

REVIEW

Damage Control in Penetrating Liver Trauma: Fear of the Unknown

Control de Daños en Trauma Hepático Penetrante: El Miedo a Lo Desconocido

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Abstract

The liver is the most commonly affected solid organ in cases of abdominal trauma. Management of penetrating liver trauma is a challenge for surgeons but with the introduction of the concept of damage control surgery accompanied by significant technological advancements in radiologic imaging and endovascular techniques, the focus on treatment has changed significantly. The use of immediately accessible computed tomography as an integral tool for trauma evaluations for the precise staging of liver trauma has significantly increased the incidence of conservative non-operative management in hemodynamically stable trauma victims with liver injuries. However, complex liver injuries accompanied by hemodynamic instability are still associated with high mortality rates due to ongoing hemorrhage. The aim of this article is to perform an extensive review of the literature and to propose a management algorithm for hemodynamically unstable patients with penetrating liver injury, via an expert consensus. It is important to establish a multidisciplinary approach towards the management of patients with penetrating liver trauma and hemodynamic instability. The appropriate triage of these patients, the early activation of an institutional massive transfusion protocol, and the early control of hemorrhage are essential landmarks in

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Conflict of Interest:

The authors declare not to have any conflict of interest

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lowering the overall mortality of these severely injured patients. To fear is to fear the unknown, and with the management algorithm proposed in this manuscript, we aim to shed light on the unknown regarding the management of the patient with a severely injured liver.

Resumen

El hígado es el órgano sólido más comúnmente lesionado en casos de trauma abdominal. El manejo del trauma penetrante hepático es un dilema para los cirujanos. Sin embargo, con la introducción del concepto de la cirugía de control de daños y los avances tecnológicos en imagenología y técnicas endovasculares han permitido que el enfoque del tratamiento cambie. La disponibilidad inmediata de la tomografía computarizada permite estadificar el grado de la lesión e incrementar la posibilidad de un manejo conservador en pacientes hemodinámicamente estables con trauma hepático. El trauma hepático severo que se asocia con inestabilidad hemodinámica tiene una alta mortalidad debido a la hemorragia activa. El objetivo de este artículo es proponer un algoritmo de manejo producto de un consenso de expertos acerca del abordaje de los pacientes hemodinámicamente inestables con trauma hepático penetrante. El manejo debe ser por parte de un equipo multidisciplinario que comienza desde la evaluación inicial de los pacientes, la activación temprana de protocolo de transfusión masiva y el control temprano de la hemorragia, siendo estos aspectos esenciales para disminuir la mortalidad. El miedo a lo desconocido es el dilema quirúrgico donde existen pocas opciones y es imperante decisiones rápidas y oportunas; por esta razón, se propone dar una luz de guía sobre lo desconocido respecto al manejo del paciente con trauma hepático severo.

Remark

1) Why was this study conducted?

The liver is the most commonly affected solid organ in cases of abdominal trauma. This article aims to propose a management algorithm for hemodynamically unstable patients with penetrating liver injury.

2) What were the most relevant results of the study?

It is important to establish a multidisciplinary approach towards the management of patients with penetrating liver trauma and hemodynamic instability. The appropriate triage of these patients, the early activation of an institutional massive transfusion protocol, and the early control of hemorrhage are essential landmarks in lowering the overall mortality of these severely injured patients

3) What do these results contribute?

To fear is to fear the unknown, and with the management algorithm proposed in this manuscript, we aim to shed light on the unknown regarding the management of the patient with a severely injured liver.

Introduction

The liver is the most commonly affected solid organ in cases of abdominal trauma ¹. Management of penetrating liver trauma is a challenge for surgeons but with the introduction of the concept of Damage Control Surgery (DCS) accompanied by significant technological advancements in radiologic imaging and endovascular techniques, the focus on treatment has changed significantly. The use of immediately accessible Computed Tomography (CT) as an integral tool for trauma evaluations for the precise staging of liver trauma has significantly increased the incidence of conservative non-operative management (NOM) in hemodynamically stable trauma victims with liver injuries ^{2,3}. However, complex liver injuries accompanied by hemodynamic instability are still associated with high mortality rates due to ongoing hemorrhage ^{4,5}. Even to this day in age, these injuries create a sense of fear among the treating surgical staff mostly based on their own personal inexperience: “To fear is to fear the unknown.” The aim of this article is to reduce this fear by performing an extensive review of the literature and proposing a management algorithm for hemodynamically unstable patients with penetrating liver injury, via an expert consensus from the Trauma and Emergency Surgery Group (CTE) of Cali, Colombia.

This article is a consensus that synthesizes the experience earned during the past 30 years in trauma critical care management of the severely injured patient from the Trauma and Emergency Surgery Group (CTE) of Cali, Colombia which is made up of experts from the University Hospital Fundación Valle del Lili, the University Hospital del Valle “Evaristo García”, the Universidad del Valle and Universidad Icesi, the Asociación Colombiana de Cirugía, the Pan-American Trauma Society and the collaboration of national and international specialists of the United States of America and Latin America.

Liver Trauma

Liver injury occurs mainly in males under the age of 40 and worldwide the most common mechanism is blunt trauma which accounts for more than two-thirds of them ⁶⁻⁸. In Latin-America however, the most common mechanism of liver trauma is penetrating injury (62%) and in Colombia the most common penetrating mechanism is gunshot wounds (88.64%), followed by stab wounds (11.36%) ¹. We have also found that 60% of patients who have penetrating liver trauma have a severe injury that requires complex surgical repair (AAST Grades III-V) (Table 1) ^{9,10}. Approximately 86% of these patients have concomitant intra-abdominal injuries which include the colon (34%), followed by the stomach and duodenum (30%) ⁶. Overall mortality ranges between 22% - 66% and factors such as age over 65 and low socio-economic status are associated with higher mortality rates ^{1,6,8,11}.

Table 1. The American Association for the Surgery of Trauma (AAST) Classification of Liver Injury ¹⁰

Grade	Description
I	Subcapsular hematoma <10% surface area Parenchymal laceration <1 cm depth Capsular tear
II	Subcapsular hematoma 10-50% surface area; intraparenchymal hematoma < 10 cm in diameter Laceration 1-3 cm in depth and ≤10 cm length
III	Subcapsular hematoma >50% surface area; ruptured subcapsular or intraparenchymal hematoma Intraparenchymal hematoma >10 cm Laceration >3 cm depth with active bleeding.
IV	Parenchymal disruption involving 25-75% of a hepatic lobe or liver injury that involving 1-3 liver segments with active bleeding
V	Parenchymal disruption >75% of hepatic lobe or more than 3 liver segments Juxtahepatic venous injury to include retrohepatic vena cava and central major hepatic veins

The high rate of liver injury in cases of abdominal trauma can be explained by the location of the organ and its size. Penetrating injuries to the liver can cause severe hemorrhage that requires early surgical intervention, in which a rapid control of the source of bleeding should be achieved given that hemorrhage is the main cause of death in these patients^{12,13}. Inadequate or delayed control of ongoing surgical hemorrhage can lead to the lethal diamond of hypothermia, coagulopathy, acidosis, and hypocalcemia. This is why patients require correction of these parameters via damage control resuscitation (DCR) and rewarming in the intensive care unit (ICU) prior to definitive surgical repair.

Initial Approach and Diagnosis

Liver trauma management in hemodynamically stable patients has rapidly evolved and NOM is currently the standard of care when feasible. Up to 33% of cases of penetrating liver trauma can be treated with NOM and close ICU surveillance^{3,7}. But such care is not indicated in patients who arrive to the Emergency Department (ED) hemodynamically unstable (Systolic Blood Pressure (SBP) <90 mmHg), those who are not responders to initial resuscitation and/or have positive peritoneal signs on initial examination. These patients should undergo immediate stabilization according to ATLS guidelines, follow DCR principles, and require surgical intervention¹⁴.

Surgical Management of Hemodynamically Unstable Penetrating Liver Injuries

DCS has been proposed as the standard of care for cases of severe liver trauma with hemodynamic instability that require initial operative management, which consists of an abbreviated laparotomy, liberal use of the Pringle Maneuver, an effective peri-hepatic packing, intra-hepatic selective vessel ligation (SVL), routine use of angiography for possible embolization and early ICU transfer for correction of patient's physiology abnormalities^{15,16}. We prospectively evaluated patients with penetrating liver trauma and found that 77% (68) received DCS with an overall mortality of 15.9%. In our review of these cases, we discovered that there were no clear-cut indications or consensus on their management and steps to follow^{9,17}.

Herein, based on our experience and with the consensus of leading experts in trauma care we propose a new algorithm for the management of penetrating liver trauma patient that arrives hemodynamically unstable (Figure 1):

- STEP 1: Massive transfusion protocol (MTP) is activated, an introducer sheath is inserted via the common femoral artery and a high flow venous catheter is placed via the common femoral vein. This can be done in the ED and/or in the operating room (OR).
- STEP 2: An exploratory laparotomy is performed immediately; the hemoperitoneum is evacuated, quantified, and auto-transfused when possible, followed by a systematic four-quadrant abdominal cavity packing. Time is given to the anesthesiologist for DCR via the previously activated MTP. Systematic four-quadrant unpacking leaving the right upper quadrant last. A direct exam of the liver is performed to identify if the injury is simple (AAST Grade I-II) or complex (AAST Grade III-V) (Table 1). If the liver injury is simple without active bleeding then perform direct compression, apply topical hemostatic agents and/or perform simple primary suture repair (hepatorrhaphy). Even simple liver lacerations may require direct selective intra-hepatic vessel and/or peripheral bile duct ligation.
- STEP 3: Complex liver injuries with active bleeding require direct packing of the injury site alongside peri-hepatic packing. If the bleeding stops, then complete DCS and leave the patient packed. The patient should immediately undergo a liver angiogram in the angio/hybrid room to further delineate any ongoing surgical bleeding that if present should

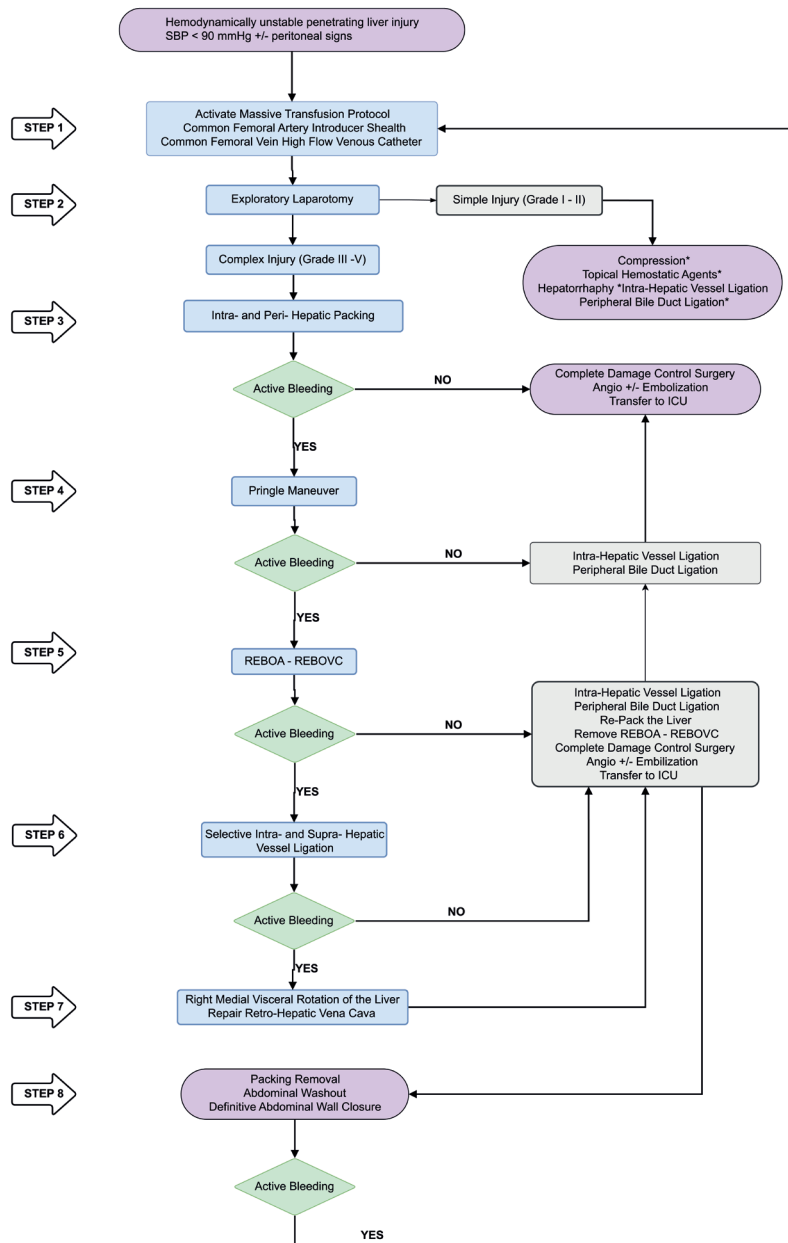


Figure 1. Surgical Management of Hemodynamically Unstable Penetrating Liver Trauma

be managed with selective endovascular angioembolization. The patient should then be transferred to the ICU to complete DCR, rewarming, acid-base, coagulopathy, and hypocalcemia correction.

- STEP 4: If bleeding persists then a Pringle Maneuver should be performed and time is given to the anesthesiologist to catch up and achieve DCR.
- If the bleeding is controlled and the patient regains hemodynamic stability, then the wound should be unpacked and selective vessel and/or peripheral bile duct ligation of the exposed liver laceration should be performed. Once this is done then the Pringle should be removed and the repair re-examined to rule out any ongoing surgical bleeding.

- If ongoing surgical bleeding is present, then the Pringle Maneuver should be reapplied and the suture ligation of the bleeding vessel performed. This step can be repeated as needed notwithstanding that the Pringle Maneuver should not be in place more than 30 minutes at any given continuous time span. The patient should then be re-packed and DCS completed.
- All patients should undergo a liver angiogram in the angio/hybrid room to further delineate any ongoing surgical bleeding that if present should be managed with selective endovascular angioembolization. The patient should then be transferred to the ICU to complete DCR, rewarming, acid-base, coagulopathy and hypocalcemia correction.
- STEP 5: If despite intra and peri-hepatic packing and a Pringle Maneuver in place, there is still active surgical bleeding from the liver then the placement and inflation of a Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) catheter in Zone I should be considered via the previously placed femoral arterial line. Simultaneously, the large high flow femoral venous catheter should be exchanged over a guidewire for an introducer sheath with the aim of floating up and inflating a Resuscitative Endovascular Balloon Occlusion of the Vena Cava (REBOVC) at the level of the retrohepatic vena cava with the goal of achieving proximal and distal vascular control of a possible retro/suprahepatic vessel injury.
- STEP 6: Once placement confirmation of both the REBOA and the REBOVC has been achieved (Figure 2) then unpacking of the liver with selective ligation of all mayor intra-hepatic and/or suprahepatic bleeding vessels should be done. If surgical bleeding control is achieved, then re-pack the liver, remove the REBOA/REBOVC re-confirming control of hemorrhage and complete DCS. The patient should undergo a liver angiogram in the angio/hybrid room to further delineate any ongoing surgical bleeding that if present should be managed with selective endovascular angioembolization. The patient should then be transferred to the ICU to complete DCR, rewarming, acid-base, coagulopathy, and hypocalcemia correction.
- STEP 7: If surgical bleeding is not achieved then the source is an injury of the retrohepatic vena cava and a right medial visceral rotation of the liver is required to expose and repair the injury. If surgical bleeding control is achieved, then re-pack the liver, remove the REBOA/REBOVC re-confirming control of hemorrhage and complete DCS. The patient should undergo a liver angiogram in the angio/hybrid room to further delineate any ongoing surgical bleeding that if present should be managed with selective endovascular angioembolization. The patient should then be transferred to the ICU to complete DCR, rewarming, acid-base, coagulopathy, and hypocalcemia correction.
- STEP 8: Once the patient has been adequately resuscitated in the ICU (between 24-72 hours), then the patient should be taken back to the OR for packing removal, abdominal washout and definitive abdominal wall closure. If the patient suffered sustained any associated bowel injuries that were initially managed by resection and left in discontinuity then bowel continuity should be restored at this time if feasible. If liver bleeding ensues then follow Steps 1-7 again until control of surgical bleeding has been achieved.

Discussion

A consensus on the management of penetrating liver trauma with hemodynamic instability is critical due to its high mortality rate and the different approaches to resolve them among surgeons throughout the world. The later has hindered the decision-making process of many physicians when confronted with these scenarios^{18,19}. We propose a new clear management algorithm in which damage control strategies have been included and we introduce the use of REBOA and REBOVC as adjuvants for hemorrhage control.

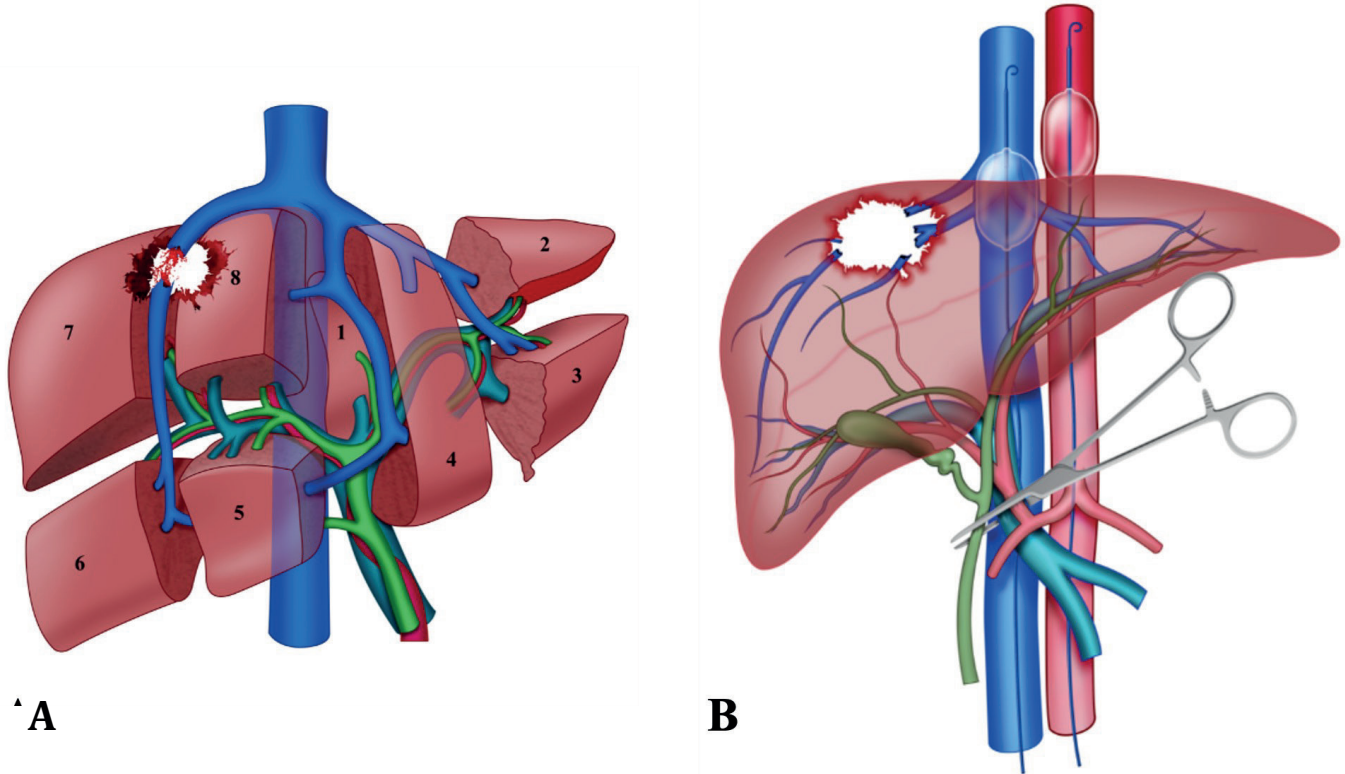


Figure 2. (A) Complex Penetrating Liver Injury; (B) Combined Open and Endovascular Liver Isolation with REBOA, REBOVC and Pringle Maneuver. The open and endovascular liver isolation is achieved performing the REBOA in Zone 1 and REBOVC at the level of the retrohepatic vena cava with the goal of achieving proximal and distal vascular control of a possible retro/suprahepatic vessel injury. The Pringle maneuver is obtained via the hepatoduodenal ligament clamping.

Mortality rates of severe liver injuries can be up to 70%, and the main determinants of outcome are initial pH, base deficit, intraoperative blood loss and post-traumatic coagulopathy^{11,16,20}. This explains the need for early activation of an institutional MTP in these cases to effectively stabilize the patient. Current surgical management of liver hemorrhage is based on direct pressure, packing of the wound, the Pringle Maneuver; hepatorrhaphy, selective vessel ligation, leaving the abdomen open and completion of DCR in the ICU²¹. It is also important to reiterate the importance of not removing the abdominal packing prior to the initial 24 hours of DCS given the high incidence of rebleeding which is three times higher than those patients in which packing was removed after the first 24 hours from their initial laparotomy^{22,23}.

REBOA has emerged as a useful tool to temporarily stop the bleeding in cases of Non-Compressible Torso Hemorrhage (NCTH). The REBOA allows not only proximal control of the source of hemorrhage but also promotes the perfusion of vital organs including the heart and brain²⁴. The concomitant use of REBOVC along with a REBOA and a Pringle Maneuver has been previously described in the literature to facilitate a combined endovascular and open isolation of the liver in cases of severe penetrating liver injuries with ongoing hemorrhage^{21,15-27}. Recently, this proposal of penetrating liver trauma was included in the guideline of liver trauma by the World Society of Emergency Surgery (WSES)²⁷. Colombia has evolved to become one of the world leaders in the use of REBOA especially regarding its use in penetrating trauma²⁸⁻³¹.

Conclusion

It is important to establish a multidisciplinary approach towards the management of patients with penetrating liver trauma and hemodynamic instability. The appropriate triage of these patients, the early activation of an institutional MTP, and the early control of hemorrhage are essential

landmarks in lowering the overall mortality of these severely injured patients. To fear is to fear the unknown, and with the management algorithm proposed in this manuscript, we aim to shed light on the unknown regarding the management of the patient with a severely injured liver.

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