJ, de Jager CP. Management of hepatic trauma: a 9-year experience in 's-Hertogenbosch. Acta Chir Belg. 2009;109:42-6.

4. Yoon W, Jeong YY, Kim JK, Seo JJ, Lim HS, Shin SS. CT in blunt liver trauma. Radiographics. 2005;25:87-104.

5. Sánchez-Bueno F, Fernández-Carrión J, Torres Salmerón G, García Pérez R, Ramírez Romero P. Changes in the diagnosis and therapeutic management of hepatic trauma. A retrospective study comparing 2 series of cases in different (1997-1984 vs. 2001-2008). Cir Esp. 2011;89:439-47.

6. Saltzherr TP, van der Vlies CH, van Lienden KP, Beenen LF, Ponsen KJ. Improved outcomes in the non-operative management of liver injuries. HPB (Oxford). 2011;13:350-5.

7. Parks RW, Chrysos E, Diamond T. Management of liver trauma. Br J Surg. 1999;86:1121-35.

8. Karamarkovi AR, Doklestić K, Djukić VR, Stefanović BD, Radenković DV, Gregorić PD, Liver injuries. Acta Chir Iugosl. 2010;57:57-67.

9. Moore EE, Burch JM and Franciose RJ. Staged physiologic restoration and damage control surgery. World J Surg. 1995;42:78- 81.

10. Markogiannakis H, Sanidas E, Michalakis I, Manouras A, Melissas J, Tsiftsis D. Predictive factors of operative or nonoperative management of blunt hepatic trauma. Minerva Chir. 2008;63:223-8.

11. Norrman G, Tingstedt B, Ekelund M, Andersson R. Non-operative management of blunt liver trauma: feasible and safe also in centres with a low trauma incidence. HPB (Oxford). 2009;11:50-6.

12. Hashemzadeh SH, Hashemzadeh KH, Dehdilani M, Rezaei S. Non-operative management of blunt trauma in abdominal solid organ injuries: a prospective study to evaluate the success rate and predictive factors of failure. Minerva Chir. 2010;65:267-74.

13. Velmahos GC, Toutouzas K, Radin R, Chan L, Rhee P, Tillou A, et al. High success with nonoperative management of blunt hepatic trauma: the liver is a sturdy organ. Arch Surg. 2003;138:475–80.

14. Feliciano DV, Rozycki GS. Hepatic trauma. Scand J Surg. 2002;91:72-9.

15. Helling TS, Ward MR and Balon J. Is the grading of liver injuries a useful clinical tool in the initial management of blunt trauma patients? European Journal of Trauma and Emergency Surgery. 2009;35:95–101.

16. Kozar RA, Moore JB, Niles SE, Holcomb JB, Moore EE, Cothren CC, et al.. Complications of nonoperative management of high-grade blunt hepatic injuries. J Trauma. 2005;59:1066-71.

17. Poletti PA, Mirvis SE, Shanmuganathan K, Killeen KL, Coldwell D. CT criteria for management of blunt liver trauma: correlation with angiographic and surgical findings. Radiology. 2000;216:418-27.

18. Christmas AB, Wilson AK, Manning B, Franklin GA, Miller FB, Richardson JD, et al. Selective management of blunt hepatic injuries including nonoperative management is a safe and effective strategy. Surgery. 2005;138:606–611.

19. Gakwaya A M. Blunt Liver Trauma in Mulago Hospital. East and Central African Journal of Surgery. 2004;9:85- 88.

20. Bismar HA, Alam MK, Al-Keely MH, Al Salamah SM and Mohammed A. Outcome of nonoperative management of blunl liver trauma. Saudi Med J. 2004;25:294-329.

21. Fang J, Chen R, Wong Y, Lin B, Hsu Y, Kao J, et al. Pooling of contrast material on computed tomography mandates aggressive management of blunt hepatic injury. Am. J Surg. 1998;176:315–19.

22. Mazilu O, Cnejevici S, Stef D, Istodor A, Dabelea C, Fluture V. Hepatic hemostasis with packing in complex abdominal traumatic lesions: indications and postoperative outcomes. Chirurgia (Bucur). 2009;104:715-8.

23. Allard MA, Dondero F, Sommacale D, Dokmak S, Belghiti J, Farges O. Liver packing during elective surgery: an option that can be considered. World J Surg. 2011; 35:2493-8.

24. Como JJ, Bokhari F, Chiu WC, Duane TM, Holevar MR, Tandoh MA, et al. Practice management guidelines for selective nonoperative management of penetrating abdominal trauma. J Trauma. 2010;68:721-33.

25. Beekley AC, Blackbourne LH, Sebesta JA, McMullin N, Mullenix PS, Holcomb JB; 31st Combat Support Hospital Research Group. Selective nonoperative management of penetrating torso injury from combat fragmentation wounds. J Trauma. 2008;64:S108-16.

26. Inaba K, Demetriades D. The nonoperative management of penetrating abdominal trauma. Adv Surg. 2007;41:51-62.

27. Demetriades D, Hadjizacharia P, Constantinou C, Brown C, Inaba K, et al. Selective nonoperative management of penetrating abdominal solid organ injuries. Ann Surg. 2006;244:620-8.

28. Pryor JP, Reilly PM, Dabrowski GP, Grossman MD, Schwab CW. Nonoperative management of abdominal gunshot wounds. Ann Emerg Med. 2004;43:344-53.