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AAST grade of liver injury is not the single most important consideration in decision making for liver trauma

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ABSTRACT

Background: The liver is one of the most injured organs in both blunt and penetrating trauma. The aim of this study was to identify whether the AAST liver injury grade is predictive of need for intervention, risk of complications and mortality in our patient population, and whether this differs between blunt and penetrating-trauma mechanisms.

Methods: Retrospective review of all liver injuries from a single high-volume metropolitan trauma centre in South Africa from December 2012 to January 2022. Inclusion criteria were all adults who had sustained traumatic liver injury. Patients were excluded if they were under 15 years of age or had died prior to operation or assessment. Statistical analysis was undertaken using both univariate and multivariate models.

Results: 709 patients were included, of which 351 sustained penetrating and 358 blunt trauma. Only 24.3 % of blunt compared to 76.4 % of penetrating trauma patients underwent laparotomy ($p< 0.001$). In blunt trauma, increasing AAST grade correlated directly with rates of laparotomy with an odds ratio of 1.7 ($p < 0.001$). In penetrating trauma, there was no statistical significance between increasing AAST grade and the rate of laparotomy. The rate of bile leak was 4.5 % (32/709) and of rebleed was 0.7 % (5/709). Five patients underwent ERCP and endoscopic sphincterotomy for bile leak, and three required angio-embolization for rebleeding. Increasing AAST grades were significantly associated with the odds of bile leak in both blunt and penetrating trauma. There was a statistically significant increase in the odds of a rebleed with increasing AAST grade in penetrating trauma. Five patients rebled, of which three died. Seven patients developed hepatic necrosis. Seventy-six patients died (10 %). There were 34/358 (9 %) deaths in the blunt cohort and 42 /351 (11 %) deaths in the penetrating trauma cohort.

Conclusion: AAST grade in isolation is not a good predictor of the need for operation in hepatic trauma. Increasing AAST grade was not found to correlate with increased risk of mortality for both blunt and penetrating hepatic trauma. In both blunt and penetrating trauma, increasing AAST grade is significantly associated with increased bile leak. The need for ERCP and endoscopic sphincterotomy to manage bile leak in our setting is low. Similarly, the rate of rebleeding and of angioembolization was low.

Background

The liver is the most-commonly injured intra-abdominal organ in blunt trauma and the second-most commonly injured organ following penetrating abdominal trauma [1–5]. The American Association for the Surgery of Trauma (AAST) liver injury grading system was first described by Moore et al. in 1989[6] and most recently updated in 2018 [7]. It is an anatomic and/or radiographic description of the extent of organ injury, stratifying injuries into five grades. A grading system should correlate with clinical course and outcome if it is to be clinically

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applicable. As the grade of injury increases the need for intervention as well as the rate of morbidity and mortality should increase in tandem [2]. Since the development of the AAST grading system there have been changes in the approach to liver trauma. A shift toward non-operative management (NOM) of liver injuries has occurred over the past three decades. This has been enabled by the ubiquitous availability of Computed Tomography (CT) scanning[5]. It is now well established that most hepatic injuries are low grade and can be managed non-operatively. Increasingly this is applied to higher grades of injury. The management of penetrating liver trauma has also changed dramatically. Following seminal reports from South Africa 1986[8,9], the safety and efficacy of selective non-operative management of penetrating liver trauma has been established by numerous reports, predominantly from the USA and also from South Africa[3,8–21]. These changes in the management of liver trauma have occurred in conjunction with other major changes in the resuscitation of trauma patients. This includes damage control resuscitation and surgery and the availability of interventional radiology. Considering these changes in the approach to liver trauma and the realization that blunt and penetrating mechanisms of trauma are not analogous it is imperative that we continue to accrue and review clinical data on liver trauma. The aim of this study was to identify whether the AAST liver injury grade predicts the need for intervention, risk of liver specific complications and mortality in our patient population, and whether this differs between blunt and penetrating traumatic mechanisms.

Study setting and the management of hepatic trauma by the pietermaritzburg metropolitan trauma service

The Pietermaritzburg Metropolitan Trauma Service (PMTS), based in the city of Pietermaritzburg, South Africa, is based at Grey's Hospital. Grey's Hospital has a catchment population of 3 million from the western part of the province of KwaZulu-Natal.

All patients with blunt torso trauma are resuscitated and are either expedited directly to the operating room due to haemodynamic instability or peritonitis, or undergo a CT scan. If imaged, the injury is graded, and the patient is selected for non-operative management based on the CT findings and patient's clinical condition. The AAST grade alone is not considered sufficient evidence to choose either operative or non-operative management.

Patients who present with a gunshot wound to the torso are resuscitated. Those with peritoneal irritation or haemodynamic instability are expedited to the operating room. A subset of patients are imaged whilst in transit to the operating room. These "drive by CT scans" may provide useful information which may allow the surgeon to limit the extent of surgery or focus to the area of concern. Clinical judgement is important in selecting those patients in whom a CT scan in transit to the operating room is appropriate. If the patient is haemodynamically stable and does not have evidence of peritoneal irritation, then a CT scan of the torso is routine. CT scan will delineate the trajectory of a bullet, demonstrate free air, and identify solid visceral injury.

Stab wounds of the torso are managed clinically. Patients with peritoneal irritation and/or haemodynamic instability are expedited to the operating room. If there is any clinical concern for a possible cardiac injury a FAST scan of the thorax will exclude hemopericardium. In the absence of an indication for surgery, the patient be admitted for serial abdominal examination.

Methods

This is a retrospective review of all liver injuries from a single high-volume trauma centre in South Africa, using data from a prospectively collected trauma registry, from December 2012 to January 2022. Inclusion criteria were all adults (15 years or older) who had sustained a traumatic liver injury. Patients were excluded if they were under 15 years of age or if they died prior to operation or radiographic assessment. Data collected included demographic details of age and sex; mean arterial pressure and heart rate at presentation, temperature, Glasgow Coma Scale (GCS), Injury Severity Score (ISS), American Association for the Surgery of Trauma (AAST) grade of liver injury, surgery undertaken, all-cause in-hospital mortality and liver-specific complications (rebleed, bile leak, necrosis).

AAST grade was determined by either the reporting radiologist in the case of CT scan, or at the time of operation. Discrepancies between radiological reports and operative findings were resolved by consensus decision. Statistical analysis was undertaken using both univariate and multivariable models. For multivariable analysis, the confounding variables adjusted for were mean arterial blood pressure, heart rate, temperature, Glasgow Coma Score, Injury Severity Score (ISS), and Abbreviated Injury Scale (AIS). Binary logistic regression models were analysed separately for each outcome listed. Linearity of AAST grade was checked using Box-Tidwell transformation. A backward stepwise method was used with entry and removal probabilities set to 0.05 and 0.1 respectively.

Results

A total of 713 patients met the inclusion criteria. Four patients were subsequently excluded from the analysis due to having sustained both penetrating and blunt mechanisms of injury leaving a total of 709 patients for analysis. The average age was 33 (range 15 – 86) and 83.5 % were male, 351 patients had a penetrating mechanism (49.3 %); of these, 182 (53.7 %) were gunshot wounds (GSW) and 163 (46.8 %) stab wounds, with three patients being both stabbed and shot and 4 having an unknown mechanism. A total of 358 patients were injured by a blunt mechanism; including 154 motor vehicle collision (MVC), 90 pedestrian-vehicle collision (PVC), 49 assaults, 31 falls, 5 crush injuries, seven struck by a blunt projectile, six motorbike collisions (MBC), two animal-related injuries, three pedestrians injured by a train, one blast injury, and ten unknown mechanisms. Patient demographic details are shown in Table 1. There was no difference between the two groups in terms of mean age ($p = 0.075$). There was a statistically significant difference in sex between the groups with females being more likely to have blunt injuries and males making up 83.4 % of all patients across the series ($p < 0.001$).

The number of patients, stratified by AAST grade and mechanism of injury, is shown in Table 2. Grade II was the most common injury grade across both mechanisms. There was no significant difference in distribution of AAST grades for blunt compared to penetrating trauma ($p = 0.334$). The number of patients undergoing laparotomy differed significantly between blunt and penetrating mechanisms, with 24.3 % of blunt compared to 76.4 % of penetrating trauma patients undergoing laparotomy. As shown in Table 3, the need for laparotomy in patients with blunt trauma was significantly associated with increasing AAST grade. When controlling for other variables, the odds of laparotomy increased by 1.6 times (95 % CI 1.2 to 2.1) for each increase in AAST grade ($p = 0.001$). Conversely, in the penetrating trauma group, increasing AAST grade was protective for increased need for operation (OR 0.62, 95 % CI 0.44 to 0.88, $p = 0.008$). The odds of operation decreased by 38 % for every increase in AAST grade after adjusting for confounders.

Table 1
Patient characteristics on admission, mean (range).

Characteristic	Blunt	Penetrating
Age	33 (15 - 86) $n = 351$	32 (15 - 79) $n = 349$
MAP (mmHg)	98 (36 - 149) $n = 353$	88 (0 - 196) $n = 348$
HR (bpm)	98 (51 - 196) $n = 353$	95 (0 - 168) $n = 351$
Temp (°C)	36.3 (32.1 - 38.6) $n = 358$	37.2 (32.2 - 39.0) $n = 351$
GCS	12 (3 - 15) $n = 349$	14 (3 - 15) $n = 341$
ISS	18 (1 - 66) $n = 358$	15 (1 - 50) $n = 351$

MAP – Mean Arterial Pressure; HR – Heart Rate; GCS – Glasgow Coma Scale; ISS – Injury Severity Score.

Table 2
Number of patients, stratified by AAST liver injury grade and mechanism of injury.

AAST Grade	Blunt, n (%)	Penetrating, n (%)	All, n (%)
1	69/358 (19.3 %)	65/351 (18.5 %)	134/709 (18.9 %)
2	138/358 (38.5 %)	152/351 (43.3 %)	290/709 (40.9 %)
3	93/358 (26.0 %)	93/351 (26.5 %)	186/709 (26.2 %)
4	51/358 (14.2 %)	37/351 (10.5 %)	88/709 (12.4 %)
5	7/358 (2.0 %)	4/351 (1.1 %)	11/709 (1.6 %)
Total	358	351	709

Table 3
Number of patients undergoing laparotomy of each AAST grade liver injury, stratified by type of traumatic mechanism, and adjusted association between AAST grade and laparotomy for each type of traumatic mechanism.

AAST Grade	Blunt mechanism, n (%) $N = 358$	Penetrating mechanism, n (%) $N = 351$
1	8/69 (11.6 %)	49/65 (75.4 %)
2	24/138 (17.4 %)	118/152 (77.6 %)
3	34/93 (36.6 %)	72/93 (77.4 %)
4	16/51 (31.3 %)	26/37 (70.3 %)
5	5/7 (71.4 %)	3/4 (75.0 %)
Adjusted Odds ratio (95 % CI)	1.6 (1.2–2.1) $p = 0.001$ $n = 344$	0.62 (0.44–0.88) $p = 0.008$ $n = 337$

A total of 76 patients died (10 %). There were 34/358 (9 %) deaths in the blunt cohort and 42 /351 (11 %) deaths in the penetrating trauma cohort. Univariate analysis of penetrating trauma showed a significant association between increasing AAST grade and mortality. With every increase in AAST grade the odds of mortality increased 1.7 times (95 % CI 1.2 to 2.4) ($p = 0.003$). However, as shown in Table 4, after adjusting for confounders, AAST grade alone did not correlate with mortality (OR 1.1, 95 % CI 0.7 to 1.8). Additionally, in those with penetrating trauma, Mean Arterial Pressure (MAP) on presentation was found to be significantly associated with mortality. With an increasing MAP on arrival, the odds of mortality decreased by 0.98 ($p = 0.03$). This association was not present in the blunt trauma group. When comparing rates of mortality with increasing AAST grade in the blunt trauma group, there was a non-statistically significant relationship (OR 1.3, CI 0.9 to 1.9).

Of the 355 patients who underwent laparotomy, 91 (25.6 %) had a pre-operative CT scan. This cohort was reviewed to compare operative and CT grading. In a single patient the operative findings were poorly documented and this patient was excluded. In the remaining patients 81/90 (90 %) the CT and operative AAST grade corresponded. In the remaining 9/90 the operative and CT grading differed by a single grade. CT scan compared to operative grading had a higher grade in four, and a lower grade in five patients.

As shown in Table 5, 44 patients developed a liver specific complication. These included bile leaks in 32 patients, re-bleeding in five patients and seven patients developed liver necrosis. Blunt and penetrating trauma patients were analysed together due to the small numbers of events. Increasing AAST grade was associated with increased odds of a rebleed (OR 4.4, 95 % CI 1.2 to 15.7, $p = 0.024$). With each increase in AAST grade the odds of rebleed increased by 4.4 times. Bile leaks also increased as AAST grade increased, for every increase in AAST grade, the odds of bile leaks increased by 1.5 times (95 % CI 1.0 to 2.3) ($p = 0.042$). There was no association between increasing AAST grade with respect to liver necrosis. Interventional radiology was sparingly available during the study period and only 3 patients underwent angiography and embolization.

Table 4
Mortality rate of patients stratified by AAST grade of liver injury and type of traumatic mechanism, and adjusted association between AAST grade and mortality for each type of traumatic mechanism.

AAST Grade	Blunt, n (%) $N = 358$	Penetrating, n (%) $N = 351$
1	6/69 (8.7 %)	4/65 (6.2 %)
2	14/138 (10.1 %)	13/152 (8.6 %)
3	8/93 (8.6 %)	16/93 (17.2 %)
4	5/51 (9.8 %)	8/37 (21.6 %)
5	1/7 (14.3 %)	1/4 (25.0 %)
Odds ratio (95 % CI)	1.1 (0.7–1.8) $p = 0.576$ $n = 352$	1.3 (0.9–1.9) $p = 0.213$ $n = 338$

Table 5
Number of liver specific complications, by AAST grade of liver injury, and adjusted association between AAST grade and complication both blunt and penetrating injuries.

AAST Grade	Rebleed, n $N = 709$	Bile leak, n $N = 709$	Liver necrosis, n $N = 709$
1	0/134	0/134	0/134
2	0/290	13/277	1/289
3	3/183	11/175	4/182
4	1/87	8/80	2/86
5	1/10	0/11	0/11
Odds ratio (95 % CI)	4.4 (1.2–15.7) $p = 0.024$, $n = 684$	1.5 (1.0–2.3) $p = 0.042$, $n = 684$	1.6 (0.8–3.4) $P = 0.207$, $n = 684$

Discussion

This series highlights several issues in the management of liver trauma, which must be considered in conjunction with AAST grade of injury. Blunt and penetrating hepatic injuries are not analogous. In the management of blunt hepatic trauma, increasing AAST grade of injury correlates with both increased need for intervention and increased morbidity. Mortality in this group is not directly correlated with AAST grade as it may be secondary to remote injury to the CNS.

With penetrating liver trauma, the need for laparotomy is determined by the potential for other hollow visceral injury rather than the AAST grade of liver injury. The mechanism (GSW vs SW) of injury, the presence of shock or peritonitis, and the potential for other extra-hepatic injuries determine the need for surgery. In the penetrating trauma subgroup, 76 % of patients required operation and increasing AAST grade did not correlate with the need for operation. As detailed above, in our centre, patients with penetrating abdominal trauma proceeded directly to laparotomy in the presence of peritonitis, haemodynamic instability, evisceration, enteric content in the wound, or evidence of fascial breach on clinical assessment. In the absence of these findings, patients with a torso GSW will proceed to CT scan. Patients with penetrating liver injuries without other indications for laparotomy, such as hollow viscus perforation, can be treated conservatively. Selective non-operative management of isolated penetrating liver injuries has been shown to be safe [3,8–21]. The assumption that operative grading of liver trauma and CT grading are equivalent is not well documented in the literature. However the data in this series suggests a there is a good correlation between operative and CT scan grading of liver trauma.

In terms of liver-specific complications, increasing AAST grade was significantly associated with the odds of bile leak in both blunt and penetrating trauma. Additionally, there was a statistically significant increase in the odds of a re-bleed with increasing AAST grade in penetrating trauma but not in blunt trauma. The management of these complications differs between well-resourced and less well-resourced environments. In more well-resourced centres there has been a liberal use of interventional radiology to augment surgical control of hepatic haemorrhage, over the last two decades. Angioembolization (AE) has been used either as a primary intervention or as part of a hybrid strategy in conjunction with surgical packing. Most contemporary reports on the management of hepatic trauma, document a rate of AE of between 2 and 20 % [22–26]. This is far higher than the rate documented in this series.

However, AE is associated with a high rate of complications and hepatic necrosis has been reported to have an incidence of between 4 and 45 % [22–26]. A systematic review and meta-analysis by Green et al. reports a pooled rate of 14.9 % with range of 0–43 %[26]. It has been suggested that the rate of hepatic necrosis has increased over the last two decades in tandem with increased use of AE, especially in acutely injured patients with high grades of injury [22–26]. In our environment with limited access to AE our rate of rebleeding was 5/713 and hepatic necrosis was 7/713. It would appear from our data that the natural history of these complications is towards resolution if initial haemorrhage can be controlled. Only a very select group of patients will require angiography and embolization for recurrent bleeding. However in this group, mortality is high.

The need for ERCP and endoscopic sphincterotomy to manage a bile leak, in our series was low. Thirty-two patients developed a bile leak and of these only five required ERCP and sphincterotomy. Historically, selective non-operative management arose in South Africa in direct response to huge volumes of trauma and limited resources, and the approach has since found a role even in well-resourced environments. This highly selective use of AE and ERCP/sphincterotomy for the management of hepatic trauma is a further example of the applicability of SNOM. The low need for AE is mirrored by other reports by contemporaries in South Africa. Navsaria et al. have published extensively on non-operative management of traumatic injuries in South Africa. In a 2019 paper[19], their group published on SNOM in liver GSW and demonstrated a success rate of 94.4 % in the 28.3 % of patients who did not require immediate laparotomy. In only one case (1/54) was AE required as an adjunct to SNOM.

There are limitations to this study. This was a retrospective review of prospectively captured data from a single centre. This raises the issue of applicability and generalisability of the data to other centres. The non-availability of interventional radiology restricts the generalisability of this data to other centres. Perhaps the single biggest limitation is the pooling of patients with diverse mechanisms of trauma. Blunt and penetrating injuries are not analogous. Future audits should focus on developing patient cohorts categorized according to mechanism to avoid this bias.

Conclusion

AAST grade in isolation is not a good predictor of the need for operation in blunt and penetrating hepatic trauma. Increasing AAST grade was not found to correlate with increased risk of mortality for both blunt and penetrating hepatic trauma. There was a significant association seen between increasing AAST grade and mortality in penetrating trauma when not adjusted for confounding variables. This association did not persist when adjusted. In both blunt and penetrating trauma, increasing AAST grade is significantly associated with increased rate of bile leak. The need for ERCP to manage bile leak in our setting is low. Similarly, the rate of rebleeding and of angioembolization was low.

CRediT authorship contribution statement

Xavier Field: Writing – review & editing, Writing – original draft, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **James Crichton:** . **Victor Kong:** Data curation, Conceptualization, Investigation, Methodology, Supervision. **Jonathan Ko:** Data curation, Formal analysis, Investigation. **Grant Laing:** . **John Bruce:** Conceptualization, Data curation, Supervision. **Damian Clarke:** .

Declaration of competing interest

I declare that I have no conflicts of interest that could bias the outcome of the research presented in this manuscript. I have no financial interests to declare.

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