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Article

The Burden of Liver Trauma in an Urban Trauma Centre in Johannesburg, South Africa

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Abstract: Background: Liver trauma is prevalent in blunt and penetrating injuries. This study examined liver trauma in a South African urban trauma centre, focusing on the unique prevalence of penetrating injuries and surgical interventions. Methods: A retrospective analysis was conducted on 512 priority one patients with liver trauma from January 2017 to December 2023 at Charlotte Maxeke Johannesburg Academic Hospital. The data collected included demographics, injury mechanisms, liver injury grades, associated injuries, Injury Severity Scores (ISS and NISS), surgical interventions, and mortality rates. Statistical analyses were performed using Stata and R software. Results: The median age of the patients was 31 years, with a predominance of male patients (91%) and of African ethnicity (95%). Penetrating trauma accounted for 73% of the cases. Most liver injuries were minor (grades I – III). There was an overall 5% mortality rate, with a higher rate observed in patients requiring emergency surgery (10% vs. 1% for non-operative management, $p < 0.001$). Just over half of the patients required emergency laparotomy, and the majority of these patients sustained penetrating liver trauma. Complications occurred in 6.6% of the patients, predominantly biliary in nature. Conclusions: This study highlights the high incidence of penetrating liver trauma in South Africa, which reflects the context of interpersonal violence. The mortality rate aligns with international standards and demonstrates the need for effective management strategies. These findings emphasise the need for tailored approaches to liver trauma based on injury patterns and demographics, and further research is needed to explore mortality and complications.

Keywords: liver trauma; penetrating; blunt; surgery; selective non-operative management; complications; mortality; associated injuries

1. Introduction

Liver trauma is very common following blunt and penetrating trauma to the lower chest and upper abdomen [1–3]. The liver is the most commonly injured organ in blunt abdominal trauma and the second most commonly injured organ in penetrating abdominal trauma [3–6]. The severity of penetrating liver injury depends on the trajectory of the missile or implement. Injuries can range from simple lacerations of the parenchyma to major vascular injuries [3].

Operative intervention for the management of liver injuries is needed in approximately 14% of patients, according to international literature. These are generally patients who initially present with hemodynamic instability, who fail non-operative management or require surgery for other intra-abdominal injuries [2,3,7–9].

Associated injuries to other organs occur in approximately 80% of patients with hepatic injury. The type of associated injuries is generally dependent on the mechanism of trauma. Patients with blunt trauma can have involvement of multiple organ systems, whereas in penetrating trauma, it is mostly surrounding structures that are injured [4–6].

The strategy used to manage liver injury depends on the patient's haemodynamic status, grade of liver injury, presence of other injuries, and medical comorbidities.

The haemodynamically unstable blunt trauma patient with a positive Focused Assessment with Sonography for Trauma (FAST) scan requires an emergent exploratory laparotomy to determine the source of intraperitoneal bleeding [6,9–12]. Patients with blunt liver injury who are haemodynamically stable and do not have other indications for exploratory laparotomy exploration can be observed. Haemodynamically stable patients with right-sided penetrating thoracoabdominal injuries that lacerate the liver can also be observed, provided that there are no associated intra-abdominal injuries. If there is any suspicion of an associated intra-abdominal injury in a penetrating trauma patient, based on the trajectory of the missile, clinical findings of peritonism, or scan findings, emergent laparotomy is mandated. Computed tomography (CT) is the preferred imaging modality to assess the severity of liver trauma and the presence or absence of other intra-abdominal injuries [6,7,9–11,13].

Complications related to liver trauma are most frequently biliary complications – bilomas, bile leaks, biliary peritonitis, and bile sepsis, which are estimated to occur in approximately 3.2% of all blunt liver trauma patients. In penetrating liver trauma, the complication rate has been reported to be 50 – 52% [6–8,14].

This study aimed to examine the burden of liver trauma in a busy urban trauma centre in South Africa. What makes this patient population unique is the significant number of patients who sustained liver injury due to penetrating injuries and the large number of patients who underwent surgical interventions. This is vastly different from the bulk of international data, which focuses on non-operatively managed blunt liver trauma.

2. Patients and Methods

Data were gathered retrospectively from all priority one patients presenting with liver trauma over a seven-year period from 1 January 2017 to 31 December 2023 at the Trauma Unit of Charlotte Maxeke Johannesburg Academic Hospital in Johannesburg, South Africa. A priority one (P1) patient was defined as a critically ill or injured patient requiring immediate attention, or an unstable patient with a potentially life-threatening injury or illness.

Data were collected regarding demographics, mechanism of injury, grade of liver injury, associated injuries to other body regions, associated intra-abdominal injuries, Injury Severity Score (ISS), New Injury Severity Score (NISS), need for emergency surgery, and mortality.

Ethical approval was obtained from the Human Research Ethics Committee of the University of the Witwatersrand.

All statistical analyses were conducted using Stata (V.18, Stata Corp, College Station, Texas, USA), R (version 4.3.2), and RStudio (2023.9.0.463) software. Continuous variables were expressed as means with standard deviations for normally distributed data and as median with interquartile range (IQR) for non-normally distributed data. Categorical variables were expressed as frequencies and percentages. Chi-square and Wilcoxon rank-sum tests were used to evaluate differences between categorical variables and differences in medians for continuous variables with p-values. The Wald test and Cox proportional hazard models were used to compute the statistical significance (p-value) of the differences between Kaplan-Meier survival curves and hazard ratios. Statistical significance was set at $P < 0.05$.

The severity of liver injury is reported using the organ injury scale (OIS) described by the American Association for the Surgery of Trauma (AAST) and were graded I – V based on CT scan or operative findings.[15]

3. Results

3.1. Demographics

Data were collected from 512 patients with complete medical records. The median age of the patients was 31 years (26 – 36). The majority of the patients (466, 91%) were male, and only 46 (9%) were female. Most patients were of African ethnicity.

Table 1. Demographic data of liver trauma patients.

Category	Characteristics	Number (%) or Median (IQR: Q1-Q3) n = 512
Age		31 (26-36)
Gender		
	Male	466 (91)
	Female	45 (9)
Ethnicity		
	African	484 (95)
	Coloured	4 (1)
	Indian	4 (1)
	Caucasian	3 (0.59)
	Asian	2 (0.39)
	Hispanic	1 (0.20)

3.2. Clinical Characteristics

Penetrating trauma to the liver was much more common than blunt trauma (73% vs. 27%). One patient experienced a combination of blunt and penetrating traumas. Of the 373 patients who sustained penetrating trauma, 212 (57%) sustained gunshot wounds, 160 (43%) were stabbed, and a sharp object impaled one.

In the blunt trauma cohort, the most common mechanism was road traffic collision, which accounted for 113 patients (82%). These were further subdivided into motor vehicle or motorcycle collisions, with 57 patients (41%) sustaining liver injuries secondary to this mechanism, and pedestrian-vehicle collisions accounting for liver injuries in 56 patients (41%). With respect to other blunt causes, 12 patients (9%) sustained a liver injury due to a fall from a height, blunt assault was the mechanism of injury in eight patients (6%), and five patients (4%) sustained liver trauma secondary to a heavy object falling on them.

Regarding the grade of liver injury, 65 patients (13%) sustained grade I liver injury, 171 patients (33%) sustained grade II liver injury, 187 patients (37%) sustained grade III liver injury, 79 patients (15%) sustained grade IV liver injury, and 10 patients (2%) sustained grade V liver injury.

The average ISS was 14 and the NISS was 19. The overall mortality rate was 5 %; blunt liver trauma patients had a 7% mortality rate compared to 5% in the penetrating trauma group ($p=0.796$). The mortality rate was 10% in the group that required emergency surgery compared with 1% in the group of patients managed non-operatively ($p < 0.001$).

Emergency laparotomy was performed in 261 (51 %) patients. Among penetrating trauma patients, 232 (62%) required surgery, while only 28 (20%) patients with blunt liver trauma required surgery ($p<0.0001$). A single patient with a combined mechanism of injury also underwent laparotomy.

Table 2. Clinical data of liver trauma patients.

Category	Characteristics	Number (%) or Median (IQR: Q1-Q3) n = 512
Blunt or penetrating mechanism		
	Penetrating	373 (73)
	Blunt	138 (27)
	Combination	1 (0.20)
Mechanism of injury		
	GSW	212 (41)
	Stab	160 (31)
	MVC/MBC	57 (11)
	PVC	56 (11)
	Fall from height	12 (2)
	Assault	8 (2)
	Heavy object falling on patient	5 (1)
	Impaled	1 (0.2)
Grade of liver injury		
	I	65 (13)
	II	171 (33)
	III	187 (37)
	IV	79 (15)
	V	10 (2)
ISS		14 (9-22)
NISS		19 (11-29)
Survival		
	Alive	484 (95)
	Dead	28 (5)
Surgery		
	Yes	261 (51)
	No	251 (49)

MVC – Motor Vehicle Collision, MBC – Motorbike Collision, PVC- Pedestrian Vehicle Collision, GSW – Gunshot Wound.

3.3. Associated Injuries

Of all patients with liver injuries, the majority (306 patients, 60%) had associated injuries.

Associated injuries to other body regions occurred in 80% of blunt trauma patients and 53% of penetrating trauma patients ($p < 0.0001$). A single patient with a combination of blunt and penetrating trauma had an associated traumatic brain injury.

The most common body area with associated injuries was the chest; overall, 30% of the patients sustained associated chest injuries. This was true for both blunt and penetrating trauma subgroups. Associated soft tissue injuries requiring surgical intervention occurred in 77 patients (15%); the majority of these were patients who experienced penetrating trauma. Twenty-five patients (4.8%) had associated traumatic brain injuries, the vast majority of which were in the blunt trauma group. Twenty-two patients (4.3%) had associated long bone fractures, 17 (3.3%) had associated spinal fractures, and 9 (1.8%) had associated pelvic fractures. Associated neck injuries were uncommon and were only observed in three patients (1%).

Associated intra-abdominal injuries occurred in 37% of patients with blunt mechanisms of injury and 64% of patients with penetrating trauma ($p < 0.0001$). A single patient with a combination of blunt and penetrating trauma had associated injury to the large bowel.

A total of 289 associated abdominal injuries were observed. In total, 114 (22%) patients had injuries to the abdominal wall or mesentery, requiring intervention. There were 51 patients (10%) with associated renal injuries, 45 (8.8%) had associated large bowel injuries, 41 (8%) had associated splenic injuries, and 28 (5.5%) had associated small bowel injuries. Intra-abdominal vascular injuries occurred in 10 (2%) patients.

Associated injuries to the spleen were the most common in the blunt trauma subgroup, while injuries to the mesentery or abdominal wall requiring repair were the most common in the penetrating trauma subgroup.

3.4. Complications

There were 34 complications in 33 patients; thus, the complication rate was 6.6% (one patient had two complications). Among the total number of complications, localised bile leak was the most common complication in 14 patients (2.7%), followed by abscess formation in seven patients (1.4%). Vascular complications occurred in 6 patients (1.2%); biliopleural fistulae occurred in 3 patients (0.6%); these were all patients who sustained penetrating trauma to the right upper quadrant. Three patients (0.6%) developed necrosis of the injured portion of the liver, one patient (0.2%) developed a very large subcapsular haematoma, and one patient (0.2%) developed biliary peritonitis.

Complications occurred more commonly in patients who required surgical management of their liver injuries (11.1% vs. 2%, $p < 0.0001$). Complications were more common in patients who sustained penetrating trauma (7.8%) than in those who sustained blunt trauma (3.6%) but not statistically significant ($p = 0.09$).

Table 3. Associated injuries and complications.

Associated injuries of other body regions				
Body region	Number (%) n = 512	Blunt trauma n = 138	Penetrating trauma n = 373	Combination n = 1
Chest injury	153 (30)	44 (32)	109 (29)	0
Soft tissue injury requiring surgical intervention	77 (15)	4 (2.9)	73 (20)	0
Traumatic brain injury	25 (4.8)	23 (17)	1 (0.3)	1 (100)
Long bone injury	22 (4.3)	19 (14)	3 (0.8)	0
Spine injury	17 (3.3)	7 (5)	10 (2.7)	0

Pelvic injury	9 (1.8)	9 (6.5)	0	0
Neck injury (excluding C-spine)	3 (0.6)	3 (2.2)	0	0
Associated intra-abdominal injuries				
Organ injured	Number (%) n = 512	Blunt trauma (%) n = 138	Penetrating trauma (%) n = 373	Combination (%) n = 1
Abdominal wall/mesentery requiring intervention	114 (22)	5 (3.6)	109 (29)	0
Kidney	51 (10)	17 (12)	34 (9.1)	0
Large bowel	45 (8.8)	3 (2.2)	42 (11)	1 (100)
Spleen	41 (8)	24 (17)	17 (4.6)	0
Small bowel	28 (5.5)	3 (2.2)	25 (6.7)	0
Intra-abdominal vascular	10 (2)	0	10 (2.9)	0
Complications related to liver trauma				
Complication	Total (%) n = 512	Blunt trauma (%) n = 138	Penetrating trauma (%) n = 373	Combination (%) n = 1
Total	34 (6.6)	5 (3.6)	29 (7.8)	0
Localised bile leak	14 (2.7)	0	14 (3.8)	0
Abscess	7 (1.4)	0	7 (1.9)	0
Vascular	6 (1.2)	3 (2.2)	3 (0.8)	0
Necrosis	3 (0.6)	1 (0.7)	2 (0.5)	0
Biliopleural fistula	3 (0.6)	0	3 (0.8)	0
Biliary peritonitis	1 (0.2)	1 (0.7)	0	0

4. Discussion

The protocol for management of liver trauma patients in this unit was initial assessment and resuscitation according to ATLS® principles.[16] Patients with blunt trauma who had free fluid on FAST examination and were haemodynamically unstable or patients with peritonism underwent exploratory laparotomy without the routine performance of a CT scan. Stable patients and those who responded to initial fluid resuscitation underwent a CT scan where the grade of the liver injury and the presence of other intra-abdominal injuries were determined. Isolated solid organ injuries in haemodynamically stable patients are routinely managed nonoperatively. At our institution, emergency access to interventional radiology was not available over weekends and after hours and rarely during working hours; therefore, all unstable patients underwent surgery.

Patients with penetrating abdominal trauma with evidence of peritoneal penetration, haemodynamic instability, or peritonitis underwent exploratory laparotomy without the routine performance of a CT scan. The only exception to this rule would be a haemodynamically stable patient without peritonism, who has an isolated penetrating wound in the right upper quadrant. If

the CT scan showed no signs of injury to other intra-abdominal organs, these patients were managed nonoperatively. All patients with high-grade liver injuries (grades IV and V) were observed in the ICU setting.

Most patients who sustained liver trauma were of African ethnicity, which correlates with the demographics of the population living in the catchment area of Charlotte Maxeke Johannesburg Academic Hospital. Liver trauma was also mainly seen in male patients which mirrors the overall trend of trauma being more common in males [17–21]. The median age of patients who sustained liver trauma in this study was 31 years. This again mirrors global trends, where a disproportionate number of traumatic injuries occur in young males, with trauma being the leading cause of death in patients younger than 35 years [21,22].

Blunt trauma is the most common cause of liver trauma globally, with literature from Europe, the United Kingdom, the Far East, India, and Scandinavia showing a preponderance of blunt hepatic trauma [21–30]. Guidelines from the Eastern Association for the Surgery of Trauma and the Western Trauma Association in the United States focus solely on blunt hepatic trauma, with no similar guidelines on penetrating liver trauma published by these societies [6,9]. Our study showed a significant preponderance of penetrating liver trauma, which is very different from the global trends. The only other region in the world that seems to have a preponderance of penetrating rather than blunt liver trauma is South America [31,32].

South Africa has long been known as one of the most violent countries in the world, with a very high incidence of interpersonal and gun violence. Efforts have been made to make access to firearms stricter by introducing the Firearms Control Act (FCA) (Act 69, 2000). This was initially very successful in reducing the rate of firearm-associated homicides; however, since 2011, the firearm-related mortality rate has been steadily increasing again which is due to a combination of relaxation of the strict licencing conditions of the FCA and police corruption that allowed increased availability of unlicensed firearms [33,34].

In the penetrating trauma subgroup, gunshot wounds were more prevalent than were stab wounds. Most blunt trauma cases occur secondary to road traffic collisions. When looking at the incidence of liver trauma secondary to interpersonal violence, by combining the injuries secondary to stabbing, gunshots and assault, 74% of patients sustained liver trauma secondary to interpersonal violence. The predominance of Grade I-III injuries (83%) mirrors the international findings [10,12,23,24,32].

The fact that the average NISS was higher than the median ISS (19 versus 14) may, in part, be because 56% of the patients sustained associated abdominal injuries and there was a high incidence of penetrating trauma in our study (73%).

The all-cause mortality rate was 5% in the study group. This mortality rate is on par with, and in some cases, lower than, what is reported in a number of local and international studies and reflects well on the appropriateness of our institution's approach to liver trauma [35–39]. Although there was a slightly higher mortality rate in the penetrating trauma group than in the blunt trauma group (7% vs. 5%), the difference was not statistically significant ($p=0.796$). The mortality rate was 10% in the group that required emergency surgery compared with 1% in the group of patients managed non-operatively ($p < 0.001$). There could be many factors that contribute to this, including the fact that these patients may have been more physiologically unwell or had more severe liver injuries. Further subgroup analyses regarding factors contributing to mortality need to be conducted to draw meaningful conclusions.

Modern management of liver trauma is increasingly moving to non-operative management in haemodynamically stable patients, and good guidelines exist regarding selective non-operative management of blunt liver trauma [6,7,9,37]. There is also a significant shift happening towards selective non-operative management of penetrating liver trauma provided that the patient is stable, the patient is not peritonitic and high-quality cross-sectional imaging excludes hollow viscus injury [14,27,38,40–42]. Some guidelines also recommend that selective nonoperative management should

only be considered in low-energy penetrating trauma (stab wounds and gunshots due to handguns) [7].

The proportion of patients with liver injuries who require emergency laparotomy is not always easy to determine because many studies do not differentiate between blunt and penetrating injuries. However, this may be because penetrating trauma is rare in certain parts of the world. In mixed cohorts, surgery is required in 20 – 30% of patients who sustain liver trauma. When comparing the need for surgery in blunt versus penetrating liver trauma, 23 – 32% of patients with blunt liver trauma and 74 – 83% of patients who sustained penetrating liver trauma required surgery [35–38]. In our study, 51% of patients required laparotomies. More patients with penetrating liver trauma required surgery (62%), which was a statistically significant difference from those who sustained blunt liver trauma. This compares favourably with the rate of emergency surgery described in other sources, as stated above. The higher rate of surgery for penetrating trauma is possibly linked to the fact that associated intra-abdominal injury occurred in 64% of the patients who sustained penetrating liver trauma.

Associated injuries to other organ systems are frequently seen in many patients who have sustained blunt liver injuries, as these are often polytraumatised [23,25,35]. This finding was mirrored in our data, where 80% of blunt liver trauma patients sustained a concomitant injury to at least one other organ system compared to 53% of penetrating liver trauma patients who sustained a concomitant injury to another organ system ($p < 0.0001$). The high number of associated injuries in the penetrating trauma subgroup was mainly due to chest injuries resulting from either multiple penetrating injuries or a thoracoabdominal penetrating injury, as well as soft tissue injuries requiring surgical intervention. Injuries to organ systems other than these were rare in the penetrating trauma subgroup.

Injuries to other abdominal solid organs were the most common associated intra-abdominal injuries in the blunt trauma subgroup, with very few injuries to a hollow viscus. Although associated abdominal wall or mesenteric injuries requiring intervention were the most common injuries in the penetrating trauma group, hollow visceral injuries were also quite common in this group. All associated intra-abdominal vascular injuries occurred in the penetrating trauma group.

Biliary complications were the most common, occurring in 3.5% of patients in our study, with an overall complication rate of 6.6%. The most common complications related to liver trauma are biliary complications including bilomas, bile leaks, biliary peritonitis, and bile sepsis. These are estimated to occur in approximately 3.2 - 7% of all patients with blunt liver trauma. In penetrating liver trauma, the complication rate has been reported to be 50 – 52%. Intrahepatic abscesses can occur after liver trauma, mostly in high-grade injuries, at a rate of 0.6 – 7%. Our results were comparable to those reported in the literature. Vascular complications in the form of pseudoaneurysms or arteriovenous fistulae, as well as large subcapsular haematomas that may lead to secondary haemorrhage, are less common at a rate of 1.7 – 5.9%. Hepatic necrosis is a rare complication, as noted in only three in our cohort. In general, some studies estimate that complications occur in 12 – 14% of patients after liver trauma [6–8,14,36,43].

Complications occurred significantly more frequently in the patients who underwent surgical management of liver trauma. This may be because these patients were more likely to have higher-grade liver injuries, but further analysis of the data needs to be performed before any conclusions can be made. Complications occurred more than twice as commonly in patients who sustained penetrating trauma, but the difference was not statistically significant.

A potential explanation for why all cases of localised bile leaks were reported in the group of patients who suffered penetrating trauma may be that these patients underwent surgery where drains were left around the liver injury. This means that even a small bile leak would have been identified in contrast with non-operatively managed blunt trauma patients, where small bile leaks that resolve spontaneously would not be diagnosed. This needs to be further investigated to reach any conclusions.

5. Conclusions

In conclusion, this study provides valuable insights into the management and outcomes of liver trauma in a low-middle-income country. The findings revealed a unique preponderance of penetrating liver trauma, reflecting the high rates of interpersonal violence in South Africa. Despite this challenging context, the mortality rate of 5% is comparable to or lower than the international standards, indicating the effectiveness of the institution's approach. This study highlights the successful implementation of non-operative management in suitable cases, while also demonstrating the necessity for surgical intervention in a significant proportion of patients, particularly those with penetrating injuries. The complication rates observed are favourable compared to those reported in the international literature, with biliary complications being the most common. These results underscore the importance of tailored management strategies based on specific injury patterns and patient demographics across different regions. Further research is warranted to explore the factors contributing to mortality and complications, which could lead to improvements in liver trauma management protocols.

Limitations of the Study

This was a retrospective single-centre study, which was open to bias. There was no long-term follow-up of the cases, and some late complications may have been missed. The high prevalence of penetrating mechanisms may have introduced bias into the data. There is a need for a multicentre prospective study on liver trauma in a low-middle-income environment.

References

1. Croce MA FT, Menke PG, Waddle-Smith L, Minard G, Kudsk KA, Patton JH Jr, Schurr MJ, Pritchard FE. 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.
2. Malhotra AK FT, Croce MA, Gavin TJ, Kudsk KA, Minard G, Pritchard FE. Blunt hepatic injury: a paradigm shift from operative to nonoperative management in the 1990s. *Ann Surg.* 2000;231(6):804-13.
3. Tinkoff G ET, Reed J, Kilgo P, Fildes J, Pasquale M, Meredith JW. American Association for the Surgery of Trauma Organ Injury Scale I: spleen, liver, and kidney, validation based on the National Trauma Data Bank. *J Am Coll Surg.* 2008;207(5):646-55.
4. Kozar RA MF, Moore EE, West M, Cocanour CS, Davis J, Biffl WL, McIntyre RC Jr. Western Trauma Association critical decisions in trauma: nonoperative management of adult blunt hepatic trauma. *J Trauma.* 2009;67(6):1144-8.
5. Hurtuk M, Reed RL, 2nd, 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.
6. Stassen NA, Bhullar I, Cheng JD, Crandall M, Friese R, Guillaumondegui O, et al. Nonoperative management of blunt hepatic injury: an Eastern Association for the Surgery of Trauma practice management guideline. *J Trauma Acute Care Surg.* 2012;73(5 Suppl 4):S288-93.
7. Coccolini F, Coimbra R, Ordonez C, Kluger Y, Vega F, Moore EE, et al. Liver trauma: WSES 2020 guidelines. *World J Emerg Surg.* 2020;15(1):24.
8. Coccolini F, Montori G, Catena F, Di Saverio S, Biffl W, Moore EE, et al. Liver trauma: WSES position paper. *World J Emerg Surg.* 2015;10:39.
9. Keric N, Shatz DV, Schellenberg M, de Moya M, Moore LJ, Brown CVR, et al. Adult blunt hepatic injury: A Western Trauma Association critical decisions algorithm. *J Trauma Acute Care Surg.* 2024;96(1):123-8.
10. Peitzman AB, Richardson JD. Surgical treatment of injuries to the solid abdominal organs: a 50-year perspective from the Journal of Trauma. *J Trauma.* 2010;69(5):1011-21.
11. 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.
12. Piper GL, Peitzman AB. Current management of hepatic trauma. *Surg Clin North Am.* 2010;90(4):775-85.

13. 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.
14. Demetriades D, Hadjizacharia P, Constantinou C, Brown C, Inaba K, Rhee P, et al. Selective nonoperative management of penetrating abdominal solid organ injuries. *Ann Surg*. 2006;244(4):620-8.
15. Kozar RA, Crandall M, Shanmuganathan K, Zarzaur BL, Coburn M, Cribari C, et al. Organ injury scaling 2018 update: Spleen, liver, and kidney. *J Trauma Acute Care Surg*. 2018;85(6):1119-22.
16. American College of Surgeons Committee on Trauma. *Advanced Trauma Life Support (ATLS) Student Course Manual*. 10 ed. Chicago: American College of Surgeons; 2018.
17. Dimich-Ward H, Guernsey JR, Pickett W, Rennie D, Hartling L, Brison RJ. Gender differences in the occurrence of farm related injuries. *Occup Environ Med*. 2004;61(1):52-6.
18. Santamarina-Rubio E, Perez K, Olabarria M, Novoa AM. Gender differences in road traffic injury rate using time travelled as a measure of exposure. *Accid Anal Prev*. 2014;65:1-7.
19. Sjogren H, Valverius P, Eriksson A. Gender differences in role of alcohol in fatal injury events. *Eur J Public Health*. 2006;16(3):267-71.
20. Turner C, McClure R. Age and gender differences in risk-taking behaviour as an explanation for high incidence of motor vehicle crashes as a driver in young males. *Inj Control Saf Promot*. 2003;10(3):123-30.
21. Soreide K. Epidemiology of major trauma. *Br J Surg*. 2009;96(7):697-8.
22. Polinder S, Meerding WJ, Mulder S, Petridou E, van Beeck E, Group ER. Assessing the burden of injury in six European countries. *Bull World Health Organ*. 2007;85(1):27-34.
23. Chien LC, Lo SS, Yeh SY. Incidence of liver trauma and relative risk factors for mortality: a population-based study. *J Chin Med Assoc*. 2013;76(10):576-82.
24. Gao JM, Du DY, Zhao XJ, Liu GL, Yang J, Zhao SH, et al. Liver trauma: experience in 348 cases. *World J Surg*. 2003;27(6):703-8.
25. Scollay JM, Beard D, Smith R, McKeown D, Garden OJ, Parks R. Eleven years of liver trauma: the Scottish experience. *World J Surg*. 2005;29(6):744-9.
26. Sinha Y, Khajanchi MU, Prajapati RP, Dharap S, Soni KD, Kumar V, et al. Management of liver trauma in urban university hospitals in India: an observational multicentre cohort study. *World J Emerg Surg*. 2020;15(1):58.
27. Stormann P, Gartner K, Wyen H, Lustenberger T, Marzi I, Wutzler S. Epidemiology and outcome of penetrating injuries in a Western European urban region. *Eur J Trauma Emerg Surg*. 2016;42(6):663-9.
28. Treska V, Skalicky T, Houdek K, Smid D. Diagnosis and treatment of liver injury--the experience of the University Trauma Center. *Bratisl Lek Listy*. 2008;109(1):10-3.
29. Whittaker G, Norton J, Densley J, Bew D. Epidemiology of penetrating injuries in the United Kingdom: A systematic review. *Int J Surg*. 2017;41:65-9.
30. Wiik Larsen J, Soreide K, Soreide JA, Tjosevik K, Kvaloy JT, Thorsen K. Epidemiology of abdominal trauma: An age- and sex-adjusted incidence analysis with mortality patterns. *Injury*. 2022;53(10):3130-8.
31. Kalil M, Amaral IM. Epidemiological evaluation of hepatic trauma victims undergoing surgery. *Rev Col Bras Cir*. 2016;43(1):22-7.
32. Zago TM, Pereira BM, Nascimento B, Alves MS, Calderan TR, Fraga GP. Hepatic trauma: a 21-year experience. *Rev Col Bras Cir*. 2013;40(4):318-22.
33. Matzopoulos R, Prinsloo M, Bradshaw D, Abrahams N. Reducing homicide through policy interventions: The case of gun control. *S Afr Med J*. 2019;109(11b):63-8.
34. Prinsloo M, Mhlongo S, Roomaney RA, Marineau L, Mamashela TA, Dekel B, et al. Injury mortality in South Africa: a 2009 and 2017 comparison to track progress to meeting sustainable development goal targets. *Glob Health Action*. 2024;17(1):2377828.
35. Afifi I, Abayazeed S, El-Menyar A, Abdelrahman H, Peralta R, Al-Thani H. Blunt liver trauma: a descriptive analysis from a level I trauma center. *BMC Surg*. 2018;18(1):42.
36. Barbier L, Calmels M, Lagadec M, Gauss T, Abback PS, Cauchy F, et al. Can we refine the management of blunt liver trauma? *J Visc Surg*. 2019;156(1):23-9.
37. Bonny P, Bogaert C, Abreu de Carvalho LF, Gryspeerdt F, Eker H, Hermie L, et al. Evolution in liver trauma management: a single centre experience. *Acta Chir Belg*. 2024;124(6):466-77.

38. Keizer AA, Arkenbosch JHC, Kong VY, Hoencamp R, Bruce JL, Smith MTD, et al. Blunt and Penetrating Liver Trauma have Similar Outcomes in the Modern Era. *Scand J Surg*. 2021;110(2):208-13.
39. Hommes M, Navsaria PH, Schipper IB, Krige JE, Kahn D, Nicol AJ. Management of blunt liver trauma in 134 severely injured patients. *Injury*. 2015;46(5):837-42.
40. Fikry K, Velmahos GC, Bramos A, Janjua S, de Moya M, King DR, et al. Successful selective nonoperative management of abdominal gunshot wounds despite low penetrating trauma volumes. *Arch Surg*. 2011;146(5):528-32.
41. Saar S, Jorgensen J, Lemma AN, Gaarder C, Naess PA, Leppaniemi A, et al. Selective non-operative management of penetrating abdominal injuries at Northern European trauma centers: the NordiPen Study. *Eur J Trauma Emerg Surg*. 2022;48(3):2023-7.
42. MacGoey P, Navarro A, Beckingham IJ, Cameron IC, Brooks AJ. Selective non-operative management of penetrating liver injuries at a UK tertiary referral centre. *Ann R Coll Surg Engl*. 2014;96(6):423-6.
43. Fischer N, Bartlett A. Surveillance imaging following liver trauma has a low detection rate of liver complications. *Injury*. 2022;53(1):86-91.

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