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Survival and Associated Risk Factors in Mechanically Ventilated Burn Patients: A Cross-Sectional Study

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ABSTRACT

Objectives: This study aimed to determine the survival rate and identify associated risk factors in mechanically ventilated (MV) burn patients.
Methods: This cross-sectional analytical study was conducted at Velayat Hospital, a burn and plastic surgery referral center affiliated with Guilan University of Medical Sciences, between March 2011, and September 2020. Data were retrieved from electronic medical records and analyzed using SPSS software (version 24.0). Patients discharged alive or lost to follow-up were treated as censored observations in a time-to-event analysis.
Results: The mean age of survivors was 19.03±30.21 years, compared to 42.54±19.30 years in the non-survivors. Men comprised 78.9% (n=30) of survivors and 64.9% (n=155) of non-survivors. The mean intensive care unit (ICU) survival time was 18.33±1.36 days (median=12±1.24 days). There were significant differences between survivor and non-survivor groups in terms of age, length of stay, presence of comorbidities, inhalation injury, sepsis, acute respiratory distress syndrome (ARDS), and acute kidney injury (AKI) ($p<0.05$). The Kaplan-Meier analysis demonstrated a significant difference in survival probability between MV and non-MV groups ($p=0.028$), with a higher survival probability observed in non-MV patients.
Conclusion: Age, length of stay, renal failure, ARDS, and sepsis were associated with increased mortality risk in MV burn patients. While these findings highlighted critical prognostic factors, causal inferences require further investigation through longitudinal or interventional studies to guide targeted therapeutic strategies.

Keywords: Burns, Mechanical ventilation, Survival, Prognosis.

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Introduction

Burn injuries represent one of the most devastating and economically burdensome traumatic events, characterized by damage to the skin or soft tissues [1, 2]. These injuries often lead to prolonged hospitalization, high costs of wound management, and significant morbidity and mortality rates [2-4]. These factors impose substantial socioeconomic burdens on affected individuals and communities [5-7]. According to the World Health Organization (WHO), burn-related injuries caused approximately 265,000 deaths globally in recent years, with 96% occurring in low- and middle-income countries [8]. Notably, burns rank among the leading causes of disability-adjusted life-years (DALYs) in developing nations [9]. In Iran, burns are the 8th-leading cause of death and the 13th-leading cause of disability [10].

While advances in clinical care have significantly reduced burn mortality rates over the past three decades [11], survivors frequently face long-term physiological complications [12, 13]. For patients with major burns (>20% total body surface area [TBSA]), mechanical ventilation (MV) is required in approximately one-third of cases [14, 15]. However, MV carries significant risks, including ventilator-associated pneumonia (VAP), acute lung injury, and nosocomial infections, all of which contribute to increased morbidity, prolonged hospitalization, and higher mortality rates [15-18]. The decision to initiate MV remains complex, relying on both clinical and hematologic parameters [19].

Previous studies highlighted the multifactorial nature of outcomes in burn patients requiring MV. For instance, A Saudi Arabian study reported a 20% mortality rate in this population, with inhalation injury and acute physiology and chronic health evaluation (APACHE-II) scores as key predictors [20]. Similarly, a Malaysian study identified higher TBSA, early systemic inflammatory response syndrome (SIRS), and MV as significant mortality risk factors [21]. Data from Sultan Ismail Hospital (n=525 over 7 years) further highlighted older age, greater TBSA, and MV requirement as independent predictors of mortality [22]. Furthermore, severe inhalation injuries, particularly when requiring MV, were consistently linked to elevated mortality [23].

Despite these findings, critical knowledge gaps persist regarding the interplay of risk factors such as MV duration, pre-existing comorbidities, and specific burn characteristics. This study aimed to address these gaps by analyzing survival trends and identifying modifiable risk factors in mechanically ventilated (MV) burn patients. Using data from a regional burn referral center, the present study aimed to provide evidence-based insights to optimize clinical decision-making and improve outcomes in this high-risk population.

Materials and Methods

This cross-sectional analytical study was conducted at Velayat Hospital, a regional burn care and plastic surgery referral center affiliated with Guilan University of Medical Sciences (Rasht, Iran). Data were collected from March 21, 2011, to September 21, 2020.

Participants

The study included adult patients over 20 years of age with second- or third-degree thermal or chemical burns affecting 20-80% of total body surface area (TBSA) who were admitted to the hospital within 24 hours post-burn and remained hospitalized for more than 7 days. Exclusion criteria consisted of patients with multiple traumas, those extubated within less than 24 hours of intubation, and cases with incomplete medical records. From an initial pool of 453 screened patients, 135 met all inclusion criteria and were enrolled in the study.

Demographic and clinical data were retrieved from the hospital information system (HIS). This information encompassed sex, age, TBSA, cause of the burn, inhalation injury status, length of hospital stay (days), and presence of comorbidities. Documented complications comprised sepsis, ventilator-associated pneumonia (VAP), acute kidney injury (AKI), and acute respiratory distress syndrome (ARDS). The time-to-event analysis was based on the duration from hospital admission until either discharge or death, measured in days.

The minimum required sample size was calculated based on a study by Ismaeil *et al.,* where the median survival for deceased and recovered groups was reported as 38 days and 8 days, respectively [20]. The required sample size was estimated by assuming an effect size of approximately 5 days, a significance level of 0.05 (α=0.05), and a power of 80%. Considering a 10% dropout rate, the minimum required sample size was 53.

All analyses were performed using statistical software (SPSS version 24.0; IBM Corp). Continuous variables were reported as mean±standard deviation (SD), while categorical variables were presented as frequencies and percentages. Group comparisons between survivors and non-survivors were conducted using appropriate statistical tests: The Chi-square test or Fisher's exact test for categorical variables, and independent samples t-tests for continuous variables. Survival probabilities were estimated using Kaplan-Meier analysis with log-rank tests to compare MV and non-MV patient groups, with statistical significance set at $p<0.05$ for all analyses.

The study protocol received ethical approval from the Ethics Committee of Guilan University of Medical Sciences (code: IR.GUMS.REC.1400.567), ensuring compliance with ethical standards for human subjects research.

Table 1. Relationship between demographic variables and mortality

Patient Characteristic	All patients n (%)	Survivor n (%)	Non-survivor n (%)	*p* value
Age groups (years)	38.6±20.36	30.51±19.69	46.75±21.30	<0.001
Sex				
Male	87 (64.4)	27 (77.1)	60 (60.0)	0.68
Female	48 (35.6)	8 (22.9)	40 (40.0)	
Comorbidity				
Yes	24 (17.8)	2 (5.7)	22 (22.0)	0.030
No	111 (82.2)	33 (94.3)	78 (78.0)	
Length of stay (days)	12.88±21.28	14.19±27.40	11.85±15.17	<0.001
TBSA %				
20-39	37 (27.4)	13 (37.1)	24 (24.0)	0.65
40-59	54 (40.0)	16 (45.7)	38 (38.0)	
>60	44 (32.6)	6 (17.1)	38 (38.0)	
Mechanism of burn				
Hot liquid	11 (8.1)	1 (2.9)	10 (10.0)	0.345
Scaled	119 (88.1)	32 (91.4)	87 (87.0)	
Electrical	4 (3.0)	2 (5.7)	2 (2.0)	
Others	1 (0.7)	0 (0.0)	1 (1.0)	
Inhalation injury				
Yes	73 (54.1)	21 (60.0)	52 (52.0)	0.014
No	62 (45.9)	14 (40.0)	48 (48.0)	

Results

After applying rigorous screening criteria, 135 patients were enrolled in this study. Table 1 presents the baseline demographic characteristics of the study participants. The sample comprised predominantly male patients (n=87, 64.4%) compared to female patients (n=48, 35.5%). The mean age of the patients was 38.6 years. The mean duration of hospitalization was 12.88±21.28 days, with an overall mortality rate of 12.5%. Statistical analysis revealed significant differences ($p<0.001$) between survivors and non-survivors in terms of age, hospitalization duration, comorbidity prevalence, and inhalation injury incidence (Table 1).

Further analysis demonstrated significant between-group differences ($p<0.05$) for several critical complications, including sepsis, ARDS, and AKI showed (Table 2).

Table 3 summarizes the results of survival probabilities among MV burn patients in the ICU, comparing survivors and non-survivors. The analysis revealed a mean survival duration of 18.33±1.36 days (median=12±1.24 days) for ICU patients. Kaplan-Meier analysis demonstrated a statistically significant difference in survival probability between groups ($p=0.028$), with non-MV patients showing significantly better survival outcomes (Figure 1).

Table 2. Medical outcomes and complications in the mechanically ventilated group

Patient Characteristic	All patients n (%)	Survivor n (%)	Non-survivor n (%)	*p* value
Infection				
yes	104 (77.0)	25 (71.4)	79 (79.0)	0.359
no	31 (23.0)	10 (28.6)	21 (21.0)	
Sepsis				
yes	33 (24.4)	3 (8.6)	30 (30.0)	<0.001
no	102 (75.6)	32 (91.4)	70 (70.0)	
ARDS				
Yes	57 (42.2)	2 (5.7)	55 (55.0)	<0.001
No	78 (57.8)	33 (94.3)	45 (45.0)	
VAP				
Yes	70 (51.9)	17 (48.6)	53 ()	0.665
No	65 (48.1)	18 (51.4)	47 ()	
AKI				
Yes	46 (34.1)	1 (2.9)	45 (45.0)	<0.001
No	89 (65.9)	34 (97.1)	55 (55.0)	

Table 3. Survival probability function in burn patients under mechanical ventilation hospitalized in the intensive care unit in two groups, deceased and survived.

Variables	Estimate±SD	Lower Bound	Upper Bound
Mean survival	18.1±33.36	15.66	21
Median survival	12.0±1.24	10.55	14.44

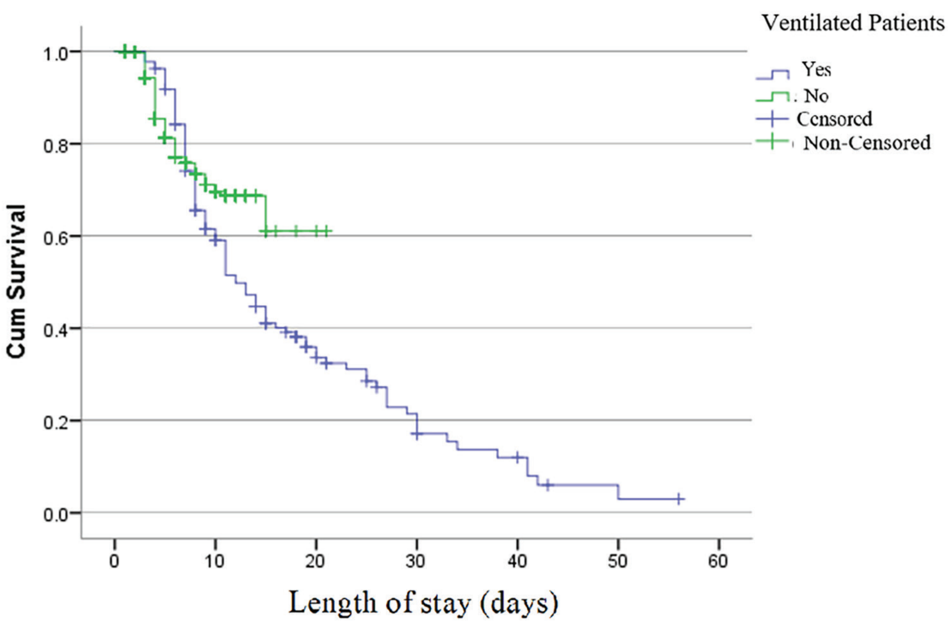

Fig. 1. Survival analysis of mechanically ventilated patients admitted to the Burn unit

Discussion

The present study analyzed survival outcomes in MV burn patients, and the results showed that the presence of inhalation injury was a significant predictor of mortality. Lip *et al.,* claimed that inhalation injury was one of the critical factors determining survival in these patients [21], which was in agreement with the findings of the present study.

Consistent with Garren *et al.,* our findings confirmed that the inhalation injury significantly increased the likelihood of prolonged mechanical ventilation [24]. Inhalation injury encompasses a spectrum of pulmonary damage caused by inhaling toxic substances during fires or other similar events [23]. It not only increases mortality risk in burn patients but also necessitates heightened clinical vigilance, particularly for those requiring ventilatory support. Current evidence supported the use of targeted antibiotics for confirmed infections in these patients, while corticosteroid therapy offered no demonstrable benefit [25]. The patient was diagnosed with sepsis, and ARDS was also a sign of non-survival of the patient under ventilator. The findings of the present study were consistent with a previous systematic review of 8,200 burn patients across 33 studies [26], which identified mechanical ventilation, renal failure, sepsis, and pre-existing conditions (notably diabetes) as key mortality predictors. In the present research, the concurrent diagnosis of sepsis and ARDS in ventilated patients was strongly associated with fatal outcomes, further underscoring the critical nature of these complications.

Our analysis identified demographic factors such as advanced age and prolonged hospital stay as significant predictors of mortality among ventilated burn patients. These findings were consistent with previous studies, such as Lip *et al.,* who reported a clear association between advanced age and increased mortality [21]. Queiroz *et al.,* in their multivariate analysis of 293 burn patients, found that both age and mechanical ventilation were associated with mortality [27]. Heyland *et al.,* reported that extended hospitalization (mean duration=17 days) significantly affected the mortality rate of patients [28]. While these observational findings highlighted important clinical correlations, they failed to establish causation. Future prospective studies are required to further elucidate these relationships and guide optimal clinical management strategies.

The present study identified infection as a significant predictor of survival outcomes in MV burn patients. These results aligned with established literature demonstrating a significant association between AKI and mortality in burn patients requiring ICU admission and mechanical ventilation (27). AKI represents a frequent complication in burn ICU patients, contributing to increased mortality rates [29, 30]. Several risk factors were identified for AKI development in this population, including advanced age, extensive or complex burn injuries, the presence of multiple organ failure, and sepsis [23]. Notably, our data corroborate these findings, showing the presence of old age and sepsis, in turn, lead to an increased risk of mortality in mechanical ventilation patients. As a result, the presence of AKI with these factors significantly increases mortality risk, underscoring the critical importance of AKI prevention and management in this patient population.

According to the results, there was no correlation between TBSA and the degree of burns with mortality rate. However, a review of similar studies indicated that TBSA and burn severity could be associated with mortality risk in burn patients. One possible explanation for this discrepancy is the difference in inclusion and exclusion criteria. In the current study, patients with severe burns (≥80% TBSA, second- and third-degree), who have a high mortality risk, were excluded to minimize confounding factors. Additionally, the sample size in the present study was significantly smaller than in comparable studies, which might also account for the differing results.

The mortality rate was higher in burn patients under MV. Lip *et al.*,'s study found that MV was associated with poorer survival in burn patients [21]. Another study by the same researcher in 2019 also showed that mechanical ventilation was associated with increased mortality in burn patients [22]. Similarly, Talizin *et al.,* [26] and Queiroz *et al.,* [27] demonstrated a significant association between MV and increased mortality in burn patients. Güldoğan e*t al.,* [31] further supported this trend in a study of 224 patients with burns covering ≥30% of TBSA, where MV exposure was associated with higher mortality. In the present study, the intersection of Kaplan-Meier survival curves suggested dynamic changes in survival probabilities over time. This phenomenon might reflect variations in the timing of complications or recovery patterns. For instance, MV patients might initially benefit from intensive supportive care, leading to higher short-term survival rates, but later face elevated risks due to nosocomial infections or multi-organ failure. Further research is required to clarify the underlying factors contributing to this dynamic change.

This study had several limitations that should be acknowledged. First, as a single-center study, the findings might lack generalizability to other clinical settings. Second, the relatively small sample size compared to similar studies might reduce the statistical power and limit the robustness of the conclusions. Although we conducted stratified analyses for key variables, including age, sex, TBSA, burn mechanism, inhalation injury, hospitalization duration, infection frequency, sepsis, VAP, AKI, and ARDS, this study did not account for other potential confounders that might affect the outcomes. Notably, the absence of data on pre-existing comorbidities (e.g., diabetes, cardiovascular diseases, or chronic respiratory conditions) and mechanical ventilation duration, which are known to significantly influence patient recovery and survival, represents a critical limitation.

Another limitation of this study was the use of Kaplan-Meier survival analysis, which failed to account for competing risks (e.g., mortality or inter-facility transfers). These competing events could preclude the primary outcome (hospital discharge) and could potentially bias survival probability estimates. Future studies should incorporate competing risk models, such as the Fine and Gray subdistribution hazard model, to provide a more accurate analysis of length of stay and related outcomes. Moreover, while we implemented manual record review and diagnostic verification procedures, potential documentation inaccuracies in medical records may have introduced bias. Although these measures reduced misclassification risk, residual confounding remains a possibility that could not be completely eliminated.

Furthermore, as a descriptive study, the findings were limited to identifying associations rather than establishing causal relationships. Although significant associations were observed between mortality and factors such as age, TBSA, and sepsis; these relationships should be interpreted with caution. Future prospective cohort studies or interventional trials would be necessary to confirm these associations and elucidate potential causative mechanisms.

Future studies should address these limitations by incorporating comprehensive data on pre-existing comorbidities and MV duration, including additional clinically relevant variables, and utilizing larger, multi-center cohorts to improve generalizability. Such methodological enhancements would help distinguish true independent risk factors from potential confounding variables among the observed associations. Furthermore, these improvements would provide more definitive evidence regarding the causal relationships between identified risk factors and clinical outcomes in burn patients.

The findings of the present study identified significant associations between mortality risk and several clinical factors—including advanced age, prolonged hospitalization, renal failure, ARDS, and sepsis in MV burn patients. The survival probability was significantly higher among non-ventilated patients. However, as a descriptive analysis, these findings could not establish causal relationships. Future prospective longitudinal studies or interventional trials are recommended to validate these observed associations, elucidate potential causal mechanisms, and inform evidence-based treatment strategies for optimizing outcomes in this vulnerable patient population.

Declaration

Ethics approval and consent to participate: This retrospective study was approved by the

Ethics Committee of Guilan University of Medical Sciences (code: IR.GUMS.REC.1400.567). As the research utilized anonymized data from the hospital information system, the ethics committee waived the requirement for individual patient consent. All patient identifiers were removed before data analysis to ensure confidentiality.

Consent for publication: Not applicable.

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