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Liver trauma management: a review of long-term outcome, advanced imaging, and comorbidities

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ABSTRACT

Background and Objective: Management of trauma-related liver injury has undergone significant changes over the past four decades. In hemodynamically stable patients, the standard of care in most level-one trauma centers has shifted toward nonoperative management with high success rates, particularly in low-grade liver injuries such as grade I and II. Advances in critical care medicine, cross-sectional imaging, and transarterial embolization techniques have contributed to improved patient outcomes and reduced mortality in patients with arterial injuries. These developments have allowed clinicians to manage many cases of liver trauma without the need for open surgery.

Method: A selective literature search was conducted in PubMed and Google Scholar for studies published between 2020 and 2025 focusing on nonoperative management of liver trauma and the role of hepatic angiography and transarterial embolization.

Findings/Results: Current literature indicates that nonoperative management of liver injuries in hemodynamically stable patients, particularly with the use of hepatic angiography and transarterial embolization (TAE), is an effective and relatively low-complication approach. However, no consensus guidelines regarding appropriate patient selection criteria have yet been published by the Society of Interventional Radiology (SIR) or the American Association for the Surgery of Trauma (AAST). Evidence suggests that TAE improves the success rate of nonoperative management and is generally well tolerated by most patients. Hepatic necrosis remains the most commonly reported complication but can be minimized through selective embolization techniques and appropriate choice of embolic agents.

Conclusion: Nonoperative management combined with hepatic angiography and transarterial embolization should be considered an important treatment option for hemodynamically stable patients with suspected arterial injury. Further prospective multicenter studies with larger sample sizes are needed to better evaluate the efficacy and safety of TAE in trauma-related liver injury.

Keywords: Liver trauma; Long-term outcomes; Advanced imaging techniques; Non-operative management.

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مدیریت ترضیضات کبدی: مرور پیامدهای بلندمدت، تصویربرداری پیشرفته و امراض همراه

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چکیده

زمینه و هدف: مدیریت صدمات کبدی ناشی از ترضیض (تروما) در طول چهار دهه گذشته دچار تحولات اساسی شده است. در مریضان هومودینامیک پایدار، استاندارد مراقبت در بسیاری از مراکز تروما سطح یک به سمت تداوی غیرجراحی با میزان موفقیت بالا تغییر کرده است، به‌ویژه در آسیب‌های کبدی با درجه پایین مانند درجه I و II. پیشرفت‌های مراقبت‌های ویژه، تصویربرداری مقطعی و تکنیک‌های انسداد شریانی از طریق کتر سبب بهبود نتایج مریضان و کاهش میزان مرگ‌ومیر در آسیب‌های شریانی شده‌اند. این تغییر رویکرد امکان مدیریت بسیاری از مریضان را بدون نیاز به جراحی باز فراهم کرده است.

روش: جستجوی انتخابی در منابع PubMed و Google Scholar در فاصله سال‌های ۲۰۲۰ تا ۲۰۲۵ انجام شد و مقالات مرتبط با مدیریت غیرجراحی ترومای کبدی و نقش آنژیوگرافی کبدی و امبولیزیشین شریانی مورد بررسی قرار گرفت.

یافته‌ها: بررسی منابع اخیر نشان می‌دهد که مدیریت غیرجراحی ترضیضات کبدی در مریضان هومودینامیک پایدار، به‌ویژه با استفاده از آنژیوگرافی کبدی و امبولیزیشین شریانی از طریق کتر (TAE)، به‌عنوان رویکردی مؤثر و کم‌عارضه شناخته شده است. با وجود نبود دستورالعمل‌های اجماعی از سوی نهادهای معتبر مانند انجمن رادیولوژی مداخله‌ای و انجمن جراحی تروما آمریکا، شواهد موجود نشان می‌دهد که این روش می‌تواند میزان موفقیت تداوی غیرجراحی را افزایش دهد. همچنین با انتخاب دقیق مریضان و استفاده از مواد مناسب برای انسداد شریانی می‌توان خطر نکروز کبدی را کاهش داد.

نتیجه‌گیری: مدیریت غیرجراحی همراه با آنژیوگرافی کبدی و انسداد شریانی از طریق کتتر باید به‌عنوان گزینه تداوی در مریضان هومودینامیک پایدار با شک کلنیکی آسیب

شریانی در نظر گرفته شود. این روش با میزان عارضه پایین همراه است، اما بیشتر مطالعات موجود گذشته‌نگر هستند و انجام تحقیقات آینده‌نگر و چندمرکزی با حجم نمونه بزرگ برای ارزیابی دقیق‌تر اثربخشی و مصونیت این روش ضروری است.

کلیدواژه‌ها: ترومای کبدی؛ پیامدهای بلندمدت؛ روش های تصویربرداری پیشرفته؛ مدیریت غیرجراحی.

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Introduction

Liver trauma is a significant clinical challenge, frequently encountered in patients with severe abdominal injuries [1]. These injuries often occur in conjunction with damage to other organs such as the spleen, kidneys, and pancreas [2, 3]. The management of liver trauma has undergone a paradigm shift in recent decades, moving away from mandatory exploratory laparotomy towards non-operative management in hemodynamically stable patients [3]. This evolution has been driven by advances in diagnostic imaging, particularly computed tomography scanning, which allows for accurate assessment of injury severity and guides treatment decisions [2]. The liver's unique anatomical location and rich vascularity make it vulnerable to both blunt and penetrating trauma. Blunt trauma, often resulting from motor vehicle accidents or falls, causes injury through deceleration forces and direct contusion [3]. Penetrating trauma, typically from gunshot or stab wounds, involves direct injury to the liver parenchyma [3]. Regardless of the mechanism, hemorrhage remains a primary concern in liver trauma, highlighting the importance of rapid diagnosis and effective management [3]. While NOM has become the standard of care in many cases, surgical intervention is still required for patients with hemodynamic instability or ongoing bleeding [1]. This review aims to provide a comprehensive overview of current liver trauma management strategies, focusing on long-term outcomes, the role of advanced imaging techniques, and the impact of comorbidities on patient outcomes. By examining these key areas, we hope to provide clinicians with the knowledge necessary to optimize the care of patients with liver trauma and improve their long-term prognosis.

Current management of liver trauma

The management of liver trauma has evolved considerably over recent decades, with a growing emphasis on non-operative strategies, especially for hemodynamically stable patients. The approach to liver injuries depends largely on the mechanism (blunt vs. penetrating), injury grade, hemodynamic status, and associated injuries.

Overview of Management Strategies

Non-operative management (NOM) has become the standard of care for bluntest liver injuries, particularly low to moderate grade lesions. Studies from tertiary care centers and developing countries have demonstrated high success rates with conservative management protocols, emphasizing careful patient selection and close monitoring [1, 4]. NOM typically involves hemodynamic stabilization, serial clinical and laboratory assessments, and the use of advanced imaging techniques such as contrast-enhanced computed tomography (CT) to grade injury severity and detect complications. For penetrating liver trauma, selective non-operative management is increasingly practiced in stable patients without peritonitis or other indications for immediate surgery [8, 9]. The advantages of the non-operative management of liver injuries (providing this is possible) are: reduction in hospital care costs, early discharge from hospital, avoiding non-therapeutic laparotomies, a reduction in intraabdominal complications and fewer blood transfusions [10]. However, high-grade injuries, haemodynamic instability, or associated hollow viscus injuries often necessitate operative intervention.

Surgical management remains critical for severe liver injuries, especially in unstable patients or those with ongoing hemorrhage. Techniques such as damage control surgery, including packing, Pringle maneuver (temporary hepatic inflow occlusion), and vascular control, are widely employed to control bleeding and stabilize patients [11-13]. Complex repairs may require advanced surgical expertise and multidisciplinary care.

Guidelines and Clinical Practices: Current clinical guidelines advocate for a tailored approach based on injury severity and patient condition. The American Association for the Surgery of Trauma (AAST) liver injury scale remains a cornerstone for injury grading, guiding management decisions. Radiological scoring systems and emerging tools such as deep learning-based CT volumetry have shown promise in predicting major arterial injuries and guiding intervention strategies [8, 14].

Table1. AAST Score.

Grade	Type	Injury description
I	Hematoma	Subcapsular<10% surface area
	Laceration	Capsular tear, <1cm parenchymal depth
II	Hematoma	Subcapsular, 10–50% surface area, intra-parenchymal <10cm in diameter
	Laceration	1–3cm parenchymal depth, <10cm in length
III	Hematoma	Subcapsular, >50% surface area or expanding; ruptured subcapsular or parenchymal haematoma, intra-parenchymal haematoma ≥10cm or expanding
	Laceration	>3cm parenchymal depth
IV	Laceration	Parenchymal disruption involving 25–75% of hepatic lobe or 1–3 Couinaud's segments within the single lobe
V	Laceration	Parenchymal disruption involving >75% of hepatic lobe or >3 Couinaud's segments within the single lobe
	Vascular	Juxtavenous hepatic injuries, i.e. retrohepatic vena cava/central major hepatic veins
VI	Vascular	Hepatic avulsion

AAST Score

The most widely accepted scoring system for assessing liver injuries is the "Moore score" (AAS Score), which is based on the Organ Injury Scale (OIS) of the American Association for the Surgery of Trauma (AAS), first published in 1989 [15]. The Moore score is regarded as the gold standard for describing liver injuries [16]. This classification system provides an anatomical description of liver injuries, ranging from I to VI, representing minimal to the most severe injuries (Tables 1;). [17] The majority of liver injuries are classified as grade I, II, or III and are typically managed successfully with conservative treatment. Conversely, most grade IV, V, or VI liver injuries require surgical intervention. The success rate of non-operative management (NOM) for hepatic trauma ranges from 82% to 100%. [17, 18] Nevertheless, many patients with high-grade liver lesions may remain hemodynamically stable and can be effectively treated with NOM in specialized centers. [19, 18] Therefore, a contemporary NOM algorithm for hepatic injuries should also consider the hemodynamic status and other associated injuries, such as through the incorporation of the Injury Severity Score (ISS). The primary aim of the AAS classification was to establish a common language for describing specific organ injuries and to facilitate clinical decision-making. The OIS committee of the AAS was

established in 1987 with the objective of developing injury severity scales for individual organs.

Moore classification/AAST liver injury

The introduction and refinement of CT scanning have significantly impacted the classification and subsequent management of liver trauma. CT scanning is capable of identifying subcapsular or central hematomas, contusions, periportal fluid tracking, as well as complex lacerations and fragmentations [9].

Angioembolization has emerged as a minimally invasive adjunct to NOM, particularly for controlling arterial hemorrhage in high-grade injuries. While effective, it carries risks such as major hepatic necrosis, necessitating careful patient selection and post-procedural monitoring [20]. In resource-limited settings, conservative management protocols have demonstrated feasibility and safety, though challenges remain related to monitoring capabilities and timely surgical intervention when needed [1,3,21]. Multidisciplinary trauma teams and standardized treatment protocols improve outcomes and reduce complications [22, 23]. Liver transplantation, although rare, has been reported as a salvage option in cases of severe hepatic trauma with irreversible liver failure [24]. This underscores the importance of individualized care pathways and advanced surgical options in complex cases. Overall, the paradigm of liver trauma management continues to shift towards less invasive, organ-preserving strategies supported by advances in imaging, interventional radiology, and critical care, while maintaining readiness for surgical intervention when indicated.

Long-term outcomes

The management of liver trauma has evolved significantly over the years, influenced by advancements in imaging technology, non-operative management protocols, and an improved understanding of the complexities associated with liver injuries. A comprehensive review of recent studies highlights the long-term outcomes associated with various treatment strategies, revealing both successes and areas where further research is needed.

Overview of long-term outcomes by management strategies

The decision between operative and non-operative management of liver trauma continues to spark debate among clinicians. A recent retrospective analysis from a tertiary care center found that selective non-operative management (NOM) demonstrated favorable long-term outcomes in blunt liver injuries, with comparable recovery rates to surgical intervention [4]. This is supported by studies indicating that non-operative strategies effectively minimize complications in patients with lower-grade injuries and maximize organ

preservation [10; 6]. Interestingly, findings suggest that both blunt and penetrating liver trauma can achieve similar outcomes in specialized healthcare settings, where the resources for advanced imaging and intervention are available [9]. These results reinforce the notion that a tailored approach based on the severity of the injury and the patient's overall condition is pivotal for optimizing long-term recovery. However, management strategies diverge significantly when addressing severe liver injuries. Complex surgical repairs are often warranted, and studies indicate that while such interventions can lead to satisfactory long-term results, the associated complications may substantially impact the quality of life [12]. Moreover, newly developed techniques like primary angioembolization show promise in managing hepatic trauma, but they also carry the risk of significant complications such as major hepatic necrosis, necessitating a careful evaluation of potential long-term outcomes [20]. In conclusion, while significant progress has been made in the management of liver trauma, particularly in the realm of non-operative strategies, a clearer understanding of long-term outcomes-including the influence of comorbidities, imaging technologies, and injury severity-is crucial for optimizing patient care and improving recovery trajectories. Continued research in these areas is essential to bridge existing gaps and enhance the standard of care in liver trauma management.

Role of advanced imaging in liver trauma

Prompt diagnosis and accurate grading of liver injuries are crucial for effective management. Advances in imaging technologies have revolutionized the approach to liver trauma, with computed tomography serving as the gold standard for trauma imaging assessment [1].

Computed Tomography (CT)

CT is invaluable for evaluating trauma patients, enabling comprehensive imaging of multiple body regions and organ systems in a single examination [25]. In hemodynamically stable patients or those stabilized after initial resuscitation, CT with intravenous contrast should be performed [2]. Contrast-enhanced CT of the abdomen can detect the presence and extent of hepatic parenchymal injury with high accuracy [21]. Multiphasic imaging, including arterial, venous, and delayed phase imaging, helps classify injuries and detect vascular shunts and pseudoaneurysms [21]. Delayed-phase CT helps in differentiating patients with active bleeding from those with contained vascular injuries [1].

Deep learning in CT volumetry

Deep learning algorithms can be used for automated volumetric segmentation of liver contrast extravasation. Deep learning-based automated method of calculating liver parenchymal disruption index was precise and clinically useful for decreasing false negative CT exams in patients without contrast extravasation [19].

Focused Assessment with Sonography for Trauma (FAST)

In hemodynamically stable patients, a FAST exam can be performed to evaluate for liver injury. Signs of liver injury on FAST examination include subcapsular fluid, perihepatic fluid, or fluid within the hepatorenal space . However, a negative FAST examination does not completely exclude liver injury [21].

Magnetic Resonance Imaging (MRI)

MRI is used for the diagnosis of biliary complications, bile leaks, and neurological complications [31].

Other imaging modalities

Ultrasound, computed tomography, magnetic resonance imaging, and angiography are crucial for diagnosing and characterizing hepatic hemangiomas [26].

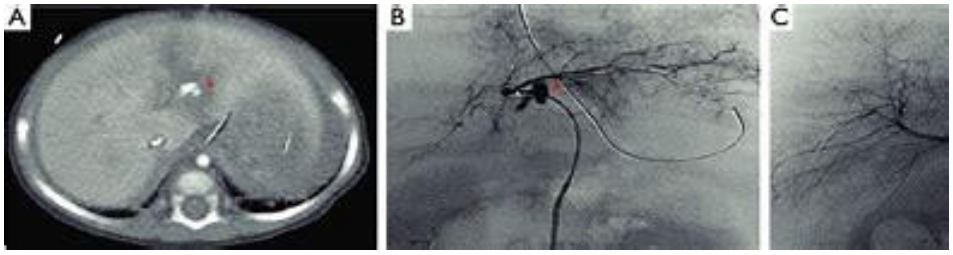

Figure 1. TAE for non-penetrating trauma. (A) Contrast enhanced CT done in an 8-month-old victim of non-accidental trauma showed arterial extravasation/pseudoaneurysm formation in the left lobe of the liver. (B) Common hepatic angiogram failed to show the extravasation/pseudoaneurysm. (C) Selective left hepatic artery injection via cannulation of an accessory left hepatic artery arising from the left gastric artery showed the site of extravasation. This was treated with gelatin sponge slurry embolization to good angiographic effect (not shown). Care was withdrawn due to significant intracranial injuries and the patient unfortunately passed shortly thereafter. Images courtesy of Dr. Keith Quencer. TAE, transarterial embolization [25].

Impact of comorbidities

Comorbidities can significantly influence the management and outcomes of liver trauma. Pre-existing conditions may affect a patient's physiological reserve, response to injury, and tolerance of various treatments. Additionally, certain comorbidities may increase the risk of complications following liver trauma. Pre-existing liver disease appears to be one of the most important pre-existing diseases influencing length of hospital stay and mortality [27].

Compromised Liver Function

Patients with pre-existing liver diseases, such as cirrhosis or hepatitis, may have impaired hepatic function, making them more susceptible to complications following liver trauma [28].

Coagulopathy

Coagulopathy, whether pre-existing or induced by liver injury, can complicate the management of liver trauma. Patients on anticoagulation therapy require careful monitoring to balance the risk of bleeding against the benefit of preventing thrombotic complications [1].

Other conditions

Hepatic hemangiomas, while often asymptomatic, can present with complications in some patients, especially when giant. The development of Kasabach-Merritt syndrome, Budd-Chiari syndrome, or other syndromes is more commonly observed in patients with some other conditions [26].

Outcomes of Cirrhotic Patient

Although liver disease has a prevalence of only 0.5% in the trauma population, it appears to be one of the most important pre-existing diseases influencing the length of hospital stay and mortality [27]. In cirrhotic patients undergoing trauma laparotomy, outcomes included mortality, complications, failure to rescue, transfusion requirements, and hospital and intensive care unit lengths of stay [29].

Non-operative management

Non-operative management of blunt liver trauma represents a safe and effective treatment for both minor and severe injuries, achieving a high success rate and an acceptable morbidity rate [6].

Further study

Despite advances in liver trauma management, several areas warrant further investigation.

Non-operative Management Optimization

While NOM has become increasingly prevalent, further research is needed to refine patient selection criteria and standardize treatment protocols [2]. Specifically, studies

should focus on identifying factors that predict successful NOM and those that indicate the need for intervention. Even borderline patients may be considered for NOM in well-developed trauma centers [1]. According to one study, the anatomical description of liver lesions is fundamental, but the decision on operative vs non-operative management is based mainly on hemodynamic status, associated injuries, and the anatomical liver injury grade [1].

Long-Term Outcomes

More comprehensive data on long-term outcomes after liver trauma are needed, including the impact of different management strategies on quality of life, chronic pain, and disability. Studies should also investigate the incidence and management of delayed complications such as bile leaks, biomass, and hepatic abscesses [25]. Mandatory late follow-up imaging is not generally indicated, and should be reserved for patients with clinical signs of complications [1].

Conclusion

Management of liver trauma is a multidisciplinary approach that prioritizes non-operative management as the first option for both adult and pediatric populations when feasible [1]. The best treatment option should be decided by considering clinical condition, anatomical injury grade, and associated injuries [1]. In hemodynamically stable patients, NOM of liver injury may be considered for every grade of lesion [21]. Many operative approaches can help stop bleeding and resolve biliary complications, avoiding or delaying strong surgery until local and systemic inflammatory responses are nearly resolved [21]. This approach may limit acute systemic evolving and chronic hepatic consequences of trauma [21]. A flawlessly orchestrated action of the multidisciplinary team is essential to promptly achieve the right decision, avoiding any delay in diagnosis, minimizing mortality and morbidity, and shortening hospital stay [21]. To reduce the stress response and subsequent immune suppression after trauma, it's crucial to minimize infection through adequate antibiotic prophylaxis and nutritional support to preserve homeostasis [21]. Reducing additional trauma from operative post-injury management is also essential [21].

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Conflict of Interest

All expenses related to the preparation of this manuscript were fully covered by the author.

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