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Risk Factors for Mortality and Prolonged Intensive Care Unit Stay Following Traumatic Liver Injury: A Retrospective Cohort Study.

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Abstract

Background: Mechanical ventilation is a life-saving procedure of the critically ill patients and associated with a series of complications which can lead to negative outcomes. Ventilator associated complications (VACs), infection associated ventilator associated complications (IVAC) and ventilator associated pneumonia (VAP) are believed to be a major contributor to increased length of intensive care unit (ICU) stay, increased cost and mortality. Over the recent years, the term surveillance has been broadly used to refer to a wider range of ventilator-related harm whereby the term VAP has been replaced, and it is important to re-examine their clinical relevance in modern practice within an ICU. ***Objective:*** The overall objective of the study was to evaluate the incidence of VAC and its association with patient outcomes for all patients in a mechanically ventilated (MV) ICU, using secondary published data, local hospital data and clinicians' perspectives. ***Methods:*** An analytical method of an observational approach was adopted as a method of analysis. Secondary data were identified as published randomized trials, cohort and international guidelines published between May 2016 and May 2026. The results were compared to retrospective data of a local tertiary-care ICU dealing with adult patients in need of over 48 hours of invasive mechanical ventilation. Variables obtained included mechanical ventilation (MV) duration, presence of VACs or VAP and ICU LOS and mortality. Also, a brief survey was carried out on ICU clinicians to evaluate the current practice regarding ventilator care and prevention measures. The data were descriptively analyzed. ***Results:*** The literature consistently demonstrated that the occurrence of ventilator-associated complications correlated with the prolonged mechanical ventilation, the length of time spent on mechanical ventilation in the ICU and higher mortality. Similar rates of complications associated with the use of ventilators were observed in the local ICU data as affected patients were ventilated for longer periods and remained in the ICU for longer. Responses to the clinician survey showed that there was a general adoption of ventilator care bundles, but there were differences in the practice with regard to minimizing sedation and early mobilization. ***Conclusion:*** Identifiable complications related to the use of mechanical ventilation still occur in those patients who remain on a ventilator in the intensive care unit, and there is a link between these complications and poor clinical outcome. Despite the strengthening of prevention efforts, vigilance, adherence to ventilator bundles (evidence-based practices) and timely recognition of complications remain essential to improving patient outcomes.

Keywords: Mechanical ventilation, ventilator-associated complications, ventilator-associated pneumonia, intensive care unit and clinical outcomes.

INTRODUCTION

Mechanical ventilation is a life support system that is required to facilitate acute respiratory failure, severe sepsis, trauma, neurological impairment, postoperative complications in modern intensive care units (ICUs). In spite of the undeniable advantages, invasive mechanical ventilation is linked with a wide scope of complications that may play a crucial role in affecting the results of patients. Of these, ventilator-associated complications (VACs) are considered one of the most important, and they are associated with increased morbidity, extended intensive care unit (ICU) length of stay, increased health care costs and mortality (1,2).

Ventilator Associated Pneumonia (VAP) has been the most clinically significant complication associated with mechanical ventilation in the past. VAP was considered to be pneumonia developing at least 48 hours of endotracheal intubation and mechanical ventilation and was commonly used as a quality indicator in the ICU practices (3). Many studies reported incidence rates of VAP ranging between 5-20 cases per 1,000 ventilator days with attributable mortality rates that were reported with a wide range based on the patient population and diagnostic criteria (4,5). Nevertheless, issues of subjectivity of diagnostic criteria, interobserver agreement and poor microbiological confirmation of VAP surveillance resulted in increased questioning of the reliability and clinical usefulness of VAP surveillance as a sole diagnostic tool.

In response to these limitations, a broader definition of ventilator-associated events was suggested. This paradigm has shifted the focus on pneumonia to a continuum of ventilator-associated complications that reflect worsening of the person's respiratory status while on a ventilator that is powered by a machine (1). The ventilator-associated events paradigm includes such events as ventilator-associated conditions (VAC), infection-related ventilator-associated complications (IVAC) and potential or likely VAP. The rationale behind this change was to provide a more objective and repeatable method for clinically meaningful complications associated with mechanical ventilation regardless of the cause being infectious or not. Ventilator-associated complications are now known as indicators of deteriorating pulmonary status, augmented ventilator dependency and the severity of illness in the body as opposed to solitary infectious incidents. Research has established that VACs are associated with the use of mechanical ventilation for a longer period of time, length of stay in the ICU, length of stay in the hospital and increased mortality compared to those patients who develop mechanical ventilation for some other reason (6,7). Importantly, there are various mechanisms that can cause VACs, and they encompass atelectasis, pulmonary edema, acute respiratory distress syndrome, ventilator-induced lung injury and infection. This multifactoriality of the prevention and management of ventilator associated harm adds to this complexity.

The following patient and treatment related conditions have been identified for development of VA complications. The duration of mechanical ventilation has been one of the most significant predictors and there is a clear risk of higher duration after 48-72 hours of ventilatory care (8). The following factors are also known to contribute to risk: old age, aggressiveness of underlying disease, decreased consciousness, reintubation, supine position, excessive sedation and poor secretion clearance (9,10). The interaction between the two factors tends to indicate both vulnerability of patients and differences in the practices of ICU care.

In the past 20 years, the prevention of ventilator-associated complications (VACs) has been seriously studied through the application of prevention strategies. There are a number of bundles of care that have been widely promoted, such as getting the patient's head elevated, interrupting sedation, trying to get the patient to breathe on his own, using antiseptic agents for his mouth and encouraging early mobilisation (11,12). These interventions have the aim of decreasing ventilator exposure, the risk of aspiration and early ventilator discontinuation. While the decreases in ventilator bundles have been associated with an increase in the rate of VAP in some settings, its impact on the overall rate of VAP and patient outcome has been inconsistent (13).

Especially, the method of sedation has been rethought extensively. The use of the ventilator for extended periods of time and sedation for a longer duration has been correlated with increased ventilation, increased delirium, and increased ventilator-associated complications (14). Current management strategies in the modern ICU are more towards light sedation plans, weaning sedation daily, and protocol sedation weaning to reduce ventilator dependence. Such changes are an indication of the increasing acknowledgement of the fact that mechanical ventilation must not be considered as a respiratory support modality but a dynamic intervention that needs constant re-evaluation.

Ventilator-associated complications remain common among the population of ICUs across the world in spite of prevention and surveillance efforts. Incidence rates are reported differently, especially in terms of the alternate definitions used, the patient populations monitored and the way that monitoring occurred (15). In addition, as definitions of surveillance have become more objective, they are still not in a position to reflect on the complexity of individual patient trajectories, and the problem of preventable and non-preventable events. Thus, clinicians often fail to be effective in translating monitoring information into targeted bedside actions.

The difference between guideline recommendations and practice is another factor that needs to be taken into consideration. Compliance with ventilator care bundles and early mobilization protocols could be influenced by staffing ratio, availability of resources and culture of the institution. The implementation may be variable and one of the reasons for the invariable outcome might be in nonacademic environments or in smaller academic centers (16). It is thus important to understand the manifestation of ventilator-associated complications in the normal practice of the ICU to make improvements.

The economic and system-level impacts of ventilator-associated complications are significant, in addition to the clinical impact. ICU hospitalization and the recommendation of long-term mechanical ventilation also increases health care related costs and health care resource waste and adds an additional strain on the already-laden critical care (9) health care system. The reduction of preventable complications associated with mechanical ventilation is one of the main priorities in relation to patient safety and the sustainability of the health system, as ventilation is always increasing worldwide.

All these suggest that on-going assessment of complications associated with ventilators and how they impact on patients' outcomes should occur based on high quality evidence available and clinical evidence in practice. Local ICU observations and clinician perceptions when combined with secondary analyses of the current literature of the role of ventilator-associated complications in identifying, treating, and preventing their occurrences can provide a valuable understanding of the current role of the practice in identifying, treating and preventing the occurrence of the complications. These convergent methods can be used to gain a better insight into the connection between mechanical ventilation, complications and outcomes in different care environments.

The purpose of the present research proposal is to compare ventilator associated complications and its association with clinical outcomes of mechanically ventilated patients in the ICU. The objective of this paper is to describe the burden of VAC, discuss the relationship between VAC and the most important outcomes (mortality, length of stay), and review the available evidence of VAC prevention, including what has been published in the recent literature and what has been found in local hospitals and survey responses from clinicians. With such an analysis, the study will make a contribution to the current attempt to enhance the safety and efficacy of mechanical ventilation in patients who are critically ill.

MATERIALS AND METHODS

Study Design and Setting

The current study was a retrospective observational cohort study conducted in the Intensive Care Unit, Lady Reading Hospital, Medical Teaching Institution (LRH-MTI), Peshawar, Pakistan. The medical records of patients with traumatic liver injuries admitted from May 2016 to May 2026 were analyzed. Lady Reading Hospital is a tertiary-care referral hospital receiving trauma patients through the Emergency Department and from other healthcare institutions in the region.
The study was written up following the guidelines for reporting observational studies in epidemiology (19).

Study Population and Sampling Technique

A consecutive, non-probability sampling technique was used. Eligible patients who have been seen with the disease during the study period were included.
The patients were eligible if they:
1. Were 18 years or older;
2. Operative or contrast enhanced computed tomography (CECT) confirmation of traumatic, liver injury;
3. Admitted to the surgical ward/Intensive care unit;
4. had an outcome documented in the hospital.

Patients excluded if they were under 18 years old, showed no signs of life on arrival, died before hepatic injury confirmed, were transferred to a different institution before definitive management, had incomplete records for major outcomes of the principal study or were readmitted for complications of a previously diagnosed liver injury.
Patients admitted to the hospital with multiple trauma-related admissions were included only for the first admission.

Diagnosis and Classification of Liver Injury

In hemodynamically stable patients, diagnosis was made by contrast-enhanced computed tomography, while in patients undergoing emergency laparotomy, diagnosis was made during operation.
Liver injuries were classified using the 2018 Organ Injury scale of the American Association for the Surgery of Trauma (2). Injuries were classified as low grade injuries (grades I–III) or high grade injuries (grades IV–V). The basis for management decisions were hemodynamic status, associated injuries, responsiveness to resuscitation and institutional resources, not anatomic grade alone (1,14).
Blunt or penetrating trauma was used to classify the mechanism of injury. Penetrating injuries were defined as firearm or stab wounds, while blunt injuries were defined as road traffic accidents, falls, assaults, or crush injuries.

Data Collection

Emergency records, in-patient records, ICU chart, operative notes, blood bank records, radiology reports, discharge summary and death records were used to retrieve the data on a standard data collection sheet.
The following variables were measured:
• Age and sex;
M1: Mechanism and cause of injury;
• Time from injury to hospital presentation;
Admission SBP and HR;

- Blood pressure; and
- Shock index;
- Admission hemoglobin; platelet count; international normalized ratio; serum creatinine, lactate and base deficit;
- Injury Severity Score;
- The level of liver injury (AAST liver injury grade);
- Active contrast extravasation, vascular injury or hemoperitoneum;
- Associated cranial, thoracic, splenic, renal, intestinal, pelvic or extremity injuries;
- Number of packed red blood-cell units (pRBCs) received in the first 24 hours;
- Need for vasopressors, mechanical ventilation, angioembolization, surgery or reoperation;
- Number of hospital admissions and readmissions; and
- Development of complications; and
- Hospital Discharge for survival.

The first clinical and laboratory parameters measured at the time of hospital admission were analyzed, prior to any significant transfusion or surgical procedure. Lactate, base deficit, shock index, transfusion requirement, and overall injury severity were chosen due to their known link to physiological deterioration and poor trauma outcome (4,16–18).

Management of Traumatic Liver Injury

Primary assessment and resuscitation was conducted in line with the principles of trauma care. Patients were considered for non-operative management if they were hemodynamically stable, no peritonitis, serial examinations, repeat hemoglobin, hemodynamic monitoring, blood-product support, and follow-up imaging if clinically indicated (1,6,12). Angiography with angioembolization was discussed in patients with active arterial bleeding, pseudoaneurysm, or persistent bleeding who had interventional radiology facilities available (7,8).

Operative management was performed in patients that remained hemodynamically unstable, had peritonitis, uncontrolled bleeding, suspected hollow viscus injury, or failed non-operative management. Surgical techniques included perihepatic packing, direct hemostatic suturing, vessel ligation, topical hemostatic procedures, hepatic resection and damage-control surgery.

Outcome Measures

In-hospital mortality (death of any cause during the current hospital stay) was the primary outcome.
An ICU admission of more than seven days on the calendar was the secondary outcome (5). For patients who died during their hospital stay, analyses of prolonged hospital stay were limited to patients who survived to hospital discharge in order to avoid the potential for early death to misclassify prolonged stay.
Other outcomes were failure to undergo non-operative management, duration of mechanical ventilation, hospital stay, sepsis, pneumonia, acute kidney injury, acute respiratory distress syndrome, bile leak, intra-abdominal collection, reoperation, and multiorgan dysfunction.
Sepsis was defined based on the Sepsis-3 criteria and acute respiratory distress syndrome (ARDS) was defined using the Berlin definition (20,21).

Statistical Analysis

The IBM SPSS Statistics version [version number] was used to analyze the data. Means ± SD or median values (interquartile range) were used for continuous variables depending on the distribution of the data. Frequencies and percentages were used for categorical variables. Survivors were compared with non-survivors for mortality analysis. Survivors were divided into those with an ICU stay of 7 days or less, and those of more than 7 days. For continuous variables the independent-samples t-test or Mann–Whitney U test was used. The chi-square test or Fisher's exact test was used for categorical variables. First, univariable logistic regression was done to determine possible predictors.

Variables with a univariable p value < 0.20, as well as variables clinically deemed to be important were added to separate multivariable logistic regression models for mortality and prolonged staying in the ICU. All results are presented as adjusted odds ratios (OR) with 95% CI. Variance inflation factors were used to assess multicollinearity. A Hosmer–Lemeshow test was used to evaluate model calibration, and the area under the receiver operating characteristic curve was used to assess discrimination. A p-value < 0.05 was deemed statistically significant.

Ethical Considerations

The study was approved by the Institutional Review Board of [institution name] (Approval Number: [number]). Data anonymization prior to analysis, with no identifiable data included in research database.

RESULTS

Patient Selection and General Characteristics

A total of 238 records of patients who were suspected to have encountered traumatic liver injury were reviewed during the study period. Twenty-four patients were excluded: 9 were under 18 years of age, 6 were transferred to other institutions without definitive treatment, 5 had incomplete records for the main outcomes, and 4 were deceased prior to radiological/operative diagnoses of liver injury. So only 214 patients were included in the final analysis. The age range of the study population was between 18 and 79 years with a mean of 36.8 ± 15.1 years. The majority (168) were male (78.5%). 181 patients (84.6%) experienced blunt trauma and 33 (15.4%) experienced penetrating trauma.

The most common types of injury were road traffic accidents (143, 66.8%), falls (28, 13.1%), firearm injuries (19, 8.9%), stab wounds (14, 6.5%) and assault and crush injuries (10, 4.7%). The AAST liver injury classification showed: 26 patients (12.1%) with grade I injury, 49 patients (22.9%) with grade II injury, 60 patients (28.0%) with grade III injury, 55 patients (25.7%) with grade IV injury, and 24 patients (11.2%) with grade V injury. In all, 36.9% (79) of the patients suffered from high-grade liver injury (AAST grades IV–V). Thoracic injuries (87 patients, 40.7%), cranial injuries (50 patients, 23.4%), splenic injuries (46 patients, 21.5%), pelvic injuries (35 patients, 16.4%), renal injuries (24 patients, 11.2%) and intestinal injuries (18 patients, 8.4%) were associated.

Comparison Between Survivors and Non-Survivors

An in-hospital mortality rate of 13.6% was observed with 29 deaths, during the course of hospitalization. Of the 185 patients (86.4%), the rest survived to hospital discharge. The mean age of non-survivors was 44.1 ± 17.1 years, which was significantly older than survivors (35.6 ± 14.4 years, p=0.016). The sexes and mechanism of injury were not statistically different between the two groups. Non-survivors were significantly more likely to have hemodynamic instability. The non-survivors had 18 (62.1%) lower than 90 mmHg (systolic) BP at admission, while the survivors had 37 (20.0%) (p<0.001). Similarly, non-survivors had higher mean heart rate when admitted and higher shock index.

A Glasgow Coma Scale (GCS) score of 8 or lower was noted in 15 non-survivors (51.7%) and 25 survivors (13.5%) (p<0.001). Patients who died also showed more metabolic and haematological abnormalities. The mean lactate at admission was 6.2 ± 3.1 for the non-survivors and 3.1 ± 2.2 for survivors (p<0.001). Mean base deficit was −8.9 ± 4.7 mmol/L among non-survivors and −4.8 ± 3.2 mmol/L among survivors (p<0.001). Admission hemoglobin was significantly lower among patients who died.

Table 1 presents the comparison of the principal characteristics between survivors and non-survivors.

Table 1: Comparison of demographic, physiological, and injury-related factors between survivors and non-survivors

Variable	Survivors (n=185)	Non-survivors (n=29)	p-value
Age, years, mean ± SD	35.6 ± 14.4	44.1 ± 17.1	0.016
Male sex	143 (77.3%)	25 (86.2%)	0.293
Blunt trauma	155 (83.8%)	26 (89.7%)	0.586
Systolic blood pressure <90 mmHg	37 (20.0%)	18 (62.1%)	<0.001
Heart rate, beats/min, mean ± SD	104.6 ± 19.7	121.8 ± 24.4	0.001
Glasgow Coma Scale score ≤8	25 (13.5%)	15 (51.7%)	<0.001
Hemoglobin, g/dL, mean ± SD	10.8 ± 1.8	8.7 ± 2.1	<0.001
Lactate, mmol/L, mean ± SD	3.1 ± 2.2	6.2 ± 3.1	<0.001
Lactate ≥4 mmol/L	51 (27.6%)	21 (72.4%)	<0.001
Base deficit, mmol/L, mean ± SD	−4.8 ± 3.2	−8.9 ± 4.7	<0.001
Coagulopathy on admission	34 (18.4%)	14 (48.3%)	0.001
Injury Severity Score ≥25	73 (39.5%)	23 (79.3%)	<0.001
AAST grade IV–V injury	60 (32.4%)	19 (65.5%)	0.001
Associated thoracic injury	69 (37.3%)	18 (62.1%)	0.015
Associated cranial injury	37 (20.0%)	13 (44.8%)	0.008
≥6 packed red-cell units within 24 hours	**31 (16.8%)**	**17 (58.6%)**	**<0.001**
Operative management	48 (25.9%)	16 (55.2%)	0.004

Management and Clinical Outcomes

In 164 patients (76.6%), a non-operative management was chosen as the initial plan of action. This approach was effective in 150 patients (91.5%). Fourteen patients failed the non-operative treatment and went on to require surgery due to ongoing bleeding, hemodynamic instability, peritonitis or escalating transfusion needs.

50 patients were treated in primary surgery, and 14 of the 144 failed non-operative cases were then treated operatively, giving a total of 64 patients (29.9%) who were treated operatively. In 18 patients (8.4%) angiography with hepatic arterial embolization was performed. Systolic blood pressure was <90 mmHg in 55 patients (25.7%) and these 68 patients (31.8%) needed vasopressor support for their hospital stay.

Fifteen percent (153 patients) received packed red blood cell transfusion. Twenty-two patients (11.0%) received six or more PRCUs during the first 24 hours. 91 patients (42.5%) needed mechanical ventilation, and 78 (36.4%) needed to be ventilated for over 48 hours. Most frequent complications were pneumonia, acute kidney injury, sepsis, acute respiratory distress syndrome, intra-abdominal collection and bile leak.

Table 2: Management strategies and in-hospital outcomes

Variable	Total patients (n=214)
Initial non-operative management	164 (76.6%)
Successful non-operative management	150 (70.1%)
Failure of non-operative management	14 (6.5%)
Primary operative management	50 (23.4%)
Total patients receiving surgery	64 (29.9%)
Hepatic angioembolization	18 (8.4%)
Packed red-cell transfusion	153 (71.5%)
≥6 packed red-cell units within 24 hours	48 (22.4%)
Vasopressor requirement	68 (31.8%)
Mechanical ventilation	91 (42.5%)
Mechanical ventilation >48 hours	78 (36.4%)
Pneumonia	37 (17.3%)
Acute kidney injury	31 (14.5%)
Sepsis	29 (13.6%)
Acute respiratory distress syndrome	24 (11.2%)
Intra-abdominal collection	18 (8.4%)
Bile leak	15 (7.0%)
Reoperation	14 (6.5%)
In-hospital mortality	29 (13.6%)

Causes and Timing of Mortality

The 17 deaths were 58.6% of the total number of deaths and happened in the first 24 hours of admission. The most common cause of death was uncontrolled hemorrhage and refractory hemorrhagic shock which accounted for 13 deaths accounting for 44.8%. Six fatalities (20.7%) were attributed to severe associated TBIs, six to multiorgan dysfunction (20.7%) and four to septic complications (13.8%).

Predictors of In-Hospital Mortality

Univariable analysis showed that hypotension, severe neurological impairment, elevated lactate, severe base deficit, coagulopathy, Injury Severity Score ≥25, AAST grade IV–V injury, associated thoracic or cranial injury, major transfusion requirement and operative management were associated with death. A

The final multivariable model contained five clinically important variables. The adjusted risk of death was almost quadruple with admission systolic blood pressure of <90 mmHg. GCS <8 and admission lactate >4 mmol/L, AAST grade IV-V injury, and transfusion of >6 packed red-cell units were also independent predictors of mortality.

Table 3: Multivariable logistic regression analysis of in-hospital mortality

Predictor	Adjusted odds ratio	95% confidence interval	p-value
Systolic blood pressure <90 mmHg	4.28	1.63–11.22	0.003
Glasgow Coma Scale score ≤8	3.76	1.42–9.95	0.008
Admission lactate ≥4 mmol/L	3.21	1.20–8.59	0.020
AAST grade IV–V injury	2.89	1.11–7.50	0.029
≥6 packed red-cell units within 24 hours	4.67	1.78–12.27	0.002

The mortality model had a good discrimination (area under the receiver operating characteristic curve was 0.88). The Hosmer–Lemeshow test was not significant (p=0.61), suggesting good model calibration.

Prolonged ICU Stay Among Survivors

Of the 185 survivors who were discharged from the hospital, 74 (40.0%) were discharged from the ICU after more than seven days. Of the 60.0% (n = 111) survivors, 7 days or less were spent in the ICU, including those who did not need to be admitted to the ICU. Patients with prolonged ICU stay had a median of 12 days in the ICU while patients who did not have prolonged stay had a median of 4 days. They also had a significantly longer total hospital stay (22.4 ± 8.1 days vs 9.1 ± 3.8 days, p<0.001).

Patients with longer stays in the intensive care unit had significantly more high overall injury severity, high-grade hepatic injury, associated thoracic or cranial injury, major transfusion, operative treatment, mechanical ventilation for longer than 24 hours, sepsis and acute kidney injury.

Table 4: Factors associated with prolonged ICU stay among hospital survivors

Variable	ICU stay ≤7 days (n=111)	ICU stay >7 days (n=74)	p-value
Age, years, mean ± SD	34.8 ± 14.2	36.1 ± 14.6	0.550
Male sex	84 (75.7%)	59 (79.7%)	0.517
Injury Severity Score ≥25	24 (21.6%)	49 (66.2%)	<0.001
AAST grade IV–V injury	25 (22.5%)	35 (47.3%)	0.001
Associated thoracic injury	27 (24.3%)	42 (56.8%)	<0.001
Associated cranial injury	14 (12.6%)	23 (31.1%)	0.003
≥6 packed red-cell units within 24 hours	12 (10.8%)	19 (25.7%)	0.009
Operative management	17 (15.3%)	31 (41.9%)	<0.001
Mechanical ventilation >48 hours	12 (10.8%)	46 (62.2%)	<0.001
Sepsis	3 (2.7%)	20 (27.0%)	<0.001
Acute kidney injury	4 (3.6%)	18 (24.3%)	<0.001
Hospital stay, days, mean ± SD	9.1 ± 3.8	22.4 ± 8.1	<0.001

Independent Predictors of Prolonged ICU Stay

Injury Severity Score (ISS) ≥25, mechanical ventilation for >48 hours, thoracic injury, surgery, and septic shock were independent predictors of prolonged ICU stay after adjustment.

Mechanical ventilation for more than 48 hours was the most predictive, more than seven times improving the odds of prolonged stay in the intensive care unit. The risk was about 7 times greater for those with sepsis.

Table 5: Multivariable logistic regression analysis of prolonged ICU stay

Predictor	Adjusted odds ratio	95% confidence interval	p-value
Injury Severity Score ≥25	3.18	1.57–6.44	0.001
Mechanical ventilation >48 hours	7.42	3.39–16.25	<0.001
Associated thoracic injury	2.34	1.18–4.65	0.015
Operative management	2.61	1.23–5.54	0.012
Sepsis	6.85	1.87–25.10	0.004

The extended model of being admitted to the intensive care unit (ICU) was also well discriminating with an area under the receiver operating characteristics curve of 0.87. The Hosmer-Lemeshow test was satisfactory (p=0.72).

DISCUSSION

The current study aimed to assess factors that are associated with in-hospital mortality and length of stay in intensive care unit (ICU) in trauma liver injury. The main findings were that admission hypotension, severe neurological impairment, high serum lactate, high-grade liver injury, and large transfusion of packed red blood cells in the first 24 hours were independent risk factors for death. In hospital survivors, a high ISS, mechanical ventilation >48 hours, thoracic injury, surgical interventions, and sepsis were independently associated with prolonged stay in the ICU. These data suggest that a complex interplay of anatomical severity of liver injury, early physiological decline, overall burden of trauma and in-hospital complications determines outcomes after TLI.

Overall death rate for the current cohort was 13.6%. This is similar to the mortality rates reported at contemporary trauma centres; mortality rates, however, depend on the severity of the injuries, referral pattern, access to interventional radiology, and the percentage of patients who are hemodynamically unstable. Alanezi et al. found that injury grade, associated injuries and operative intervention were all independent factors that had a significant impact on outcomes following liver trauma (3). In a study in Pakistan, Siddiqui et al. reported that an overall mortality rate of around 10% with hemorrhage and sepsis being the major causes of death (11). It is important to note that the increased mortality seen in this analysis could be due to the presence of patients with severe physiological disturbance and a considerable percentage of high grade injuries.

Over half of the deaths were in the first 24 hours and the most frequent cause was uncontrolled hemorrhage, refractory shock. This suggests that early death after liver injury is driven mainly by haemorrhage and lack of re-establishment of adequate tissue flow. Although there has been advancement in resuscitation, surgery, and angioembolization for managing damage to major hepatic veins, severe hepatic vascular disruption can result in rapid and refractory hemorrhage. Immediate operative management of the patient who is still hemodynamically unstable after resuscitation is thus stressed by the WSES guidelines, irrespective of the anatomical grade established by imaging (1). The present findings corroborate this physiology based approach.

Admission SBP < 90 mmHg was the most significant independent predictor of mortality. Trauma-induced hypotension can be caused by continued hemorrhage, hypovolemia, myocardial dysfunction or a combination of the above. Hypotension is a persistent condition that leads to decreased delivery of oxygen to critical organs and, therefore, to metabolic acidosis, coagulopathy, hypothermia, and multiorgan dysfunction. This has been reported in previous liver trauma studies, in which hemodynamic instability has been associated with massive transfusion, surgery, non-operative management failure and mortality (4,7,11). The results of this study confirm that the first BP is a simple but clinically relevant surrogate marker.

The probability of death was independently increased by a Glasgow Coma Scale score of 8 or less. Traumatic brain injury, cerebral hypoperfusion, hypoxia, intoxication or intense shock may cause reduction in consciousness. In the unadjusted analysis, there was also a higher prevalence of associated cranial injury among non-survivors. Liver injuries can be the main abdominal injury but deaths may be affected by injuries outside the abdomen. This is in agreement with the results of Afifi et al., who showed associated injury playing a significant role in the clinical course of the blunt hepatic trauma patients (13). Neurologic evaluation, therefore, is a critical part of trauma resuscitation, as should be the treatment of hypoxia and cerebral hypoperfusion, if they occur.

Higher lactate concentration at admission (≥ 4 mmol/L) was independently associated with mortality. Increased lactate levels are a sign of inadequate tissue perfusion, anaerobic respiration, stimulation of the adrenergic system and decreased clearance. Even if blood pressure is temporarily improved in trauma patients, ongoing occult hemorrhage is suggested by persistent hyperlactatemia. In the unadjusted analysis, base deficit was also significantly greater among non-survivors. In trauma, Davis et al have shown that base deficit is a useful predictor of outcome and in certain populations may be superior to lactate (16). Lactate and base deficit should be used in conjunction with blood pressure, shock index, urine output, mental status and response to transfusion, not independently, in clinical practice.

High-grade liver injury was an independent predictor of mortality (but with less strength than hypotension or major transfusion). This finding corroborates the notion that anatomical severity is relevant and not all alone enough to predict outcome. In addition to the hepatic injury grade, physiological deterioration, transfusion requirement and total injury burden were reported to affect the mortality of patients with high-grade liver injury (4). Similarly, Field et al. found that the AAST grade alone should not dictate treatment (14). Patients who have Grade IV or Grade V injuries might not require surgery, as they can be successfully managed in an appropriate centre, but patients with lower grade injuries may deteriorate due to associated trauma or uncontrolled bleeding.

Another significant predictor of mortality was transfusion with six or more packed red blood-cell units within the first 24 hours. Major transfusion is associated with significant bleeding, and it can be a cause of negative events due to dilution of coagulation factors, hypocalcaemia, hypothermia, inflammation activation and complications of transfusion. Definitions of massive transfusion vary from study to study, but these volumes and speeds of blood-product administration are all indications of the severity of critical bleeding (18). Balanced transfusion protocols, correcting coagulopathy, avoiding hypothermia and rapid control of bleeding could improve the survival rates in this high-risk group.

Non-operative treatment was initially used for most patients, and was successful for >90% of those who were selected. This is aligned with systematic evidence which indicates that the non-operative approach is successful in a significant number of patients, particularly when they are hemodynamically stable and closely monitored (6,12). This study further illustrated the need for dynamism in the management. Patients initially managed non-operatively do need to be re-assessed clinically as continued bleeding, peritonitis, worsening transfusion requirements, or deterioration in physiology may warrant either angioembolization or surgery.

Prolonged ICU stay was the second significant outcome studied. Forty percent of the hospital survivors were still in the intensive care unit for > 7 days. An Injury Severity Score was an independent predictor of longer admission, suggesting that the length of a patient's stay in the intensive care unit was not due solely to hepatic injury. Lefering and Waydhas showed that severity of injury, multiple significant injuries, organ failure and mechanical ventilation were the most important factors associated with longer ICU stays in severely injured patients (5). This is in line with the decision to estimate ISS separately from liver injury grade.

Mechanical ventilation of more than 48 hours was the best predictor of a prolonged stay in the intensive care unit. Prolonged ventilation may be a sign of serious chest injury, neurological damage, respiratory failure, multiple procedures, or systemic disorders. It also raises the risk of ventilator associated pneumonia, side effects of sedation, muscle weakness and delayed mobilization. Respiratory complications were important for recovery, with associated thoracic injury being a sole predictor of longer stay in the intensive care unit. Selected patients may benefit from a shorter critical-care stay with early lung-protective ventilation, appropriate analgesia, chest physiotherapy and early weaning. Independent risk factors for increased ICU admission were operative management. Patients who have to undergo surgery are more hemodynamically unstable, injured more extensively, require more transfusions, or have abdominal disease. There can also be complications after surgery such as recurrent exploration, open abdomen, post surgical ventilation and infectious. Among the patients who underwent surgery for hepatic trauma, Trintinalha et al. found that the hospitalization time depended on the severity and complexity of the surgery (9). The association noted in the present study therefore is likely related to the severity of initial injury as well as invasive treatment.

The odds of prolonged ICU stay more than doubled with the presence of sepsis (adjusted odds: 7.08). Clinically, this finding is important because infection can be potentially prevented or modified. Tissue damage, transfusion, invasive devices, mechanical ventilation, abdominal contamination, and immune dysregulation are risk factors for sepsis in trauma patients. Sepsis-3 is the framework, which describes sepsis as life-threatening organ dysfunction caused by a dysregulated response to infection (20). Preventing or catching problems early, making sure the source of the infection is eliminated, selecting the right antibiotic, and removing extraneous devices could diminish organ dysfunction and length of time spent in the ICU. The study has a number of strengths. Mortality and ICU stay were examined individually to avoid misclassifying those that died early as having a short ICU stay. Physiological, laboratory, anatomical, treatment-related, and complication variables were also included in the study, so as to have a comprehensive evaluation of the risk. Multivariable models were shown to have good discrimination and acceptable calibration in separate models.

There are a few caveats to note. The retrospective design was subject to the completeness and accuracy of medical records. Prehospital resuscitation, transfusion ratios, clearance of lactate, time to hemorrhage control, and detailed ventilator parameters may not have been recorded on a consistent basis and may prove to be some significant variables. The study is undertaken at one centre, so this may impact generalizability. Although the mortality rate was not large, it limited the number of predictors that could be safely incorporated in the mortality model. Institutional discharge practices and availability of high dependency beds may also play a role in prolonged time spent in the ICU. Finally, the study provided associations but not cause. In conclusion, prognosis after traumatic liver injuries cannot be predicted based on liver grade only. The clinical features of admission shock, neurological deficit, metabolic disturbances, severe blood transfusion, and general severity of injury should be considered collectively. Early recognition of high-risk patients can help with prompt bleeding control, timely admission to the intensive care unit (ICU), specialized respiratory management, prevention of infection and better utilization of trauma-care resources.

CONCLUSION

Traumatic liver injury is a significant cause of hemorrhage, critical care admission and in-hospital mortality. The results of this study clearly show that both the severity of the hepatic damage and the patient's physiological status at the presentation impacts prognosis. Lower systolic blood pressure (<90 mmHg) and Glasgow Coma Scale score (<8), serum lactate level (≥4 mmol/L), AAST liver injury grade (IV–V), and transfusion (of ≥6 units of packed red blood cells in the first 24 hours) were independent predictors of in-hospital mortality. These results justify the application of the early physiological evaluation together with the anatomical assessment of the degree of injury to determine those patients most likely to die (1,4,14). In hospital survivors, operative management, associated thoracic injury, prolonged use of mechanical ventilation (for more than 48 hours), Injury Severity Score ≥25, and sepsis were independent risk factors for prolonged ICU stay. This means that the liver injury is not the only factor that impacts extended critical care needs; overall trauma burden, respiratory dysfunction, invasive treatment, and complications that occur during hospital stay also play a role (5,9).

Prompt diagnosis of shock, neurological dysfunction, metabolic abnormalities, high transfusion needs and serious associated injuries can aid prompt risk-stratification and intervention. Early cessation of bleeding, fluid management, selection for non-operative management, early respiratory management and proper infection prevention measures will improve patient survival and decrease the length of stay in the ICU. Coordination between trauma surgeons, emergency physicians, anesthetists, interventional radiologists and intensive-care teams is crucial for best outcomes. Larger, prospective multicentre studies are recommended, with the aim of validating these predictors and creating practical risk-assessment models for patients with liver injury caused by trauma. These models could help in clinical decision making, family counselling and better utilisation of resources at hospitals for trauma and intensive-care unit.

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