Alexandria Journal of Medicine (2013) 49, 223–227

Alexandria University Faculty of Medicine

Alexandria Journal of Medicine

www.sciencedirect.com

ORIGINAL ARTICLE

The role of non-operative management (NOM) in blunt hepatic trauma

Ayman Zaki Azzam *, Abdel Hamid Gazal, Mohammed I. Kassem, Magdy A. Souror

General Surgery Department, Faculty of Medicine, Alexandria, Egypt

Received 20 July 2012; accepted 21 October 2012
Available online 10 January 2013

KEYWORDS

Blunt liver trauma;
Non operative management;
Failure of non operative management

Abstract *Background:* NOM in blunt hepatic trauma is the preferred treatment in otherwise stable patients.
Aim: To evaluate the role of NOM in blunt hepatic trauma, avoiding unnecessary surgery.
Methods and patients: Forty-four patients who presented with blunt hepatic trauma were admitted to the Emergency Unit. The patients were evaluated clinically. Abdominal computerized tomography was done to all hemodynamically stable patients and who were stabilized by the initial resuscitation. Staging of liver injury was done according to the scoring of the American Association for the Surgery of Trauma (AAST). Initially, all patients were treated conservatively and the patients who needed laparotomy later were considered as failure of NOM. Liver injuries due to penetrating causes were excluded. An informed consent was taken from each patient.
Results: Blunt trauma was the mechanism of injury in 44 patients (60.2%) including road traffic accidents in 42.5%. The peak age was between 20 and 30 years. The male to female ratio was 10:1. The majority of patients have multiple injuries with 10% having isolated liver injury. Thirty-six patients (82%) had one or more associated extra-abdominal injuries. Surgery was indicated in 14 patients (32%). The mean admission systolic pressure was lower in the NOM failure group (90 vs. 122 mmHg with $p < 0.04$). Complications occurred more in the operative group, chest infection occurred in 21.4% with a p value of 0.001, hyperpyrexia occurred in 21.4% with a p value of 0.001, and wound infection in 14.2% with a p value of 0.025. Mortality occurred in 7 patients. The cause of death in patients with blunt hepatic trauma was liver related in 2 patients due to hemorrhage and DIC.
Conclusion: NOM in blunt hepatic trauma is the preferred treatment in otherwise stable patients. The factors that can suspect failure of NOM were the development of hemodynamic instability or the presence of associated injury that mandates immediate exploration.

* Corresponding author.
E-mail address: aazzam70@yahoo.com (A.Z. Azzam).
Peer review under responsibility of Alexandria University Faculty of Medicine.

ELSEVIER Production and hosting by Elsevier

1. Introduction

The prevalence of blunt liver injury has increased during the past 3 decades.[1] In spite of it being protected, it is the second most frequently injured organ following blunt liver trauma.[2] Associated injuries of other organs, uncontrolled hemorrhage and the development of sepsis contribute to the morbidity

2090-5068 © 2012 Production and hosting by Elsevier B.V. on behalf of Alexandria University Faculty of Medicine.
http://dx.doi.org/10.1016/j.ajme.2012.10.003

and mortality after liver injuries.[3] Management of hepatic injuries has evolved over the past 30 years. Prior to that time, a diagnostic peritoneal lavage positive for blood, was an indication of exploratory laparotomy because of the concern of the ongoing hemorrhage, and/or missed intra-abdominal injuries needing repair. Non-operative management in blunt hepatic trauma has become the standard of care in hemodynamically stable patients. About 80% of bleeding after liver injuries has stopped bleeding by the time of laparotomy.[4]

1.1. Objective

The aim is to evaluate the safety of non-operative management in hemodynamically stable patients after blunt hepatic trauma.

2. Methods and patients

During the period of study (1 year), from first of June 2008 to 31st of May 2009, 243 patients with abdominal trauma were admitted to the Emergency Unit, General Surgery Department, Alexandria University, Alexandria, Egypt. Forty-four patients presented with different grades of liver injuries after blunt trauma. All patient data were collected including demographics, mechanism of injury, associated injuries, grade of liver injury, blood products received, total length of stay days in the intensive care unit, complications and mortality. The patients were evaluated clinically. Plain radiography of the spine, chest and pelvis was done to all patients. Abdominal computerized tomography (CT scan) was done to all hemodynamically stable patients and the patients who were stabilized by the initial resuscitation. Patients with multiple injuries, such as head and chest trauma, had appropriate additional studies. CT scans were reviewed and the liver injuries were graded according to the new scoring system revised by the American Association for the Surgery of Trauma (AAST) in 1995.[5] Initially, all patients were treated with NOM. NOM required strict bed rest, close observation, continuous monitoring of hemoglobin and hematocrit and periodic CT of the abdomen. The patients who needed laparotomy later were considered as failure of NOM. The aim of operative management is to control the bleeding and bile leak, remove devitalized tissue, repair visceral injuries and to provide adequate drainage of the abdomen, thus reducing the incidence of infection. The amount of fluid collected was named small (< 250 cc, or 1–2 intra-abdominal spaces), moderate (250–500 cc or 2–4 intra-abdominal spaces) and large amount (> 500 cc or more than 4 intra-abdominal spaces) after Knudson.[6] Liver injuries due to penetrating causes were excluded from the study. An informed consent was taken from each patient.

2.1. Statistics

Data were analyzed using SPSS for Windows version 11.5 (SPSS Inc, Chicago, IL, USA). Data are expressed as mean ± SD unless otherwise stated. A value of $p < 0.05$ was considered significant.

3. Results

During the 1 year study period, from 1st of June 2008 to 31st of May 2009, 243 patients with abdominal trauma were admitted to the Emergency Unit. The incidence of the commonly injured abdominal organs was liver in 30%, spleen in 27%, stomach in 11.5%, colon in 10.5%, and small intestine in 8%. A total of 73 patients sustained different grades of liver trauma.

The age distribution of the patients with liver injury was; from 2.5 to 10 years in 22%, from 10 to 20 years in 22%, from 20 to 30 years in 26%, from 30 to 40 years in 11%, and more than 50 years old in 1%. The peak was between 20 and 30 years. The male to female ratio was 10:1.

The type of trauma in the studied patients was blunt in 44 patients (60.2%) and penetrating in 29 patients (39.8%). The mechanism of blunt trauma was road traffic accidents in 42.5% including drivers, pedestrians (2.7%) and motorcycles, and non-traffic causes including fall from the height in 15% and bicycle accident in 2.7%.

The majority of patients have multiple injuries with 10% having an isolated liver injury without any associated intra-abdominal or extra-abdominal injuries. Thirty-six patients (82%) had one or more associated extra-abdominal injuries, the commonest were chest trauma in 25 patients in which 8 mandates chest tubes, then head injuries in 23 patients, then long bone fractures in 14, pelvic fractures in 5 and soft tissues injuries in 3.

The clinical picture in patients with liver injury includes tenderness in the right hypochondrium in 36 patients (82%), rigid abdomen in 15 patients (34%), abrasions of the anterior abdominal wall in 14 patients (32%), rib fracture in 12 patients (27%), rebound tenderness in the right hypochondrium in 11 patients (25%), generalized abdominal distension in 8 patients (18%), no specific sign in 7 patients (16%) and the abdomen could not be assessed in 2 patients with severe head injuries and presented with coma (4.5%). There were 20 patients who presented with hemodynamic instability, 14 of them respond to the immediate resuscitation measures in the form of intravenous fluid infusion and blood transfusion. The mean was 2 units (range 2–3) of packed RBCs with continuous bedside monitoring of the vital signs, US and CT scan follow up. The other 6 patients did not improve with the conservative measures and needed exploration from 6 to 12 h from the presentation. The mean was 4 units (range 4–6) of packed RBCs but even with massive resuscitation they did not improve and mandate rapid exploration. No free intra-peritoneal fluid was detected in 5 patients, a small amount in 10 patients, moderate amount in 21 patients and large amount in 8 patients.

The length of intensive care unit stay was 1–12 days with the average of 4 days although not significant but it was more in the operative group. The length of hospital stay was 4–31 days with the average of 12 days which is significantly more in the operative group with a p value of 0.02.

Segment of the injured liver was recorded according to the Couinaud's Nomenclature[7] in the studied patients of which some patients have more than one affected segment; segment I in 2 patients (2%), segment II in 11 patients (25%), segment III in 10 patients (23%), segment IV in 7 patients (16%), segment V in 7 patients (16%), segment VI in 6 patients (14%), segment VII in 8 patients (18%) and segment VIII in 7 patients (16%).

Grading of liver injuries was done in the studied patients which was grade I in 10 patients (23%), grade II in 12 patients (27%) (Fig. 1), grade III in 13 patients (29%), grade IV in 6 patients (14%) and grade V in 3 patients (7%).

All the patients were treated initially with NOM. Surgery was indicated in 14 patients (32%). Hemodynamic instability after initial resuscitation was the indication of surgery in 6 patients. The CT done showed liver injuries; of grade III in 1 patient, grade IV in 4 patients and grade V in 1 patient. Associated abdominal injuries were the indication of surgery in 8 patients which were diagnosed preoperatively by the CT or discovered at the time of exploration.

Surgical procedures for liver related causes done in 6 patients were; hepatotomy to ligate the bleeding vessels in 2 patients (Fig. 2), suturing and resectional debridement in 2 patients, perihepatic packing in 1 patient, right hepatic artery ligation with formal right hepatectomy and repair of inferior vena cava (IVC) in 1 patient.

Associated abdominal injuries (non liver related cause) in the studied patients were 19 which were present in eight patients. Three patients had 3 more injuries and 5 patients had 2 more injuries. The injuries were; duodenal injury in 1, colon injury in 1, stomach injury in 2, small intestine injury in 2, gall bladder injury in 1, diaphragmatic tear in 2, renal injury in 2, retroperitoneal hematoma in 3, and splenic injury in 5. These patients underwent operations within 12–72 h from admission. The liver injuries in these patients stopped bleeding by the time of operation.

Three patients had severe head injuries and became hemodynamically unstable during craniotomy; they underwent laparotomy with nothing done during the explorations. All the three patients died due to their head injuries and excluded from the failure group.

Patients successfully treated with NOM were compared with patients who failed NOM due to liver-related causes; there were no significant differences in age, and admission transfusion. The mean admission systolic pressure was lower in the non operative management failure group (90 vs. 122 mmHg $p < 0.04$). Although statistically significant all patients initially responded to resuscitation. Thus, the factors that can predict failure of non operative management were the development of hemodynamic instability and the presence of associated injury that mandates immediate exploration.

Figure 1 CT film showing grade II subcapsular hematoma in segment VIII that was managed non-operatively.

Figure 2 Operative view showing grade III injury in segments V and VIII after hepatotomy and vessel ligation.

Complications occurred more in the operative group, chest infection occurred in 21.4% with a p value of 0.001, hyperpyrexia occurred in 21.4% with a p value of 0.001, and wound infection in 14.2% with a p value of 0.025. These three complications were significantly more in the operative group than in the non-operative group. Inferior vena cava thrombosis, hepatic artery thrombosis followed by pseudo-aneurysm, postoperative hemorrhage, biloma, hyperbilirubinemia, prehepatic collection, and calculus cholecystitis each occurred in one patient (7%). Complications that occurred in the non-operative group were much lower, chest infection in 3.3%, hyperpyrexia in 6.6%, hyperbilirubinemia in 3.3%, biloma in 3.3%, and prehepatic collection in 3.3% of patients.

Mortality occurred in 7 patients (15.9%). The cause of death in patients with liver injury was liver related in 2 patients (4.5%) due to hemorrhage and disseminated intravascular coagulopathy (DIC). Two deaths occurred due to pulmonary sepsis and multiple organ failure (4.5%), and 3 deaths due to associated head injury (6.9%). Regarding the relation between the grade of liver injury and the patient outcome; one mortality occurred with grade II injury, one with grade III injury; three with grade IV injury; and two with grade V injury.

4. Discussion

The liver is the most common organ injured by abdominal trauma.[8] The incidence of liver injury in patients with blunt trauma has been reported to be 1–8%.[9] However, the whole body CT scan can detect up to 25% of liver injuries in patients with blunt trauma.[9] Operative management was the standard for liver injuries till the beginning of 1990s. The main rationale was hemostasis and bile drainage.[8] Various operative techniques for severe injuries were described including omental packing, mesh wrapping, hepatic artery ligation, gauze packing, hepatic resection and hepatic transplantation.[10,11] However, surgical reports confirm that up to 80% of liver injuries have stopped bleeding by the time of exploration.[12–14] Since early 1980s, sporadic reports of adult patients treated non-operatively for blunt liver trauma have appeared in the literature with the aim of reducing the mortality and morbidity from hemorrhage and sepsis.[10,15]

Improvement in the imaging techniques, particularly CT scanning, has added a great impact in the management of liver trauma, and this has contributed much in the marked reduction in the number of patients requiring surgery and in the generalized acceptance of non-operative management as an effective therapeutic strategy for liver injuries in hemodynamically stable patients.[16]

In the present study, the mechanism of injury was blunt liver trauma in 60% of patients presented with liver injuries. It was reported in other studies to be the most common mechanism of injury and ranges from 56% to 76%.[8]

In 1985, Meyer et al.,[17] recommended the following clinical criteria for the selection of patients for non-operative management: hemodynamic stability, absence of peritoneal signs, good quality CT scans, an experienced radiologist, the ability to monitor patients in an intensive care setting, the facility for immediate surgery if required, a simple parenchymal laceration or intra-hepatic hematoma with less than 125 ml of free intraperitoneal blood and no other significant intra-abdominal injuries. Farnell et al.,[15] extended the amount of intraperitoneal blood to 250 ml and introduced specific CT requirements which include subcapsular or intra-parenchymal hematomas, unilobar fracture, absence of devitalized tissue and absence of other intra-abdominal injuries. Then, Feliciano[18] suggested that any blunt liver injury, regardless its magnitude, should be managed non-operatively, if the patient is hemodynamically stable and has a hemoperitoneum of less than 500 ml.

In the present study, all the patients were treated initially with NOM. Indication of surgery is considered as failure of NOM. Surgery was indicated in 14 patients (32%). Hemodynamic instability after initial resuscitation was the indication of surgery in 6 patients. Associated abdominal injuries were the indication of surgery in 8 patients which were diagnosed preoperatively by the CT or during laparotomy. Failure of NOM occurs almost in all series but the natural course of liver injuries can give gradual deterioration with a fall in the hemoglobin level or an increase in the fluid requirements rather than acute hemodynamic decompensation.[19] So, by close monitoring and supervision, patients who fail the initial NOM can be detected early and treated properly. The clinical course of the patients is what mandates the alteration in the management and not the CT.[19] That is why the initial CT scan is mandatory in hemodynamically stable patients or patients who stabilized after initial resuscitation but repeat CT scans should be obtained only if indicated. Most of the authors believe that the ultimate decisive factor in favor of NOM should be the hemodynamic stability of the patient at presentation or after initial resuscitation, irrespective of the grade of liver injury on CT scan or the amount of hemoperitoneum.[16,18,20–23] Associated abdominal injuries were the indication of surgery in 8 patients which were diagnosed preoperatively by the CT. These associated abdominal injuries were also found to be a significant factor that indicated the failure of NOM and mandate surgery as soon as possible. Some authors have many areas of concern about the discrepancy between the CT findings and the operative findings for blunt liver injuries,[24] the risk of missing other intra-abdominal injuries and the risk of continued hemorrhage, hemobilia, bile leak and sepsis. On the other hand, many studies found that patients treated with NOM required significantly fewer transfusions than surgically treated patients with comparable liver injuries.[19] Also, the complications in the patients treated with NOM showed not to be greater than on those treated surgically.[25] In our series, complications occurred more in the operative group, chest infection occurred in 21.4% with a p value of 0.001, hyperpyrexia occurred in 21.4% with a p value of 0.001, and wound infection in 14.2% with a *p* value of 0.025. These three complications were significantly more in the operative group than in the NOM group.

In the present study, the average length of intensive care unit stay was 4 days and the average length of hospital stay was 12 days. In the report of other group it was 13 days.[16,26]

Mortality occurred in 7 patients (15.9%). The cause of death in patients with liver injury is liver related in 2 patients due to hemorrhage and DIC (4.5%). Two deaths were due to pulmonary sepsis and multi-organ failure (4.5%), and 3 deaths due to associated head injury (6.9%). Deaths that occurred early were due to hemorrhage and shock while late deaths occurred due to sepsis and multiple-organ failure. One study showed that the mortality was 69.2% in the presence of head trauma and 7.3% without head trauma. Although, other associated injuries were not significant factors in mortality, they may lead to hemorrhage and shock which affect greatly the patient's survival.[8] Concomitant injuries can raise the mortality rate to reach 10–30%.[27] The mortality rate has fallen over the last decades from 66% to the current levels of 10–15%.[28–30] In other reports it ranges from 4.1% to 11.7%.[9,13,26] The advances in the knowledge of the liver anatomy, pathophysiology, anesthesia, enhanced resuscitation and intensive care have shared in this improvement. Most early deaths are due to uncontrolled hemorrhage and associated injuries while most late deaths were due to head injuries and sepsis with multiple organ failure.[10,31] Shock on admission is an important variable affecting death, but aggressive resuscitation with immediate exploration and hemostasis with early control of sepsis are paramount.

Regarding the relation between the grade of liver injury and the patient outcome; two mortalities occurred with grade I, two mortalities with grade II injury, one with grade III injury; one with grade IV injury; and one with grade V injury. Patients with low grade liver injuries had also mortality rates. Some authors found that there is a relation between the mortality rate and the grade of liver injury.[29,32–34] This is true for considering mortality due to liver related injuries only, but not from mortality due to non liver related causes. This entails that the extrahepatic liver injuries have their impact on the mortality rate. Two cases with liver related cause for mortality died, and the grades of liver injury were grade IV and grade V. They died from hemorrhage and DIC. Central hepatic vein involvement is difficult to manage and may cause death, this was agreed with Asensio,[35] and colleagues who had a mortality rate of 87% when direct trials were carried out to repair hepatic veins or the retro-hepatic vena cava.

Three patients had severe head injuries and became hemodynamically unstable during craniotomy; they underwent laparotomy with nothing done during the explorations. The three patients died due to their head injuries and excluded from the failure group. There is a lack of relationship between the neurological impairment and the decision for NOM which was documented in many reports.[36,37] Hemodynamic stability, absence of abdominal CT scan findings indicating exploration, and correcting metabolic deficits are sufficient to treat the patient with NOM.

In conclusion, NOM of blunt liver trauma is a safe treatment option even with higher grades of liver injury, with acceptable probabilities of complications. Management of liver trauma must be carried out in a specialized center with a well trained team, including experienced liver surgeon, anesthetist who know how to deal with such cases, and interventional radiologist who can manage complications. Appropriate intensive care unit is mandatory. In a non specialized center with inexperienced surgeons, the advice is to place perihepatic packs to control hemorrhage and to transfer the patient to a specialized center for definitive treatment. The non operative management of blunt liver trauma is the treatment of choice for otherwise hemodynamically stable patients. Hemodynamically unstable patients must be explored immediately. The preferred options for liver injury repair in our experience are the hepatotomy and direct ligature of the vessels and bile ducts or resectional debridement. The presence of associated injury that mandates immediate exploration is also an indication of exploration. Concomitant injuries, especially head injuries had significant impact on mortality and morbidity.

References

1. Lucas CE, Ledgerwood AM. Changing times and the treatment of liver injury. *Am Surg* 2000;**66**(4):337–41.
2. Cox EF. Blunt abdominal trauma. A 5-year analysis of 870 patients requiring celiotomy. *Ann Surg* 1984;**199**(4):467–74.
3. Olsen WR, Redman HC, Hildreth DH. Quantitative peritoneal lavage in blunt abdominal trauma. *Arch Surg* 1972;**104**(4):536–43.
4. Beal SL. Fatal hepatic hemorrhage: an unresolved problem in the management of complex liver injuries. *J Trauma* 1990;**30**(2):163–9.
5. Moore EE, Cogbill TH, Jurkovich GJ, Shackford SR, Malangoni HR, Champion HR. Organ injury scaling: spleen and liver (1994 revision). *J Trauma* 1995;**38**(3):323–4.
6. Knudson MM, Maull KI. Nonoperative management of solid organ injuries. Past, present, and future. *Surg Clin North Am* 1999;**79**(6):1357–71.
7. Couinaud C. Surgical anatomy of the liver revisited. C Couinaud, 15 rue Spontini, Paris, 1989.
8. Yaman I, Nazli O, Tugrul T, Isguder AS, Bozdag AD, Bolukbasi H. Surgical treatment of hepatic injury: morbidity and mortality analysis of 109 cases. *Hepatogastroenterology* 2007;**54**(77):1507–11.
9. Matthes G, Stengel D, Seifert J, Rademacher G, Mutze S, Ekkernkamp A. Blunt liver injuries in polytrauma: results from a cohort study with the regular use of whole-body helical computed tomography. *World J Surg* 2003;**27**(10):1124–30.
10. Fabian TC, Croce MA, Stanford GG, Payne LW, Mangiante EC, Voeller GR, et al. Factors affecting morbidity following hepatic trauma. A prospective analysis of 482 injuries. *Ann Surg* 1991;**213**(6):540–7, discussion 8.
11. Reed 2nd RL, Merrell RC, Meyers WC, Fischer RP. Continuing evolution in the approach to severe liver trauma. *Ann Surg* 1992;**216**(5):524–38.
12. Pachter HL, Feliciano DV. Complex hepatic injuries. *Surg Clin North Am* 1996;**76**(4):763–82.
13. Croce MA, Fabian TC, Menke PG, Waddle-Smith L, Minard G, Kudsk KA, et al. Nonoperative management of blunt hepatic trauma is the treatment of choice for hemodynamically stable patients. Results of a prospective trial. *Ann Surg* 1995;**221**(6):744–53, discussion 53-5.
14. Sikhondze WL, Madiba TE, Naidoo NM, Muckart DJ. Predictors of outcome in patients requiring surgery for liver trauma. *Injury* 2007;**38**(1):65–70.
15. Farnell MB, Spencer MP, Thompson E, Williams Jr HJ, Mucha Jr DM, Ilstrup DM. Nonoperative management of blunt hepatic trauma in adults. *Surgery* 1988;**104**(4):748–56.
16. Pachter HL, Hofstetter SR. The current status of nonoperative management of adult blunt hepatic injuries. *Am J Surg* 1995;**169**(4):442–54.
17. Meyer AA, Crass RA, Lim Jr RC, Jeffrey RB, Federle MP, Trunkey DD. Selective nonoperative management of blunt liver injury using computed tomography. *Arch Surg* 1985;**120**(5):550–4.
18. Feliciano DV. Continuing evolution in the approach to severe liver trauma. *Ann Surg* 1992;**216**(5):521–3.
19. Meredith JW, Young JS, Bowling J, Roboussin D. Nonoperative management of blunt hepatic trauma: the exception or the rule? *J Trauma* 1994;**36**(4):529–34, discussion 34-5.
20. Durham RM, Buckley J, Keegan M, Fravell S, Shapiro MJ, Mazuski J. Management of blunt hepatic injuries. *Am. J Surg* 1992;**164**(5):477–81.
21. Carrillo EH, Platz A, Miller FB, Richardson JD, Polk Jr HC. Non-operative management of blunt hepatic trauma. *Br J Surg* 1998;**85**(4):461–8.
22. Knudson MM, Lim Jr RC, Oakes DD, Jeffrey Jr RB. Nonoperative management of blunt liver injuries in adults: the need for continued surveillance. *J Trauma* 1990;**30**(12):1494–500.
23. Federico JA, Horner WR, Clark DE, Isler RJ. Blunt hepatic trauma. Nonoperative management in adults. *Arch Surg* 1990;**125**(7):905–8, discussion 8-9.
24. Croce MA, Fabian TC, Kudsk KA, Baum SL, Payne LW, Mangiante EC, et al. AAST organ injury scale: correlation of CT-graded liver injuries and operative findings. *J Trauma* 1991;**31**(6):806–12.
25. Bynoe RP, Bell RM, Miles WS, Close TP, Ross MA, Fine JG. Complications of nonoperative management of blunt hepatic injuries. *J Trauma* 1992;**32**(3):308–14, discussion 14-5.
26. Pachter HL, Spencer FC, Hofstetter SR, Liang HG, Coppa GF. Significant trends in the treatment of hepatic trauma. Experience with 411 injuries. *Ann Surg* 1992;**215**(5):492–500, discussion -2.
27. Gourgiotis S, Vougas V, Germanos S, Dimopoulos N, Bolanis I, Drakopoulos S, et al. Operative and nonoperative management of blunt hepatic trauma in adults: a single-center report. *J Hepatobiliary Pancreat Surg* 2007;**14**(4):387–91.
28. Cogbill TH, Moore EE, Jurkovich GJ, Feliciano DV, Morris JA, Mucha P. Severe hepatic trauma: a multi-center experience with 1,335 liver injuries. *J Trauma* 1988;**28**(10):1433–8.
29. Krige JE, Bornman PC, Terblanche J. Liver trauma in 446 patients. *S Afr J Surg* 1997;**35**(1):10–5.
30. Sherlock DJ, Bismuth H. Secondary surgery for liver trauma. *Br J Surg* 1991;**78**(11):1313–7.
31. Bender JS, Geller ER, Wilson RF. Intra-abdominal sepsis following liver trauma. *J Trauma* 1989;**29**(8):1140–4, discussion 4-5.
32. 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**(5):475–80, discussion 80-1.
33. Hurtuk M, Reed 2nd RL, Esposito TJ, Davis KA, Luchette FA. Trauma surgeons practice what they preach: the NTDB story on solid organ injury management. *J Trauma* 2006;**61**(2):243–54, discussion 54-5.
34. Parks RW, Chrysos E, Diamond T. Management of liver trauma. *Br J Surg* 1999;**86**(9):1121–35.
35. Asensio JA, Roldan G, Petrone P, Rojo E, Tillou A, Kuncir E, et al. Operative management and outcomes in 103 AAST-OIS grades IV and V complex hepatic injuries: trauma surgeons still need to operate, but angioembolization helps. *J Trauma* 2003;**54**(4):647–53, discussion 53-4.
36. Shapiro MB, Nance ML, Schiller HJ, Hoff WS, Kauder DR, Schwab CW. Nonoperative management of solid abdominal organ injuries from blunt trauma: impact of neurologic impairment. *Am Surg* 2001;**67**(8):793–6.
37. Keller MS, Sartorelli KH, Vane DW. Associated head injury should not prevent nonoperative management of spleen or liver injury in children. *J Trauma* 1996;**41**(3):471–5.