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RESEARCH

Trauma to Liver and Spleen: Evaluating the Role of Transfusion and Associated Injuries in Treatment Outcomes

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Abstract

Background/Aim The liver and spleen are the most commonly injured solid organs in abdominal trauma. The impact of haemostatic resuscitation and additional injuries on treatment strategies and clinical outcomes remains to be elucidated. This multicentered study aims to address the knowledge gap and contribute to the literature by presenting the initial analysis data.

Materials and Methods This retrospective observational study analyzed trauma patients with liver and spleen injuries admitted to participant hospitals in Turkey between January 1, 2019, and January 1, 2022. Only patients with liver and/or spleen injuries in the gastrointestinal system were included in the study design. Demographic, clinical, laboratory, radiology, and transfusion data were collected.

Results A total of 242 patients were included, with a mean age of 36.2 ± 19.1 years, and 78% were male. Blunt and penetrating mechanisms comprised 86.4% and 13.6% of injuries. The overall non-operative management (NOM) rate was 74.4%, with a failure rate of 2.3% for the liver, 8.8% for the spleen, and 24.2% for combined liver and spleen injuries. Operative patients had higher transfusion rates (83.3% vs. 25.3%). Transfusion was associated with increased ICU and hospital length of stay (LOS). Mortality rates were higher in the operative group (66.7% vs. 33.3%), particularly in patients with additional head and thoracic injuries.

Conclusion NOM remains the preferred treatment strategy for hemodynamically stabilized patients with liver and spleen trauma, demonstrating favorable outcomes with lower transfusion rates and shorter hospital stays. However, failure rates increase with higher-grade injuries and concomitant extra-abdominal trauma.

Keywords Liver injury · Spleen injury · Concomitant injury · Haemostatic resuscitation · Transfusion

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1 Introduction

The liver and spleen are at risk of injury in both blunt and penetrating trauma, and these injuries can be life-threatening. Although less common than the blunt mechanism, the penetrating mechanism also contributes significantly to the epidemiology of hepatic and splenic trauma [1–4]. The American Association for the Surgery of Trauma (AAST) scoring scales are the most widely used systems for the classification/categorization of organ injuries, primarily based on CT findings and reported to correlate with clinical management and patient outcomes [4–6]. Depending on the severity and presence of vascular injuries, injuries sustained by these organs may cause significant blood loss and hemodynamic instability that require emergency laparotomy [4, 7]. However, non-operative management (NOM) protocols for both blunt and penetrating liver and/or spleen injuries have been implemented and have become the mainstay of treatment for selected patients [8, 9].

The liver and spleen are in the left and right hypochondrium, and their anatomy is relevant to trauma and concomitant injuries. Despite the abundance of isolated liver and spleen injury literature, some studies reported on additional extra-abdominal injuries [4, 10–12]. Moreover, the impact of haemostatic resuscitation strategies and massive transfusion on operative and NOM approaches and patient outcomes is yet to be elucidated.

Although Turkey has multidimensionally advanced health system, multicentre trauma and transfusion studies are scarce [13]. As an academic surgeon lecturing on gastrointestinal injuries and haemorrhagic shock, this study aimed to address the knowledge gap and provide updated national medical data on liver and spleen trauma management.

2 Methods

The study was designed as a retrospective observational study to analyse our current research questions and hypotheses using data between January 1, 2019, and January 1, 2022. Approval of the study was obtained from the University of Health Sciences, Gulhane Scientific Research Ethics Committee. KTU Faculty of Medicine, Mugla Sitki Kocman University Faculty of Medicine, Hacettepe University Faculty of Medicine, Istanbul University Faculty of Medicine, Istanbul Medeniyet University Goztepe Prof. Dr. Suleyman Yalcin City Hospital consented and participated in the study. The study included only non-cirrhotic liver and spleen trauma cases, ensuring the exclusion of other gastrointestinal injuries. The study was designed to include patients above 18 years of age. Surgical intervention is considered the primary treatment for liver, spleen, or combined injuries. Patients with liver and/or splenic injuries who required surgical intervention within 72 h because of ongoing or delayed hemorrhage causing hemodynamic instability were classified as NOM failures. Patients with additional vascular injuries were excluded from the study. Patients' medical records included mortality and time, additional organ injuries, mechanisms of injuries, vital signs, shock index (SI), surgery and radiology reports, hospital LOS, ICU (intensive care unit) LOS, initial Hb (Haemoglobin level at admission), and other blood test results, use of tranexamic acid, AAST injury grades, ISS (Injury Severity score) values, viscoelastic test results were collected. Along with the liver and/or spleen injury scores, AIS (Abbreviated Injury Scale) scores for additional injuries to other anatomical regions were integrated to calculate the overall ISS. For patients with both liver and spleen injuries, the highest AAST score was analysed. SI values were graded ($SI < 0.6$ -no shock, $SI \geq 0.6$ to < 1—mild shock, $SI \geq 1$ to < 1.4—moderate shock, $SI \geq 1.4$—severe shock) according to Mutschler et al. 's study [14]. Inconsistently recorded or missing variables such as antiplatelet/anticoagulant use, morbidities, plasma lactate, base excess, fibrinogen levels, and blood coagulation test results were inevitably excluded during analyses and not reported. Clinical transfusion of blood components data was verified by checking data from participant centre blood banks. Five pooled/random platelet transfusion units were recorded as one apheresis platelet unit. Four-hour (transfusion of ≥ 5 units of blood) and 24-h (transfusion of ≥ 10 units of blood) massive transfusion (MT) rates were recorded [13].

2.1 Statistical Analyses

Continuous, nominal, and ordinal data descriptive statistics were presented as mean $\pm$ SD, percentages, and median (when appropriate). Analyses of two dichotomous and dichotomous-continuous variables were performed using the Chi-Square and Point Biserial correlation tests, respectively. The Chi-Square homogeneity test with Bonferroni corrected z-test was used to determine differences between independent multinomial and dependent dichotomous groups. The Fisher's Exact Test analysed the associations of dependent and independent dichotomous variables. The correlation between dichotomous and continuous variables was analysed using Point Biserial and Pearson's Correlation tests, respectively. A one-way ANOVA test determined group differences between independent multinomial and dependent continuous variables. The Bonferroni adjusted One-way ANCOVA test determined group

differences between continuous and dichotomous variables, adjusting for covariates. Differences between independent dichotomous variables and continous dependent variables were analyzed using independent samples t-test. Binomial logistic regression was used to predict a dichotomous dependent variable given one or more independent variables. Kruskal Wallis H test was used to analyse multinomial group differences and ordinal dependent variables. Statistical significance was set at <0.05.

3 Results

Our retrospective study identified 242 patients between 2019 and 2022. Most of the patients were male, comprising 189 (78%) individuals. The mean age of the patients was 36.2 ± 19.1 years. Data revealed that there were 101 (41.7%) liver injuries (Group 1), 124 (51.3%) spleen injuries (Group 2), and 17 (7%) patients with both liver and spleen injuries (Group 3). Unsurprisingly, 209 (86.4%) injuries were due to blunt mechanisms, and non-operative treatment was preferred in 180 (74.4%) patients. Tables 1, 2, and 3 show the descriptive statistics and statistical analyses between groups. Patients' SI values were statistically significantly lower in the NOM groups when compared to operative groups ($p<0.05$). (Table 3) Although the ICU and hospital LOS were shorter in the Groups 1–3 NOM subgroups, the differences were insignificant ($p>0.05$). (Tables 4, 5, 6) Transfusion rates and ICU and hospital LOS were not statistically significantly associated ($p>0.05$). There were no statistically significant differences between blunt or penetrating mechanisms of injuries in terms of mortality rates in any injury groups ($p>0.05$). Out of the patients studied, only 57 (23.6%) had isolated Group 1–3 injuries, while 185 (76.4%) presented with additional extra-abdominal injuries. (Fig. 1). NOM and operative patients' transfusion rates were 29.1% and 82%, respectively ($p<0.001$). Transfusions of erythrocyte concentrates (EC), fresh frozen plasma (FFP), and platelets (Plt) were statistically significantly correlated ($p<0.001$) in any injury groups.

Group 1 injuries were caused by blunt mechanisms, stabbing, and gunshot wounds in 80 (79.2%), 11 (10.9%), and 10 (9.9%) patients, respectively. Only 25 (24.8%) of Group 1 patients sustained isolated liver injuries (72%, blunt mechanisms). The NOM failure rate was 2.3%. Associated kidney injuries were due to blunt mechanisms in 4 of 6 (67%) cases. (Fig. 1).

Operative and NOM patients' respective transfusion rates were 83.3% and 25.3%, and the difference was statistically significant ($p<0.001$). Patients who received EC transfusion had statistically significantly higher ICU ($p=0.002$) and hospital LOS ($p<0.001$). Patients that received transfusions

Table 2 Arrival SI (Shock Index) values in each injury group

Injury groups	Treatment	SI value mean ± SD	95% CI	*P* value
Group 1	NOM	0.7 ± 0.19	[−0.8, −0.34]	<0.001*
	Operative	1.34 ± 1		
Group 2	NOM	0.7 ± 0.21	[−0.25, −0.07]	<0.001*
	Operative	0.9 ± 0.2		
Group 3	NOM	0.7 ± 0.13	[−0.8, −0.11]	0.015*
	Operative	1.17 ± 0.4		

*There were statistically significant differences between the NOM (nonoperative management) and operative treatments in terms of SI values ($p<0.05$)

Table 1 Descriptive statistics and results of statistical analyses between group 1, group 2, and group 3

Variables	Injury groups	Mean ± SD	95% Confidence interval	*P* value
Age (years)	Group 1	34 ± 18	31–38.1	$p>0.05^{*,b}$
	Group 2	36 ± 19	33–40	$p>0.05^{**,b}$
	Group 3	44 ± 19	34.8–55	$p>0.05^{***,b}$
ICU LOS (days)	Group 1	3.5 ± 7.5	2–5	$p>0.05^{*,b}$
	Group 2	3.2 ± 7.7	1.8–4.6	$p>0.05^{**,b}$
	Group 3	7.8 ± 16.6	0.7–16.3	$p>0.05^{***,b}$
Hospital LOS (days)	Group 1	8.9 ± 10.1	6.8–10.9	$p>0.05^{*,b}$
	Group 2	8.7 ± 7.2	7.4–10	$p=0.04^{**,a}$
	Group 3	15.4 ± 20.1	5–25.7	$p=0.018^{***,a}$
ISS	Group 1	16 ± 13.8	14.4–19.3	$p>0.05^{*,b}$
	Group 2	17 ± 13	22.1–49.3	$p<0.01^{**,a}$
	Group 3	18 ± 15	15.7–19.7	$p<0.001^{***,a}$

Group 1: Liver İnjury, Group 2: Spleen Injury, Group 3: Liver + Spleen Injury, ICU: Intensive Care Unit, LOS: Length of Stay, ISS: Injury Severity Score, *p value of Group 1 and 2 comparison, **p value of Group 1 and 3 comparison, ***p value of Group 2 and 3 comparison, [a]Comparisons between the groups show the differences are statistically significant (bold), [b]Statistically not significant

Table 3 Descriptive statistics and results of statistical analyses of all injury groups

Variables		Group 1 (%)	Group 2 (%)	Group 3 (%)	*P* value
Treatment choice	NOM[d]	82.2	72.6	41.2	$p>0.05^{*,b}$
	Operative	17.8	27.4	58.8	$p=0.001^{**,a}$ $p=0.001^{***,a}$
Mortality[c]	None	91.1	94.4	70.6	$p>0.05^{*,b}$
	Present	8.9	5.6	29.4	$p=0.005^{**,a}$ $p=0.005^{***,a}$
Mortality time groups	First 24 h	33.3	28.6	60	$p>0.05^{*,b}$
	> 72 h	66.7	71.4	40	$p>0.05^{**,b}$ $p>0.05^{***,b}$
Mechanism of injury	Blunt	79.2	91.1	94.1	$p=0.02^{*,a}$
	Penetrating	20.8	8.9	5.9	$p=0.02^{**,a}$ $p>0.05^{***,b}$
Blunt mechanism	NOM[d] vs. Operative	88.8 vs.11.3[b]	43.8 vs. 56.3[a]	75.9 vs. 24.1[a]	$p=0.002^{b}$ $p>0.05^{a}$
Penetrating mechanism	NOM[d] vs. Operative	57.1 vs. 42.9[b]	0 vs. 100[a]	45.5 vs. 54.5[a]	$p=0.002^{b}$ $p>0.05^{a}$
Additional injuries	None	24.8	24.2	5.9[a]	$p>0.05^{*,b}$
	Present	75.2	75.8	94.1[a]	$p=0.003^{**,a}$ $p=0.003^{***,a}$

*p value of Group 1 and 2 comparison, **p value of Group 1 and 3 comparison, ***p value of Group 2 and 3 comparison, [a]Comparisons between the groups show the differences are statistically significant (bold), [b]Statistically not significant. [c]Overall mortality rate, [d]Nonoperative management, ¥Transfusion data in patients with Shock Grade ≥ 1

had higher mean ISS values (27.4 ± 15.1 vs. 9.5 ± 7.5, $p<0.001$). Operative and NOM subgroups' data was adjusted for covariates (additional injuries). The mean difference in the ISS scores was 12.4 (95 CI [4.7–20], $p=0.002$), SI values were 0.37 (95 CI [0.2–0.5], $p<0.001$), transfused EC units was 4.3 (95 CI [2.1–6.4], $p<0.001$), FFP units was 7.8 (95 CI [3.7–11.9], $p<0.001$), and Plt units was 3.6 (95 CI [1.5–5.5], $p<0.001$), respectively. However, the mean difference in the initial Hb (haemoglobin) levels was not statistically significant ($p>0.05$). (Table 4).

Nine (8.9%) deaths occurred among Group 1 patients, and all sustained additional (11.1% head, 33.3% thoracic, 11.1% kidney, 44.4% multiple) injuries. The mean mortality time was 8.9 ± 8.4 days. The mortality rate was statistically significantly lower in the non-operative than in the operative group (33.3% vs. 66.7%) ($p<0.001$). Additional injuries were statistically significantly associated with mortality and mortality time ($p<0.001$). When adjusted for covariates, between mortality-present and no-mortality subgroups, the mean difference in the ISS scores was 22.5 (95 CI [13.1–31.8], $p<0.001$), transfused EC units was 5.7 (95 CI [2.9–8.4], $p<0.001$), FFP units was 16.6 (95 CI [12.0–21.0], $p<0.001$), and Plt units was 6.1 (95 CI [3.6–8.6], $p<0.001$). However, the mean differences in SI and initial Hb values were not statistically significantly different ($p>0.05$).

The majority (90.2%) of Group 2 injuries were due to blunt mechanisms, due to stab wounds in 7 (5.7%) and gunshot wounds in 5 (4.1%) cases. Only 26 (23.2%) blunt and 2 (28.5%) penetrating injury (due to stab wounds) patients sustained isolated injuries. (Fig. 1) Patients with blunt and penetrating spleen injuries also sustained additional kidney injuries in 5 (4.1%) and 3 (2.4%) cases, respectively. The NOM failure rate was 8.8% in this group. Patients who received EC transfusion had statistically significantly higher ICU ($p=0.003$) and hospital LOS ($p=0.003$). Patients that received transfusions had higher mean ISS values (26.6 ± 13.5 vs. 10.1 ± 7.2, $p<0.001$). Transfusion rates were statistically significantly higher in the operative group (81.8%) when compared to the NOM patients ($p<0.001$). Operative and NOM subgroups' data was adjusted for covariates, and the mean difference in the ISS score was 10.9 (95 CI [6.2–15.6], $p<0.001$), SI value was 0.14 (95 CI [0.04–0.23], $p=0.008$) and transfused EC units were 1.7 (95 CI [0.4–3.03], $p=0.01$), respectively. However, the mean differences in initial Hb levels, transfused FFP, and platelet units were insignificant ($p>0.05$). (Table 5).

Seven deaths (5.6%) occurred in Group 2, and all were presented with additional injuries. Head, thoracic, and multiple injuries comprised 14.3%, 28.6%, and 57.1%, respectively. The mean mortality time was 7.7 ± 9.1 days. There was no statistically significant difference between the non-operative and operative groups' mortality rates (42.9% vs. 57.1%) ($p>0.05$). Additional injuries were statistically significantly associated with mortality and mortality time ($p<0.001$). When adjusted for covariates, the mean difference in mortality-present patients' mean ISS score was 17.8 (95 CI [9.2–26.5], $p<0.001$), SI value was 0.3 (95 CI [0.1–0.5], $p<0.001$), transfused EC units was 6.7 (95 CI

Table 4 Descriptive statistics of liver injury patients

Group 1 (Liver Injury) patients	
NOM group: 83 (82.2%) patients	Operative group: 18 (17.8%) patients
Mechanism:	Mechanism:
Blunt: 71 (85.5%) Penetrating: 12 (14.5%)	Blunt: 9 (50%) Penetrating: 9 (50%)
ISS: 13.3 ± 11.8	ISS: 29.5 ± 16
Mortality: 3 (3.6%)	Mortality: 6 (33.3%)
Initial Hb (g/dL): 13 ± 2.45	Initial Hb (g/dL): 10.9 ± 2.9
ICU LOS (days): 3.1 ± 7.9	ICU LOS (days): 5.2 ± 4.9
Hospital LOS (days): 8.4 ± 10.7	Hospital LOS (days): 11 ± 6.3
AAST grades:	AAST grades:
Grade I-III: 80 (96.4%)	Grade II-III: 7 (38.8%)
Grade IV: 3 (3.6%)	Grade IV-V: 11 (61.2%)
SI grades:	SI grades:
No shock: 10 (12%)	No shock: 0
Mild shock: 63 (75.9%)	Mild shock: 5 (27.8%)
Moderate shock: 9 (10.8%)	Moderate shock: 9 (50%)
Severe shock: 1 (1.2%)	Severe shock: 4 (22.2%)
SI Grade ≥ Mild shock[e]	SI grade ≥ Mild shock[e]
Mean EC: 1 ± 2.6	Mean EC: 7.4 ± 6.9
Mean FFP: 0.9 ± 3.4	Mean FFP: 8.6 ± 13.2
Mean Plt: 0.01 ± 0.1	Mean Plt: 4.05 ± 8.4
Transfusion rate: 21 (25.3%)	Transfusion rate: 15 (83.3%)
First 4-h MT: 2 (2.4%)	First 4-h MT: 3 (16.7%)
24-h MT: 0	24-h MT: 6 (33.3%)
Total transfused blood/Blood products:	Total transfused blood/Blood products:
Whole blood: 0	Whole blood: 2 Units
EC: 74 Units	EC: 134 Units
FFP: 65 Units	FFP: 155 Units
Apheresis-derived Plt: 1 Unit	Apheresis-derived Plt: 73 Units
Overall, 2 of 10 MT patients received no platelet transfusions in both operative/operative groups	EC: FFP: Plt: 1: 1.1: 0.5

Nominal and Ordinal data: Number of Cases (%), Continuous data: Mean ± SD. ISS Injury Severity Score, Hb Hemoglobin, LOS Length of stay, AAST American Association for the Surgery of Trauma, EC Erythrocyte Concentrate, FFP Fresh Frozen Plasma, Plt Platelet, SI Shock Index, MT Massive Transfusion. [e]Patients with mild shock and above, operative treatment required statistically significantly higher EC, FFP and Plt units than the NOM group

[4.6–8.8], $p < 0.001$), FFP units was 5.4 (95 CI [3.6–7.3], $p < 0.001$) and platelet units was 4.4 (95 CI [2.5–6.3], $p < 0.001$). However, the mean difference in initial Hb values was not statistically significantly different ($p > 0.05$).

Group 3 injuries were caused by blunt and firearms mechanisms in 16 (94.1%) and one (5.9%) patient, respectively. Only one (5.8%) patient in Group 3 sustained an isolated injury (a blunt mechanism) (Fig. 1). The NOM failure rate was 24.2% in this group. Additional grade 2 left kidney injury was present in one patient. Patients that received transfusions had higher mean ISS values (42.8 ± 23.9 vs. 18.2 ± 10.1); however, the difference was not statistically significant ($p > 0.05$). Transfused/not transfused patients' ICU and hospital LOS were not statistically significantly different ($p > 0.05$). Transfusion rates were not statistically significantly different between the operative and NOM groups ($p > 0.05$). When adjusted for covariates (additional injuries), there were no statistically significant differences between the operative/NOM subgroups in terms of the ISS scores, initial Hb levels, SI values, and the total transfused blood component units ($p > 0.05$). (Table 6).

There were 5 (29.4%) mortalities in Group 3 patients. The mean mortality time was 18 ± 30 days. All patients sustained associated injuries (40% thoracic, 60% multiple), which were all due to blunt mechanisms. There was one (20%) mortality in the non-operative group, whereas four

Table 5 Descriptive statistics of Group 2 patients

Group 2 (Splenic Injury) patients	
NOM group: 90 (73.1%) patients	Operative group: 33 (26.9%) patients
Mechanism:	Mechanism:
Blunt: 85 (94.4%)	Blunt: 27 (81.8%)
Penetrating: 5 (5.6%)	Penetrating: 6 (18.2%)
ISS: 12.9 ± 10.4	ISS: 27.1 ± 14
Mortality: 3 (3.3%)	Mortality: 4 (12.1%)
Initial Hb (g/dL): 13.3 ± 1.9	Initial Hb (g/dL): 12.8 ± 2
ICU LOS (days): 3 ± 8.7	ICU LOS (days): 3.3 ± 4.4
Hospital LOS (days): 8.3 ± 7.7	Hospital LOS (days): 9.5 ± 5.5
AAST grades:	AAST grades:
Grade I-II: 62 (67.9%)	Grade II: 4 (12.1%)
Grade III: 28 (32.1%)	Grade III: 5 (15.2%)
SI Grades:	Grade IV-V: 24 (72.7%)
No shock: 11 (12.2%)	SI Grades:
Mild shock: 69 (76.7%)	No shock: 1 (3%)
Moderate shock: 7 (7.8%)	Mild shock: 18 (54.5%)
Severe shock: 3 (3.3%)	Moderate Shock: 14 (42.4%)
SI grade ≥ Mild shock	Severe Shock: 0
Mean EC[a]: 0.9 ± 2.4	SI Grade ≥ Mild Shock
Mean FFP[b]: 1 ± 3	Mean EC[a]: 2.8 ± 3.3
Mean Plt[b]: 0.5 ± 2.8	Mean FFP[b]: 1.8 ± 1.9
Transfusion rate: 25 (27.8%)	Mean Plt[b]: 0.1 ± 0.5
First 4-h MT: 3 (3.3%)	Transfusion Rate: 27 (81.8%)
24-h MT: 0	First 4-h MT: 4 (12.1%)
Total transfused blood/Blood products:	24-h MT: 1 (3%)
Whole blood: 0	Total transfused blood/Blood Products:
EC: 85 Units	Whole Blood: 0
FFP: 86 Units	EC: 89 Units
Apheresis-derived Plt: 45 Units	FFP: 59 Units
EC: FFP: 1: 0.9: 0.5	Apheresis-derived Plt: 4 Unit
Overall, 5 of 10 MT patients received no platelet transfusions in both operative/operative groups	EC: FFP: Plt: 1: 0.7: 0.05

Nominal and Ordinal data Number of Cases (%), Continuous data Mean ± SD. ISS Injury Severity Score, Hb Hemoglobin, LOS lengthe of stay, AAST American Association for the Surgery of Trauma, EC Erythrocyte Concentrate, FFP Fresh Frozen Plasma, Plt Platelet, SI Shock Index, MT Massive Transfusion. [a]Patients with mild shock and above required statistically significantly higher EC units transfusions in the operative group ($p < 0.05$). [b]Patients with mild shock and above, transfused FFP and Plt units were not statistically different between the NOM and operative groups ($p > 0.05$)

(80%) mortalities were in the operative group, and the statistical significance was not significantly different ($p > 0.05$). Additional injuries were statistically significantly associated with mortality ($p = 0.006$); however, their association with mortality time was not statistically significant ($p > 0.05$). When adjusted for covariates, mortality-present patients had significantly higher ISS scores and were transfused more EC units ($p = 0.002$, $p = 0.004$, respectively). However, SI values, initial Hb levels, and transfused FFP and platelet units were not statistically significantly different ($p > 0.05$).

Tranexamic acid infusion was only performed in five operatively treated patients in groups 2 and 3. Besides the lack of/inconsistencies in recorded coagulation tests that were not reported, the authors report that the participating centres do not currently use viscoelastic tests to manage trauma.

Table 6 Descriptive statistics of Group 3 patients

Group 3 (Live and Splenic Injury) patients	
NOM group: 7 (41.1%) patients	Operative group: 10 (58.9%) patients
Mechanism:	Mechanism:
Blunt: 7 (100%)	Blunt: 9 (90%)
Penetrating: 0	Penetrating: 1 (10%)
ISS: 25.3 ± 9.2	ISS: 43.6 ± 28.3
Mortality: 1 (14.3%)	Mortality: 4 (40%)
Initial Hb (g/dL): 12.7 ± 1.3	Initial Hb (g/dL): 12.6 ± 1.8
ICU LOS (days): 5.4 ± 6.1	ICU LOS (days): 9.5 ± 21.4
Hospital LOS (days): 10 ± 5.8	Hospital LOS (days): 19.2 ± 25.6
AAST grades:	AAST grades:
Grade I-II: 3 (42.8%)	Grade I-II: 2 (20%)
Grade III: 3 (42.8%)	Grade III: 4 (40%)
Grade IV: 1 (14.4%)	Grade IV-V: 4 (40%)
SI grades:	SI grades:
No shock: 0	No shock: 0
Mild shock: 6 (85.7%)	Mild shock: 3 (30%)
Moderate shock: 1 (14.3%)	Moderate shock: 4 (40%)
Severe shock: 0	Severe shock: 3 (30%)
SI grade ≥ Mild shock	SI grade ≥ Mild shock
Mean EC[b]: 1.4 ± 2.5	Mean EC[b]: 7.1 ± 7.7
Mean FFP[b]: 2.5 ± 4.4	Mean FFP[b]: 5.2 ± 7.8
Mean Plt[b]: 0	Mean Plt[b]: 0.1 ± 0.3
Transfusion rate: 3 (42.9%)	Transfusion rate: 9 (90%)
First 4-h MT: 1 (14.3%)	First 4-h MT: 5 (50%)
24-h MT: 0	24-h MT: 2 (20%)
Total transfused blood/Blood products:	Total transfused blood/Blood products:
Whole Blood: 0	Whole blood: 0
EC: 10 Units	EC: 71 Units
FFP: 18 Units	FFP: 52 Units
Apheresis-derived Plt: 0 Unit	Apheresis-derived Plt: 1 Unit
EC: FFP: 1: 1.18	EC: FFP: Plt: 1: 0.7: 0.01
Overall, 6 of 7 MT patients received no platelet transfusions in both operative/operative groups	

Nominal and Ordinal data Number of Cases (%), Continuous data Mean ± SD. ISS Injury Severity Score, LOS Length of stay, Hb Hemoglobin, AAST American Association for the Surgery of Trauma, EC Erythrocyte Concentrate, FFP Fresh Frozen Plasma, Plt Platelet, SI Shock Index, MT Massive Transfusion. [b]Patients with mild shock and above, transfused EC, FFP and Plt units were not statistically different between the NOM and operative groups ($p > 0.05$)

4 Discussion

North America has the highest percentage of penetrating injuries, while in Europe, blunt mechanisms are responsible for most of the injuries [10, 15]. Trauma studies from Turkey show that 66% to 90% of these injuries result from blunt mechanisms [16–18]. Our study showed 79.2%, 90.2%, and 94.1% of liver, spleen, and concomitant liver-spleen injuries (overall 86.4%) were due to blunt mechanisms, respectively. Blunt injuries to the liver and spleen generally occur after severe trauma, and thus, they are often associated with additional (central nervous system, spine, hollow viscera) injuries [4, 16]. Our results support the above statements. As an indirect measure of trauma severity quantification, injury severity score (ISS) is commonly used, and arguably, a value > 15 is often used for severe trauma [19]. Overall, 38% of patients' ISS were > 15 in our study, 83.7% were due to blunt mechanisms, and 94.6% had additional injuries. Multiple and thorax injuries comprised 47.8% and 26.1% of cases, respectively. These severe trauma patients were often treated nonoperatively (54.3%), which may explain their significantly higher hospital LOS. The reason why most of the

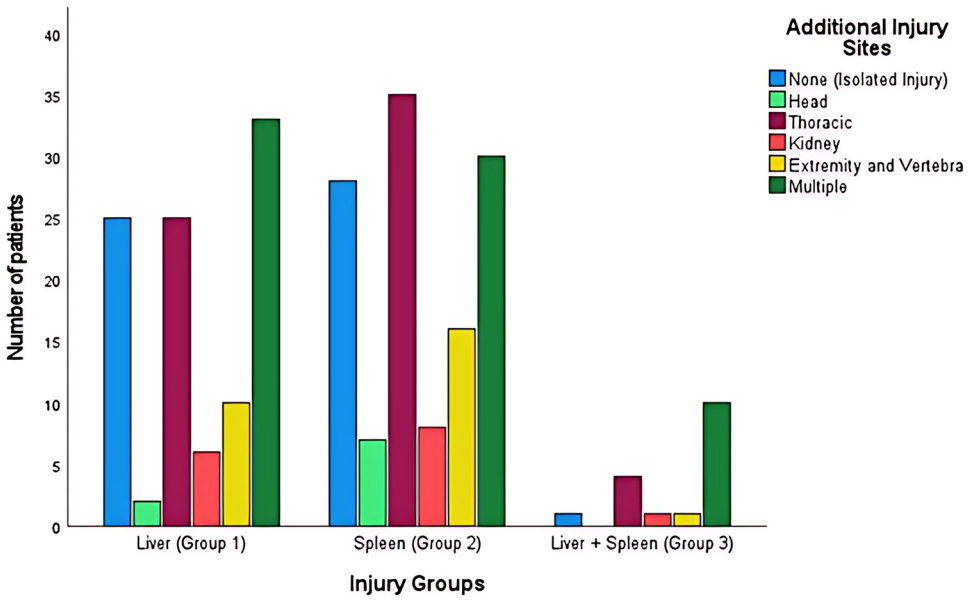


Fig. 1 describes the statistical significance of the differences between blunt or penetrating mechanisms of injuries in terms of mortality rates in any injury groups

study participants had severe trauma could be that the data were collected only from level 1 trauma centres. Unsurprisingly, concomitant liver-spleen injury patients' ISS values were also significantly higher. In our study, transfusion was associated with increased ICU and hospital LOS. This association was attributable to increased injury severity among patients with liver and spleen injuries. Additional injuries were associated with higher mortality rates in all study groups and earlier mortality time in liver and splenic injury groups. Liver and spleen injuries have been reported to be related to concomitant kidney injuries in 12.8% of cases [20]. In our study, additional kidney injuries were present in 6.1% of cases, 66.6% of them were due to blunt mechanisms, and all underwent NOM.

Hinton, in 1926, noted that most bleeding from the injured liver spontaneously stopped by the time of surgery and advocated non-operative treatment in relatively common liver injuries [21]. Since then, numerous studies have confirmed the efficacy of NOM and successfully performed in up to 97% of blunt liver and 60% to 98% of spleen injuries, provided that the patient is hemodynamically stable [8–10]. Operative treatment is performed in 5–15% of cases and is reserved for patients with signs/symptoms of bleeding. Stab wounds to the abdomen have been successfully treated with NOM, which also includes some patients with liver injury [9]. Our study showed that Group 1 and Group 2's NOM rates were 82.1% and 72.6%, respectively. The NOM rate in Group 3 was 41.1% (all were due to blunt mechanisms), which was significantly lower than the other patient groups. This result may be due to the presence of more severe and complicated trauma (lower SI and higher ISS values, higher percentage of additional injuries). While the overall NOM rate in blunt injuries was (67.3%), the NOM rates for stab wounds and gunshot wounds (GSW) in Group 1 and Group 2 were 9.6% and 4.8%, 4.4% and 1.1%, respectively. These results indicate that surgical teams' NOM decisions may depend on multiple factors, even for penetrating trauma patients. NOM has been associated with shorter ICU and hospital LOS, although Malaki et al. reported no significant difference [4, 9, 22]. Our study also revealed a shorter ICU and hospital LOS, although the differences were not statistically significant.

However, using NOM for GSW has remained controversial due to higher NOM failure rates [23]. Liver/splenic injury and splenic injury NOM failure rates of 3.3% and 11% have been reported [9, 10]. The NOM failure rate for Group 1 was 2.4%, and these patients sustained AAST grade 3 and 4 injuries due to blunt mechanisms. The NOM failure rate for Group 2 was 15.5%, and these patients sustained Grade II-III (78.6%) and IV (21.4%) injuries due to blunt trauma (85.7%) and stab wounds (14.3%). There were no mortalities in Group 1 and 2 NOM failure patients. There was only one (14.2%) NOM failure in Group 3 that sustained a Grade 4 injury due to a blunt mechanism, and the patient had died. All reported NOM failures were due to liver and/or spleen injury related to haemorrhage in our study. Statistical analyses showed that the number of NOM patients was below the expected values.

Over the past two decades, significant progress has been made in managing spleen and liver injuries [8]. This improvement is due mainly to advancements in resuscitation techniques, which now focus on replacing significant blood loss with balanced blood product (EC, FFP, Plt; 1:1:1 ratio) transfusions aiming to reconstitute the whole blood lost during bleeding [8, 22]. Likewise, the Turkish Critical Bleeding and Massive Transfusion Guide prioritizes limited

crystalloid infusion and early institution of hemostatic resuscitation and recommends the use of tranexamic acid [13]. In our study, the blood component transfusion ratios for the operative groups with liver, spleen, and combined liver-spleen injuries were 1:1.1:0.5, 1:0.7:0.05, and 1:0.7:0.01, respectively. The fact that some patients undergoing massive transfusion in these groups did not receive any platelet transfusions further highlights a significant gap in practice. Studies such as PROPPR and PROMMTT have shown that while the overall impact on long-term mortality may be limited, early and adequate platelet and plasma administration is crucial for survival in the acute phase of hemorrhagic shock [24, 25]. As highlighted in previous research, these suboptimal findings underscore an urgent need for nationwide action to improve platelet availability [12]. Despite the strong emphasis on hemostatic resuscitation, the literature review of the liver and/or spleen injury only focuses on erythrocyte concentrate transfusions, excluding other blood components. To our knowledge, this is the first report on investigating liver and/or spleen injuries and blood/blood component resuscitation. EC, FFP, and Plt unit transfusions were correlated in our study. Robinson et al. reported an overall 45%, 81.4% operative, and 30% NOM transfusion rates [22]. Our respective transfusion rates were 42.1%, 82%, and 29.1%, which were similar despite different injury patterns and clinical settings. As reported in the literature, NOM was associated with lower transfusion rates in our study [8, 9]. Richardson states that most protocols allow an observation period with up to 4 units of blood transfusion for hepatic injury patients [9]. Our study identified 6 MT NOM patients within 4 h (transfusion of $\geq$4 units of EC within 4 h), and only one splenic injury patient required surgical intervention. The authors believe this should be addressed by prospective studies that include routine and viscoelastic coagulation tests, which is an important weakness of our study. Moreover, balancing blood components to create an optimal ratio adjusted for each patient's requirements and using viscoelastic tests are paramount. This is lacking in Turkish trauma care, and the use of tranexamic acid is still not considered by surgical teams despite the national massive transfusion guideline [13]. Blood component use is currently empirical, which may lead to unnecessary transfusions. Reaching the desired blood component ratio may take up to 3 h during transfusions. Thus, national strategies for using warm, fresh whole blood, low-titer group O whole blood, and cold-stored platelets are required [26–28].

Historically, there has been a steady decline in liver injury mortality rates: 60% to 80% in World War I, 27% in World War II, 12.7% in civilian reports from the 1960s, 6% and 4.2% in the 1980s, and 1990s, respectively [29]. The NOM mortality rate was 3.6%, 3.3%, and 14.3%, respectively. Unlike liver trauma, which has decreased considerably in the last two decades, splenic trauma rates have remained at 6% to 7% due to the presence of additional injuries. However, mortality of isolated splenic injury has been at 0% for 40 years [10]. Overall, the mortality rate of liver and/or spleen injuries was 8.7%, including additional injuries. While further stratifying the mortality data to negate the possible effects of additional injuries and their severities, seems profoundly difficult, the liver and/or spleen injury-specific overall mortality rate appears to be 2.4%. Mortality rates were notably higher in patients with thoracic and head trauma, which is consistent with previous literature emphasizing a strong correlation between ISS and mortality. However, without further stratification and adjustment for the severity of additional injuries, their impact on mortality rates may be unnecessarily generalized. Unfortunately, the included patient population and mortality rates were statistically inadequate to reveal further associations and risk factors. Our results indicate that LOS and mortality rates also increased as ISS values increased.

Our results demonstrate that NOM is a viable and safe option for patients with a low SI. However, we observed that surgical intervention was more frequently performed in patients with SI $\geq$1.4. Given that SI is widely used as a prognostic indicator in trauma patients, tailoring early resuscitation strategies based on SI values may enhance the success of NOM. In clinical practice, it is crucial to closely monitor patients with SI $\geq$1.0 who are considered NOM and, when necessary, proactively plan interventional radiology procedures or early surgical intervention to prevent NOM failure.

Although our findings indicate that NOM patients had a shorter hospital stay than operative cases, this difference did not reach statistical significance. Larger-scale studies are warranted to determine whether a more pronounced correlation between treatment type and hospital stay duration emerges in broader datasets.

Our study revealed that patients requiring blood transfusions were likelier to experience NOM failure. A substantial proportion of NOM failure cases involved AAST Grade III or higher injuries and additional associated injuries. This finding suggests that early transfusion requirements may indicate hemodynamic instability, warranting careful patient evaluation before pursuing NOM. Future studies should explore the role of viscoelastic testing (e.g., ROTEM/TEG) in optimizing transfusion strategies and improving the predictive accuracy of NOM success versus failure.

Our study has significant limitations inherent to its retrospective nature and the lack of a national trauma database. Lack of treatment criteria, agreed transfusion protocols or standardized NOM protocols across participitaing centers constitute some of these limitations. Our study design involved 77 variables, a confounding

factor for reporting in a single paper. Collecting accurate data required multiple re-review attempts by the authors. Investigating incomplete or inconsistent available data, the lack of uniform clinical protocols, and the failure to adhere to national guidelines have led to numerous unanswered research questions that must be addressed in the following prospective multicentre studies. The lack of a centralized trauma database is a significant deficiency not only in countries like Turkiye but also in more organized countries like the European Union. Trauma and transfusion require analyses of coagulation test data, which is also lacking in this paper. On the other hand, the authors speculate that the current research may have addressed a crucial national knowledge gap.

5 Conclusion

This study provides a comprehensive analysis of liver and spleen injuries in 242 trauma patients over four years, highlighting key trends in injury mechanisms, treatment approaches, and patient outcomes. Most injuries resulted from blunt trauma, with NOM as the preferred approach due to its association with lower SI values and shorter ICU and hospital stays. However, these differences were not always statistically significant. NOM was successfully implemented in most cases, though failure rates varied across injury groups, the highest observed in patients with combined liver and spleen injuries.

Patients undergoing operative management had significantly higher transfusion rates, and erythrocyte concentrate transfusions were associated with longer ICU and hospital stays. Mortality rates were notably higher in operative groups, with additional injuries being a key determinant of patient outcomes. The findings emphasize the importance of careful patient selection for NOM to optimize clinical outcomes and reduce unnecessary surgical interventions. Further research is necessary to refine trauma management strategies, particularly in centres where viscoelastic testing is not yet incorporated.

In summary, our findings reinforce the value of NOM for appropriately selected trauma patients while highlighting the need for ongoing improvements in transfusion strategies and trauma care protocols.

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Data Availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors declare no competing interests.

Informed Consent Not available.

Human and Animal Rights Not applicable.

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References

1. Matthes G, Stengel D, Seifert J, Rademacher G, Mutze S, Ekkernkamp A. Blunt liver injuries in polytrauma: results from a cohort study with the regular use of whole-body helical computed tomography. World J Surg. 2003;27(10):1124–30. https://doi.org/10.1007/s00268-003-6981-0.
2. Harbrecht BG, Zenati MS, Ochoa JB, Puyana JC, Alarcon LH, Peitzman AB. Evaluation of a 15-year experience with splenic injuries in a state trauma system. Surgery. 2007;141(2):229–38.
3. Malaki M, Mangat K. Hepatic and splenic trauma. Trauma. 2011;13(3):233–44. https://doi.org/10.1177/1460408611400972.
4. Moore EE, Cogbill TH, Malangoni MA, Jurkovich GJ, Shackford SR, Champion HR, et al. Organ injury scaling. Surg Clin North Am. 1995;75(2):293–303. https://doi.org/10.1016/s0039-6109(16)46589-8.
5. Croce MA, Fabian TC, Kudsk KA, Baum SL, Payne LW, Mangiante EC, et al. AAST organ injury scale: correlation of CT-graded liver injuries and operative findings. J Trauma. 1991;31(6):806–12.
6. Uranüs S, Mischinger HJ, Pfeifer J, Kronberger L Jr, Rabl H, Werkgartner G, et al. Hemostatic methods for the management of spleen and liver injuries. World J Surg. 1996;20(8):1107–11. https://doi.org/10.1007/s002689900169.
7. Gaarder C, Gaski IA, Næss PA. Spleen and liver injuries: When to operate? Curr Opin Crit Care. 2017;23(6):520–6. https://doi.org/10.1097/MCC.0000000000000458.
8. Richardson JD. Changes in the management of injuries to the liver and spleen. J Am Coll Surg. 2005;200(5):648–69. https://doi.org/10.1016/j.jamcollsurg.2004.11.005.
9. Fodor M, Primavesi F, Morell-Hofert D, Kranebitter V, Palaver A, Braunwarth E, et al. Non-operative management of blunt hepatic and splenic injury: a time-trend and outcome analysis over a period of 17 years. World J Emerg Surg. 2019;14(1):29. https://doi.org/10.1186/s13017-019-0249-y.
10. Ekiz F, Yücel T, Emergen I, Gürdal SO, Gönüllü D, Yankol Y. Künt karin travmasi sonrasi izole abdominal solid organ yaralanmalari olan olgular ile beraberinde ekstraabdominal yaralanmalari da olan olgularin konservatif tedavi sonuçlarinin karşilaştirilmasi

[The comparison of the results of the conservative treatment between isolated solid organ injuries and those injuries associated with extraabdominal injuries after blunt abdominal trauma between isolated solid organ injuries and those injuries associated with extraabdominal injuries after blunt abdominal trauma]. Ulus Travma Acil Cerrahi Derg. 2003;9(1):23–29. Turkish

11. Sartorelli KH, Frumiento C, Rogers FB, Osler TM. Nonoperative management of hepatic, splenic, and renal injuries in adults with multiple injuries. J Trauma. 2000;49(1):56–61. https://doi.org/10.1097/00005373-200007000-00008.
12. Ünlü A, Yılmaz S, Akbasli IT, Karaagac Akyol T, Akkapulu N, Tumer M, et al. MATRA-A: a study on massive transfusion. Vox Sang. 2021;116(8):880–6. https://doi.org/10.1111/vox.13082.
13. Mutschler M, Nienaber U, Münzberg M, Wölfl C, Schoechl H, Paffrath T, et al. The shock index revisited—A fast guide to transfusion requirement? A retrospective analysis on 21,853 patients derived from the traumaregister DGU. Crit Care. 2013;17(4):R172. https://doi.org/10.1186/cc12851.
14. van Breugel JMM, Niemeyer MJS, Houwert RM, Groenwold RHH, Leenen LPH, van Wessem KJP. Global changes in mortality rates in polytrauma patients admitted to the ICU-a systematic review. World J Emerg Surg. 2020;15(1):55. https://doi.org/10.1186/s13017-020-00330-3.
15. Yazici P, Aydin U, Sozbilen M. Comparison of isolated and concomitant liver injuries: Is hepatic trauma entirely responsible for the outcome? Acta Chir Belg. 2010;110(6):598–602.
16. Baygeldi S, Karakose O, Özcelik KC, Pülat H, Damar S, Eken H, et al. Factors affecting morbidity in solid organ injuries. Dis Markers. 2016;2016:6954758. https://doi.org/10.1155/2016/6954758.
17. Gönültaş F, Kutlutürk K, Gok AFK, Barut B, Sahin TT, Yilmaz S. Analysis of risk factors of mortality in abdominal trauma. Ulus Travma Acil Cerrahi Derg. 2020;26(1):43–9. https://doi.org/10.14744/tjtes.2019.12147.
18. Palmer C. Major trauma and the injury severity score-Where should we set the bar? Annu Proc Assoc Adv Automot Med. 2007;51:13–29.
19. Nakao S, Katsura M, Yagi M, Ogura H, Oda J. Assessing associated factors for failure of non-operative management in pediatric blunt liver and spleen injuries: a secondary analysis of the SHIPPs study. Eur J Trauma Emerg Surg. 2024;50(5):2249–57. https://doi.org/10.1007/s00068-024-02575-y.
20. Hinton JW. Injuries to the abdominal viscera: their relative frequency and their management. Ann Surg. 1929;90(3):351–6. https://doi.org/10.1097/00000658-192909000-00003.
21. Reed BL, Patel NJ, McDonald AA, Baughman WC, Claridge JA, Como JJ. Selective nonoperative management of abdominal gunshot wounds with isolated solid organ injury. Am J Surg. 2017;213(3):583–5. https://doi.org/10.1016/j.amjsurg.2016.11.027.
22. Negoi I, Paun S, Hostiuc S, Stoica B, Tanase I, Negoi R, et al. Mortality after acute trauma: progressive decreasing rather than a trimodal distribution. J Acute Dis. 2015;4:205–9. https://doi.org/10.1016/j.joad.2015.03.001.
23. Robinson WP 3rd, Ahn J, Stiffler A, Rutherford EJ, Hurd H, Zarzaur BL, et al. Blood transfusion is an independent predictor of increased mortality in nonoperatively managed blunt hepatic and splenic injuries. J Trauma. 2005;58(3):437–44. https://doi.org/10.1097/01.ta.0000153935.18997.14.
24. Nguyen M, Piracchio R, Kornblith LZ, Callcut R, Fox EE, Wade CE, et al. Dynamic impact of transfusion ratios on outcomes in severely injured patients: targeted machine learning analysis of the Proppr randomize clinical trial. J Trauma Acute Care Surg. 2020;89(3):505–13.
25. Meyer CH, Grady Z, Nguyen JH. Does the 1:1:1 transfusion ratio mortality benefit hold true in ultra-massive transfusion? A study from the product (patient related outcomes during ultra-massive transfusion multi-center trial) consortium. Am Surg. 2025;91(9):1484–91.
26. Eksert S, Ünlü A, Aydın FN, Kaya M, Aşık MB, Kantemir A, et al. Analysis of anatomical localization and severity of injury in patients with blood transfusion in urban terrain hospital. Ulus Travma Acil Cerrahi Derg. 2020;26(6):937–42. https://doi.org/10.14744/tjtes.2020.94789.
27. Sperry JL, Cotton BA, Luther JF, Cannon JW, Schreiber MA, Moore EE, et al. Whole blood resuscitation and association with survival in injured patients with an elevated probability of mortality. J Am Coll Surg. 2023;237(2):206–19. https://doi.org/10.1097/XCS.0000000000000708.
28. Eker İ, Yılmaz S, Çetinkaya RA, Pekel A, Ünlü A, Gürsel O, et al. Generation of platelet microparticles after cryopreservation of apheresis platelet concentrates contributes to hemostatic activity. Turk J Hematol. 2017;34(1):64–71. https://doi.org/10.4274/tjh.2016.0049.
29. Stanković N. War liver injuries. Vojnosanit Pregl. 2005;62(1):3–10. https://doi.org/10.2298/vsp0501003s.

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