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Key Predictors of Mortality in Burn Patients: Insights from a Study of 1167 Cases with a Novel Volume Index Approach

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Abstract

Background: Following car accidents, falls, and interpersonal violence, burn injuries rank fourth among the most common types of trauma worldwide. The incidence of burn injuries is significantly higher in developing countries compared to developed low- and middle- income countries. Therefore, it is crucial to identify the contributing factors, that lead to increased mortality and morbidity among burn patients. According to the literature, age, inhalation injury, Total Body Surface Area (TBSA), and sex significantly influence the morbidity and mortality of burn patients. However, there are limited studies extensively evaluating the association between laboratory tests and mortality.

Methods: A comprehensive understanding of the characteristics of burn injuries and the factors predisposing patients to a higher risk of death can help clinicians identify high-risk patients and make informed decisions to minimize morbidity and mortality rates.

Results: This study identifies key predictors and factors influencing mortality among burn patients, providing clinicians with a deeper understanding of burn cases. The findings are based on data collected from a referral center specializing in burns and plastic surgery. Additionally, the Volume Index is introduced for the first time as a predictive factor for mortality.

Conclusion: Volume index and thrombocytopenia are novel and effective indices of poor prognosis among burned patients.

Keywords: Accidents, Body surface area, Burns, Developing countries, Morbidity, Plastic, Surgery

Introduction

With an annual worldwide mortality of approximately 200,000 cases, burn injuries represent a significant public health concern, particularly in developing countries (1). Following car accidents, falls, and interpersonal violence, burn injuries rank fourth among the most common types of trauma worldwide (2). High-income countries have reduced the incidence and severity of burn injuries by providing better infrastructure compared to low- and middle-income countries (3).

Burn injuries induce a persistent hypermetabolic state that can lead to protein catabolism, insulin resistance, growth retardation, and cardiac dysfunction (4). Additionally, victims often experience multi-organ impairment and a hyperinflammatory state characterized by excessive production of cytokines and acute-phase reactants (5,6). This hyperinflammatory state is triggered by a 10- to 50-fold overproduction of glucagon, catecholamines, and cortisol. Mortality and morbidity in burn patients are primarily attributed to the failure to manage this hypermetabolic and hyperinflammatory state effectively (1,5).

According to the literature, factors such as age, inhalation injury, Total Body Surface Area (TBSA), and sex significantly influence the morbidity and mortality of burn patients (7,8). However, the limited number of studies and the restricted scope of their parameters highlight the need for further research to better understand the factors associated with mortality. Despite recent advances in burn patient management, mortality rates remain high (7,8).

Accurately identifying the predictors and contributors to mortality among burn patients is critical for timely recognition of high-risk individuals and their prompt management to minimize fatalities. Nonetheless, there is a scarcity of comprehensive studies evaluating laboratory tests and their association with mortality. This study aims to fill that gap by identifying the risk factors, predictive indicators, and laboratory parameters associated with mortality, focusing on data from burn patients in northwest Iran.

Materials and Methods

Study subjects and variables

Patients were selected from the Plastic and Reconstructive Center of the Sina Educational, Research, and Treatment Center (Sina Hospital) in Tabriz, Iran, a referral center for northwest Iran. The medical records of all patients admitted to the Plastic and Reconstructive Surgery wards [including the men's ward, women's ward, children's ward, and Burn Intensive Care Unit (BICU)] at Sina Hospital in 2019 were retrieved from the hospital archive (n=1,410). Of these, 243 cases did not meet the inclusion criteria and were excluded from the study. The remaining 1,167 cases were reviewed by two independent researchers (AG and SH) and entered into two separate computerized databases.

The variables analyzed included ID number, admission date, discharge or death date, sex, age, profession, marital status, season, etiology (accidental, suicidal, homicidal, or conflict), type of burn (scalds, fire, electrical, chemical, or contact burns), percentage of Total Body Surface Area (TBSA%) affected, Abbreviated Burn Severity Index (ABSI), vital signs at admission, Glasgow Coma Scale (GCS) score, burn depth, presence of inhalation injury, presence of gas inhalation, number of surgical procedures, anatomical distribution of burns (head and neck, upper extremities, torso, and lower extremities), length of hospital stay, time interval from burn to admission, prior admission to another hospital for more than 6 *hr*, presence of fractures, traumatic burn injuries, cardiac, pulmonary, renal, or hepatic complications, presence of hyper/hypothermia, past medical history, fluid therapy during the first 24 *hr* post-injury, presence and type of shock, presence and type of infections, laboratory test results, and final status (discharge or death (1,9-11).

The Volume Index (VI) was calculated using the formula: VI=TBSA%×stage [(1st-degree burn size×1) +(2^{nd}-degree burn size×2)+(3^{rd}-degree burn size×3)+(4^{th}-degree burn size×4)].

The two datasets were subsequently merged, cross-verified, and triple-checked against the archive to resolve inconsistencies and maintain data integrity.

Inclusion criteria

- Patients with all types of skin burn injuries, with or without inhalation injuries.
- Patients admitted to the Plastic and Reconstructive Surgery wards (men's, children's, women's, and BICU) at Sina Hospital.

Exclusion criteria

- Burn injuries resulting from trauma.
- Patients not admitted to the Plastic and Reconstructive Surgery wards at Sina Hospital.
- Intestinal burns caused by ingestion of chemical substances leading to Gastrointestinal (GI) burns.

Statistical analysis

Statistical analysis was conducted using SPSS version 26 software. The tests applied included the T-test and ANOVA for parametric variables, and the Chi-square test, Mann-Whitney U test, and Pearson correlation for non-parametric variables. Data were visualized using tables, histograms, box plots, and error bars. Results were reported as means, Standard Deviations (SD), Odds Ratios (OR) with corresponding 95% Confidence Intervals (95% CI), and p-values.

The exhaustive CHAID (Chi-square Automated Interaction Detection) algorithm in SPSS was utilized to construct decision trees. This method categorizes study parameters into a decision tree by dividing the sample into two subgroups based on the most statistically significant risk factor (highest Chi-square value). Subgroups are then further divided iteratively by the next most significant risk factor. Statistical tests were two-tailed, and a p-value <0.05 was considered statistically significant.

Results

Demographic characteristics of the population

As shown in table 1, among the 1,167 patients included in the study, 63.8% were male, and 36.2% were female. Most patients were younger than 10 years old, while the lowest frequency of cases occurred in the 10–20-year age group. The mean time from injury to admission was 1,812.9 *min* for men (*min*: 3 & max: 36000 *min*) and 2,021.5 *min* for women (*min*: 15 & max: 86400 *min*). Patients were admitted to this center within a time range of 3 to 86400 *min*. The significant variation in admission times and the long interval between burns and admission to our center were due to the referral of patients from various regions in northwestern Iran and even from neighboring countries. The mean TBSA and ABSI were slightly higher among women (12.5 and 5%, respectively) compared to men (11.7 and 3.67%).

The minimum and maximum TBSA values were 1 and 100%, respectively in both groups, while the minimum ABSI was 2 for both groups, with maximum ABSI scores of 16 for women and 26 for men. Women underwent fewer reconstructive surgery sessions on average (mean: 0.49) compared to men (mean: 0.55). The decision to perform surgery was based on the severity of symptoms, the necessity of surgical intervention, and the clinical condition of the patients. Inhalation injuries were more common in men (6.9%) than in women (5.4%), whereas gas inhalation was more frequent in women (3%) than in men (1.8%).

Among male patients, the most common burn stages were 3rd, 2nd, 4th, and 1st-degree burns, while for female patients, the order was 2nd, 3rd, 4th, and 1st-degree burns. All 4th-degree burns occurred in electrically burned patients, all of whom were eventually discharged. Burns caused by scalds (64.2% in women, 44.9% in men) and fire (24.1% in women, 37.8% in men) were significantly more common than those caused by chemicals (4.7% in women, 7.1% in men), contact burns (5.9% in women, 6.3% in men), and electrical burns (0.9% in women, 3.7% in men). Accidental burns accounted for the majority of cases (98.3% in women, 98.5% in men), followed by suicidal (0.9% in women, 0.5% in men), homicidal (0.4% in women, 0.2% in men), and interpersonal conflict-related burns (0.2% in women, 0.1% in men).

Demographic features of deceased patients

Of the 72 deceased cases, the overall mortality rate was 6.2% in 2019, with 61.1% being male and 38.9% female (Table 2). The mean age of deceased men was 38.37 years, compared to 38 years for women. The highest mortality was observed in the 40–50-year age group (frequency: 15, percentage: 16.1%) (Figure 1). The mean time from injury to admission among deceased patients was 1,224.42 *min* for men and 1,805.28 *min* for women. TBSA and ABSI were 63.5% and 9.73 for men and 59.79% and 10.32 for women, respectively. Deceased women underwent more reconstructive surgeries on average (1.14) compared to men (0.45). Inhalation injuries were more prevalent among men (43%) than women (27.2%). Gas inhalation was noted in 19 patients (10 men and 9 women), and 23 patients were admitted to

Table 1. Demographic features of cases

		Sex							
		Male				Female			
		Mean	Count	Standard deviation	% of Males (n=745)	Mean	Count	Standard deviation	% of females (n=422)
	Total	27.659	745	21.213	100% (63.8% of total)	27.678	422	24.418	100% (36.2% of total)
Age (yr)	x <=10	3.190	232	2.584	31.1%	2.981	160	2.332	37.9%
	10< x <=20	15.891	64	2.846	8.6%	15.552	29	3.123	6.9%
	20< x <=30	26.124	97	2.705	13%	26.087	46	2.573	10.9%
	30< x <=40	35.281	153	2.917	20.5%	35.404	57	2.770	13.5%
	40< x <=50	45.548	93	2.869	12.4%	45.340	53	2.889	12.6%
	50< x <= 60	54.980	51	2.796	6.8%	55.467	30	2.921	7.1%
	60< x	70.491	55	8.576	7.4%	73.766	47	8.822	11.1%
Injury to admission interval (*min*)		1812.91	-	3873.88	-	2021.53	-	5496.84	-
TBSA%		11.7	-	16.8	-	12.5	-	16.2	-
ABSI		3.67	-	2	-	5	-	2	-
Number of operations		0.55	-	1.31	-	0.49	-	0.99	-
Length of stay (*hr*)		203.09	-	173.74	-	209.47	-	186.28	-
Inhalation injury		-	52	-	6.9%	-	23	-	5.4%
Smoke Inhalation		-	14	-	1.8%	-	13	-	3%
History of admission in other centers (more than 6 *hr*)		-	41	-	5.5%	-	22	-	5.2%
Burn stage	1	-	7	-	9.3%	-	3	-	0.7%
	2	-	338	-	45.3%	-	214	-	50.7%
	3	-	384	-	51.5%	-	200	-	47.3%
	4	-	14	-	1.8%	-	4	-	0.9%
Type of injury	Scalds	-	335	-	44.9%	-	271	-	64.2%
	Fire	-	282	-	37.8%	-	102	-	24.1%
	Contact	-	47	-	6.3%	-	25	-	5.9%
	Electrical	-	28	-	3.7%	-	4	-	0.9%
	Chemical	-	53	-	7.1%	-	20	-	4.7%
Etiology	Accidental	-	734	-	98.5%	-	415	-	98.3%
	Suicidal	-	4	-	0.5%	-	4	-	0.9%
	Homicidal	-	2	-	0.2%	-	2	-	0.4%
	Conflict	-	1	-	0.1%	-	1	-	0.2%

Significant p-value is considered <0.05; percentage of Total Body Surface Area (TBSA%); Abbreviated Burned Severity Index (ABSI).

another hospital for over 6 *hr* before being transferred to the referral center. Third-degree burns were the most prevalent injury type among men (44.4%), whereas second-degree burns were most common among women (41.6%). Burns of accidental etiology were the most frequent cause of death, followed by other etiologies.

Factors affecting mortality

To address the factors associated with in-hospital mortality in burned patients, we divided the population into two groups and examined the relevant parameters for each. As shown in table 3, deceased patients had a significantly higher mean TBSA (62.06%) compared to survivors (8.7%). Their mean ABSI was also notably higher (9.96 *vs*. 3.77). In addition, the deceased patients were, on average, significantly older (38.23 years) compared to the survivors (26.97 years).

Laboratory tests revealed that the deceased patients had significantly lower pH and HCO_3 levels, along with higher values for BS, PT, K, HCO3, Hct, WBC, and BUN at admission. Furthermore, at the time of the last check, they had lower pH, Plt, and Ca levels, but higher PCO_2, PTT, AST, and BUN levels. Additionally, changes in Hb levels were more pronounced in the deceased patients compared to survivors. Interestingly, the platelet count in the

Table 2. Demographic features of dead cases

		Sex							
		Male				Female			
		Mean	Count	Standard deviation	% of total (n=72)	Mean	Count	Standard deviation	% of total (n=72)
Age (yr)		38.37		21.213		38		22.81	38.9%
Injury to admission interval (*min*)		1224.42		1.963.22		1805.18		2472.39	-
TBSA%		63.5	44	24.63	61.1%	59.79	28	28.53	-
ABSI		9.73		2.44		10.32		3.08	-
Number of operations		0.45		1.02		0.58		1.14	-
Length of stay (*hr*)		218.02		219.26		214.82		188.35	-
Inhalation injury		-	31	-	43%	-	20	-	27.7%
Smoke Inhalation		-	10	-	13.8%	-	9	-	12.5%
History of admission in other centers (more than 6 *hr*)		-	13	-	18%	-	10	-	13.8%
Burn stage	1	-	0	-	0%	-	0	-	0%
	2	-	4	-	5.5%	-	3	-	41.6%
	3	-	32	-	44.4%	-	23	-	31.9%
	4	-	7	-	9.7%	-	2	-	27.7%
Type of injury	Scalds	-	4	-	5.5%	-	6	-	8.3%
	Fire	-	40	-	55.5%	-	21	-	29.1%
	Contact	-	0	-	0	-	1	-	1.3%
	Electrical	-	0	-	0	-	0	-	0
	Chemical	-	0	-	0	-	0	-	0
Etiology	Accidental	-	39	-	54.1%	-	23	-	31.9%
	Suicidal	-	3	-	4.1%	-	3	-	4.1%
	Homicidal	-	1	-	1.3%	-	2	-	2.7%
	Conflict	-	1	-	1.3%	-	0	-	0

Significant p-value is considered <0.05; percentage of Total Body Surface Area (TBSA%).

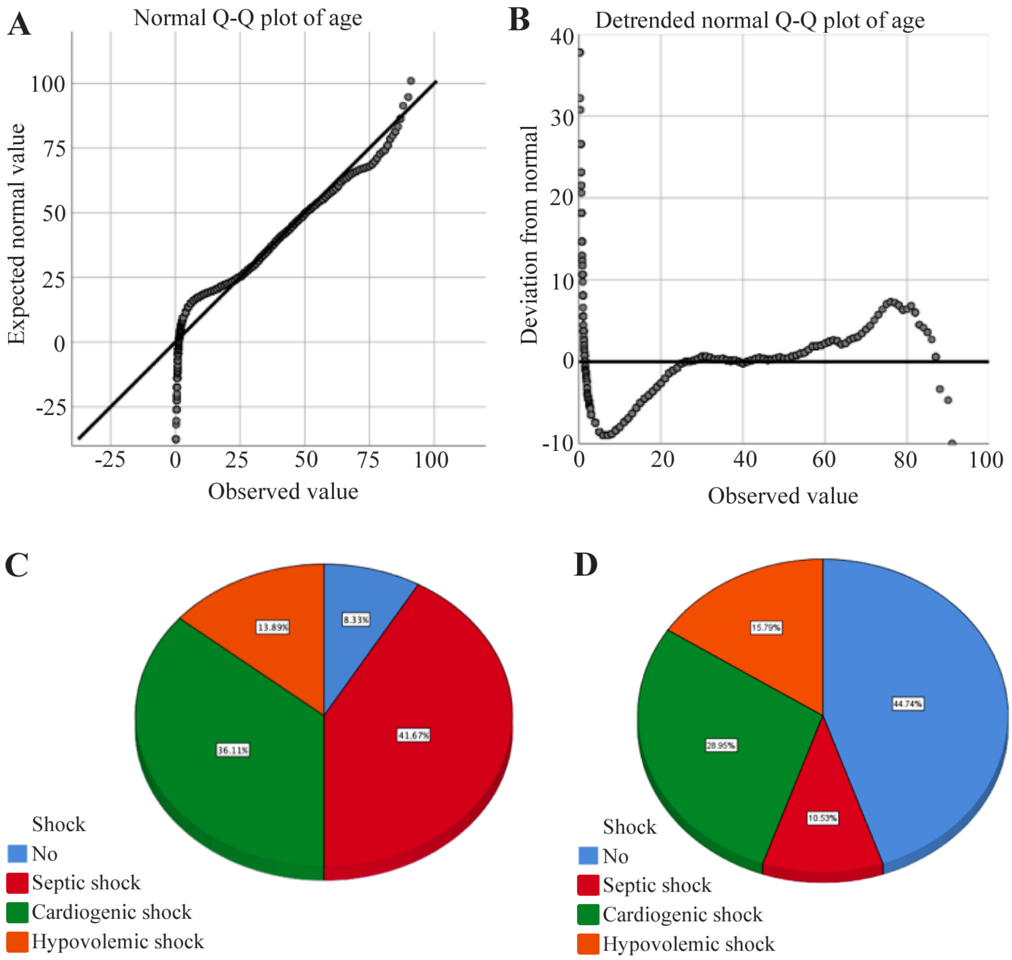

Figure 1. A and B: Q-Q plot showing age distribution among dead; C: pie chart of types of shock occurred among expired patients; D: pie chart of the types of infection, 40 cases (27%) got more than one type of infection, and 23 of these cases with more than one type of infection were expired (57.5%).

deceased group showed a significant decrease during hospitalization (mean change=-80874.49), whereas the platelet count in the survivor's group significantly increased (mean change=77119.21).

As shown in table 4, several factors were found to increase mortality rates among burned patients. These included hypothermia and respiratory failure, which were associated with death in all affected patients. Other factors included a decreased level of consciousness, respiratory tract burns, renal failure, infections, fire-related burn injuries, prior admission to other centers for more than 6 *hr*, fever, abnormal vital signs at admission, coagulopathy, thrombocytopenia, hypoalbuminemia, acidosis, and previous medical conditions. Based on these observations, the following factors were identified as influencing in-hospital mortality in burned patients:

Respiratory complications

Respiratory failure, which occurred in 37.8% of the deceased patients, was a major contributor to mortality, leading to death in 100% of cases, with a significant OR of ∞ ($p<0.001$). Respiratory tract burns were present in 6.4% of all cases and 70.8% of deceased cases, with an OR of 108.375 ($p<0.001$), making it one of the strongest predictors of death in burned patients. This may be due to airway and lung inflammation that predisposes patients to respiratory failure. Gas inhalation was also linked to higher mortality, with an incidence rate of 2.3% in all patients and 26.3% in deceased patients, increasing the risk of death by 48.710 times ($p<0.001$). Additionally, ARDS occurred in 11.2% of deceased cases.

Table 3. Lab tests and the mortality among burned patients

Parameter	Mean		SD		95%CI of the difference	p-value
	Lived	Expired	Lived	Expired		
TBSA %	8.700	62.056	8.5287	26.0805	-55.8572, -50.8539	<0.001
ABSI	3.77	9.96	1.753	2.703	-6.623, -5.752	<0.001
Age	26.97	38.23	22.24	22.41	5.94-16.57	<0.001
BS1	118.35	151.98	54.675	68.538	-49.021, -18.246	<0.001
PT1	12.523	14.718	1.3950	6.7571	-2.8037, -3.8729	<0.001
INR1	1.1404	1.4568	0.87425	1.56956	-0.55939, -0.07336	0.011
K1	4.227	4.639	0.4421	0.6049	-0.5249, -0.2989	<0.001
HCO_3 1	22.757	20.321	3.0987	5.1728	0.7057-4.1667	0.006
PH1	7.3818	7.3146	0.7735	0.12548	0.02499-0.10944	0.002
Hct1	40.284	45.562	6.2380	10.4402	-6.9303, -3.6258	<0.001
WBC1	11072.756	19200.000	5067.5142	12444.90447	-9595.3121,-6659.1769)	<0.001
BUN1	29.17	39.97	12.786	20.377	-14.143, -7.450	<0.001
pH2	7.4293	7.1873	0.06302	0.18744	0.17075-0.17075	<0.001
PCO_2 2	35.0745	56.210	7.5414	25.2551	-30.0100, -10.9204	<0.001
Plt2	343768.21	134079.35	175459.832	76728.648	165016.274- 254361.442	<0.001
Ca1	8.143	7.648	0.877	0.821	0.1235-0.8673	0.01
Ca2	8.295	7.488	0.877	0.821	0.2960-1.3180	0.003
Na2	138.91	142.27	3.547	8.227	-5.133, -1.58	<0.001
PTT2	33.560	56.822	1.0770	9.7338	-405915, -5.9318	0.009
AST2	32.61	78.62	20.07	90.846	-89.757, -2.256	0.040
BUN2	27.909	65.922	24.8268	48.9513	-49.029-26.9968	<0.001
∆Hb	-2.0084	-4.4817	3.15944	3.91076	1.45897-3.48759	<0.001
∆Plt	77119.21	-80874.49	154841.723	130240.201	114742.173-201245.223	<0.001

K1 (Potassium level at the point of admission), BS 1 (Blood Sugar level at the point of admission), PT1 (Prothrombin Time at the point of admission), pH1 (pH value at the point of admission), pH2 (last checked pH value of the blood), PCO_2 2 (last checked PCO_2 value of the blood), Plt (last checked Platelet count of the blood), Hct1 (Hematocrit at the point of admission), WBC1 (blood leukocytes count at the point of admission), BUN1 (Blood Urea Nitrogen value at the point of admission), BUN2 (the last BUN checked), Ca2 (last checked Calcium level), HCO_3 1 (HCO_3 at the point of admission), PTT 2 (the last Partial Thromboplastin Time checked), AST 2 (the last Aspartate Aminotransferase checked); (∆X=X2 – X1), percentage of Total Body Surface Area (TBSA%); Abbreviated Burned Severity Index (ABSI).

Circulation

As shown in figure 1B, circulatory failure accounted for 36.1% of deaths, primarily due to sudden cardiac death and arrhythmias caused by electrolyte disturbances. However, no specific electrolyte disturbance was found to be directly associated with increased circulatory failure, suggesting further studies are needed to clarify this relationship.

Electrolyte and acid/base disorder

Electrolyte disturbances were observed in 18.5% of admitted patients, with 83.3% of deceased patients having at least one abnormal electrolyte level. Among the electrolytes routinely measured (Na, K, Ca, Mg),

Table 4. Factors associated with mortality among burned patients

Parameter	Odds ratio	p-value
Decreased level of consciousness at the point of admission	193.617	<0.001
Respiratory tract burn	108.375	<0.001
ARF	77.714	<0.001
Iatrogenic infection	52.260	<0.001
Gas (smoke) Inhalation	48.710	<0.001
Acinetobacter infection	24.308	<0.001
Pseudomonas infection	21.230	<0.001
E. coli infection	20.336	<0.001
Klebsiella pneumonia infection	15.083	<0.001
Burning caused by fire	13.254	<0.001
Admission in other centers >6 *hr*	10.466	<0.001
Infection induced by burn injury (burn site infection)	9.64	<0.001
Abnormal vital signs at the time of admission	9.529	<0.001
Enterococcus faecalis infection	9.478	<0.001
Yeast infection	9.478	<0.001
Coagulopathy	8.089	<0.001
Fever	7.04	<0.001
Staphylococcus aureus infection	5.618	<0.001
Hypoalbuminemia	4.74	<0.001
Acidosis	3.179	0.005
Previous medical conditions	2.838	<0.001
Hypothermia	∞	<0.001
Respiratory failure	∞	<0.001

ARF: Acute Renal Failure; *E. coli*: *Escherichia coli.*

disturbances in calcium levels at admission and during hospitalization were associated with higher mortality rates. Mean calcium levels were higher in survivors (p=0.01 and 0.003). Disturbances in last checked sodium (Na_2) and potassium (K_2) were also associated with higher mortality (p<0.001), with a significant difference in sodium levels between survivors and deceased patients (Table 3). Additionally, acidosis was noted in 50% of deceased cases and less than 1% of discharged patients, with an OR for mortality of 3.719 (p<0.001) (Table 4). The results of pH, HCO_3, and PCO_2 tests are shown in table 3, which align with the effects of respiratory failure and acidosis (metabolic or respiratory) on mortality.

Renal failure

Acute Renal Failure (ARF) occurred in 2.7% of all patients and 33.3% of deceased patients. The OR for ARF related to mortality was 77.714 (p<0.001), highlighting the significant role of renal failure in predicting death among burned patients. Electrolyte disturbances in burned patients are often due to the loss of the skin barrier, and renal failure may exacerbate mortality by impairing the kidney's ability to regulate electrolytes.

Coagulopathy

Coagulopathy was present in 34.8% of admitted patients and 79.1% of deceased patients. The OR for coagulopathy-related mortality was 8.089 (p<0.001), as shown in table 4. Additionally, the INR1 and PT1 levels were higher in deceased patients at admission, indicating the presence of coagulopathy at the time of admission. The trend in platelet counts (ΔPlt) during hospitalization showed a significant decrease in deceased patients, while it increased in survivors. This suggests bone marrow unresponsiveness, with other potential factors such as hemodilution due to resuscitation fluids and platelet activation. A Pearson correlation coefficient of -0.355 (p<0.001) between ΔPlt and ABSI indicated that more severe burns were correlated with a greater reduction in platelet counts. The same pattern was observed for the ΔHb values. Based on this result, we suggest using the trend of platelet value as a predictive factor of worse prognosis and mortality in a burn injury. This decreasing platelet value, along with disturbed PTT2, indicates the importance of incidence of coagulopathy among deceased patients.

Infection

As shown in figure 1C, wound infection was the most common infection type (44.7%), followed by septicemia (28.95%), pneumonia (15.79%), and Urinary Tract Infection (UTI) (10.53%). Infections were strongly associated with increased mortality, with ORs for iatrogenic infections and wound

Table 5. Microbial species causing infection among burned patients

Infection types		Patients			
		Discharged		Expired	
		Count	Row N %	Count	Row N %
Pseudomonas aeruginosa (P. aeruginosa)		1079	95.2%	54	4.8%
	P. aeruginosa	16	48.5%	17	51.5%
	P. aeruginosa (Heavy growth)	0	0.0%	1	100.0%
Acinetobacter		1081	95.2%	54	4.8%
	Acinetobacter	14	45.2%	17	54.8%
	Acinetobacter (Heavy growth)	0	0.0%	1	100.0%
Enterococcus		1090	94.0%	69	6.0%
	Enterococcus faecalis	5	62.5%	3	37.5%
Escherichia coli (E. coli)		1090	94.2%	67	5.8%
	E. coli	4	44.4%	5	55.6%
	ESBL	1	100.0%	0	0.0%
Candida albicans (C. albicans)		1090	94.0%	69	6.0%
	C. albicans	2	50.0%	2	50.0%
	Yeast	3	75.0%	1	25.0%
Staphylococcus aureus (S. aureus)		1046	94.8%	57	5.2%
	Coagulase negative *S. aureus*	13	81.3%	3	18.8%
	Gram-positive Cocci	0	0.0%	1	100.0%
	MRSA	15	78.9%	4	21.1%
	MRSA (Heavy growth)	1	100.0%	0	0.0%
	MSSA	2	100.0%	0	0.0%
	MSSA & Coagulase neg *S. aureus*	1	50.0%	1	50.0%
	Staphylococcus epidermidis (S. epidermidis)	2	100.0%	0	0.0%
	S. aureus	14	73.7%	5	26.3%
	S. aureus & Coagulase negative Staphylococcus	1	100.0%	0	0.0%
	Streptococcus spp.	0	0.0%	1	100.0%
Klebsiella pneumonia (K. pneumonia)		1086	94.4%	64	5.6%
	K. pneumonia	9	52.9%	8	47.1%
Gram-negative bacilli (other than *P. aeruginosa*)		1094	93.9%	71	6.1%
	Stenotrophomonas maltophilia	1	100.0%	0	0.0%
	Corynebacterium	0	0.0%	1	100.0%
Other		1093	94.1%	69	5.9%
	Proteus	0	0.0%	1	100.0%
	Citrobacter	0	0.0%	1	100.0%
	Gram-negative Coccobacillus	1	50.0%	1	50.0%
	Influenza	1	100.0%	0	0.0%

Extended-Spectrum Beta-Lactamase: ESBL; Methicillin-Resistant Staphylococcus aureus (MSRA); Methicillin-Susceptible Staphylococcus aureus (MSSA).

infections (caused by the burn injury) of 52.260 ($p<0.001$) and 9.64 ($p<0.001$), respectively. Table 5 lists the species of bacteria linked to higher mortality, including Acinetobacter, *Pseudomonas aeruginosa*, *Escherichia coli* (*E. coli*), *Klebsiella pneumonia*, *Enterococcus faecalis*, Yeasts, and Staphylococcus, with OR values presented in table 4.

Other factors

As shown in table 4, hypoalbuminemia, history of medical conditions, delayed admission (more than 6 *hr*), fire-related burn injuries, hypothermia, fever, disturbed vital signs at admission, and a lowered GCS were associated with increased mortality. Notably, a decreased GCS was strongly correlated with death and was associated with TBSA, VI, and ABSI values ($p<0.001$). Burn injuries induce a hypermetabolic state, and nutritional status affects serum albumin levels and tissue recovery. Higher WBC levels at admission were significantly associated with higher mortality ($p<0.001$), as shown in table 3. The trend in ΔHb and ΔPlt changes suggests that more severe cases with greater ABSI values had a more significant reduction in platelet counts ($p<0.001$).

Additionally, burn injuries cause dehydration, leading to an increased concentration of blood components such as hematocrit (Hct), platelets (Plt), and WBC. Upon admission to the hospital and initiation of fluid replacement therapy, these components typically become diluted, resulting in a decreasing trend. However, elevated levels of these components at the time of admission indicate more severe dehydration, delayed admission, infection, or insufficient pre-hospital fluid resuscitation. As expected, higher WBC levels at admission are significantly associated with increased mortality ($p<0.001$), as shown in table 3. Additionally, a greater reduction in hemoglobin (ΔHb) and platelets (ΔPlt) during the hospital stay was observed in severe cases with higher ABSI scores ($p<0.001$), suggesting bone marrow unresponsiveness.

The required fluid volume for each patient during the first 24 *hr* of admission was calculated using the Parkland formula (4 *ml*×TBSA (%)×body weight (*kg*); 50% administered in the first 8 *hr*, and the remaining 50% over the next 16 *hr*). Hydration was deemed adequate if the fluid volume and frequency administered matched the calculated amount. More than 95% of patients received adequate hydration within the first 24 *hr*, and this parameter showed no significant difference between survivors and non-survivors.

Based on the statistical analysis and findings, decision trees were developed to summarize the critical aspects of this study and provide a practical guideline for managing physicians and surgeons. These decision trees, presented in figures 2 and 3, are based on ABSI criteria and offer comparable predictive value to ABSI.

VI as a new predictor of mortality among burned patients

A new index, the VI, was introduced to enhance mortality prediction. VI was calculated for each patient and its predictive power evaluated using both the CHAID algorithm and the ROC curve. The mean VI for survivors and non-survivors was 22.71 and 221.13, respectively, while the median VI was 15 for survivors and 195 for non-survivors ($p<0.001$).

As illustrated in figure 2, the VI correctly predicted outcomes in 98.6% of discharged cases, 68.1% of deceased cases, and 96.7% of all cases overall. Additionally, the ROC curve comparison demonstrated high predictive sensitivity for both ABSI (Area: 0.976, $p<0.001$) and VI (Area: 0.967, $p<0.001$). Based on these results, VI was proposed as a novel and effective prognostic tool for evaluating burn injury outcomes.

Discussion

Burn injuries are a common type of trauma that significantly impact the daily lives of victims and their families. Previous studies have identified several factors associated with higher mortality rates, including age, TBSA affected, coagulopathy, electrolyte disturbances, and sepsis (12) there are no reviews on machine learning (ML. A comprehensive understanding of these factors enables clinicians to identify high-risk patients and make informed decisions to reduce morbidity and mortality.

In this study, key factors that predicted and influenced mortality in burn patients were identified. By analyzing data from a specialized referral center for burn and plastic surgery, clinicians are provided with valuable insights into the management of burn cases. The present findings are both significant and consistent with prior research (13,14). Notably, laboratory tests were included as part of the present study's clinical decision-making framework. One strength of this study was its large sample size, which included burn patients of all ages and genders. However, the heterogeneity of the study population could be considered a limitation. To address this, for potential confounding factors and applied statistical methods were accounted to mitigate their effects.

The literature highlights the degree and extent of burns as critical factors affecting mortality. To address these variables simultaneously, a novel VI was proposed. While most studies rely on expert opinions to grade burn depth—an approach with inherent

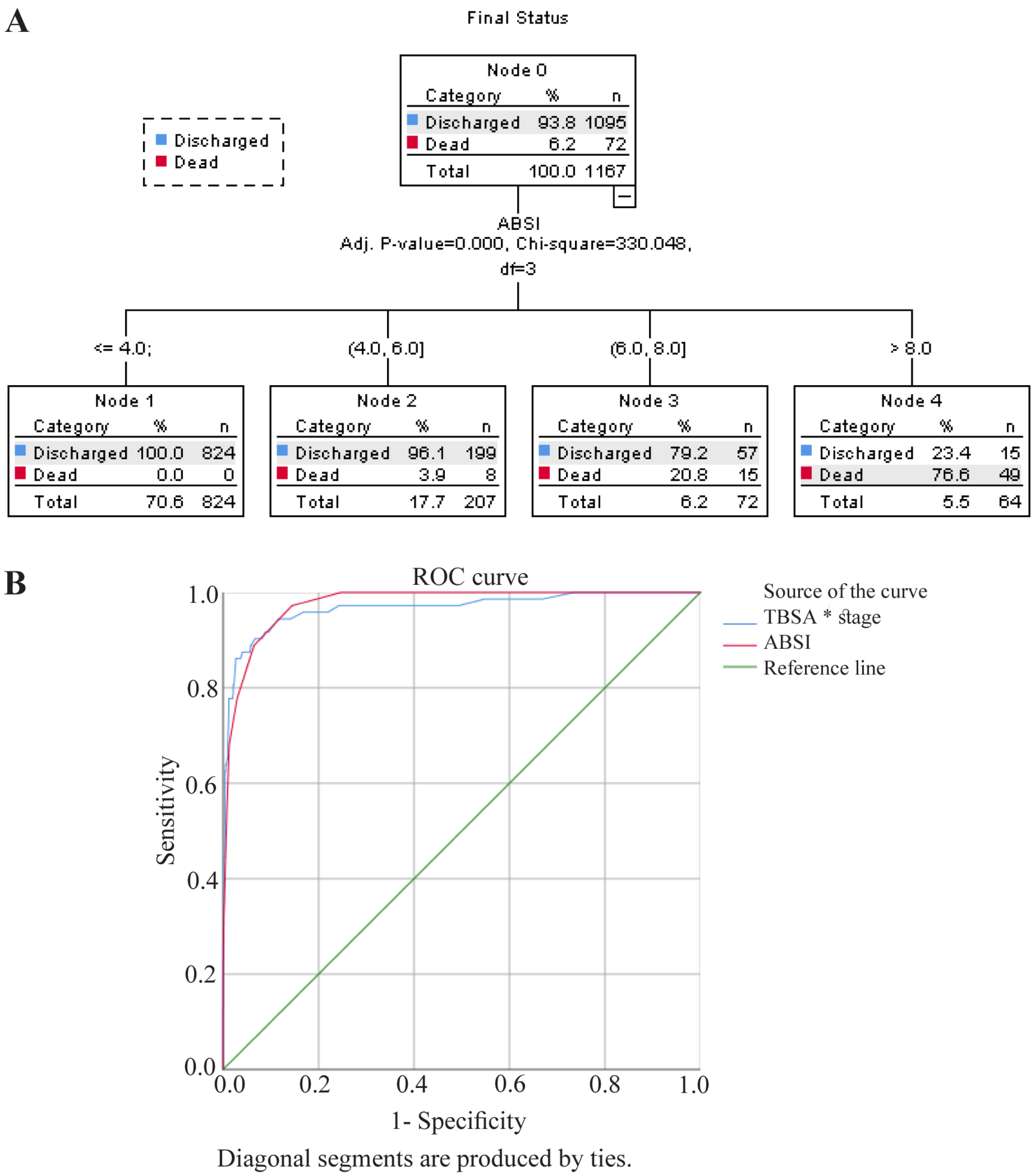

Figure 2. A) Decision tree extracted using CHAID analysis of the ABSI of the patients; Correct prediction in 98.6% of discharged cases, 68.1% of expired cases, and 96.7% overall prediction correctness. B) ROC curve evaluating sensitivity of ABSI (Area: 0.976, p<0/001) and VI (TBSA*Stage) (Area: 0/967, p<0/001) for prediction of death in this population.

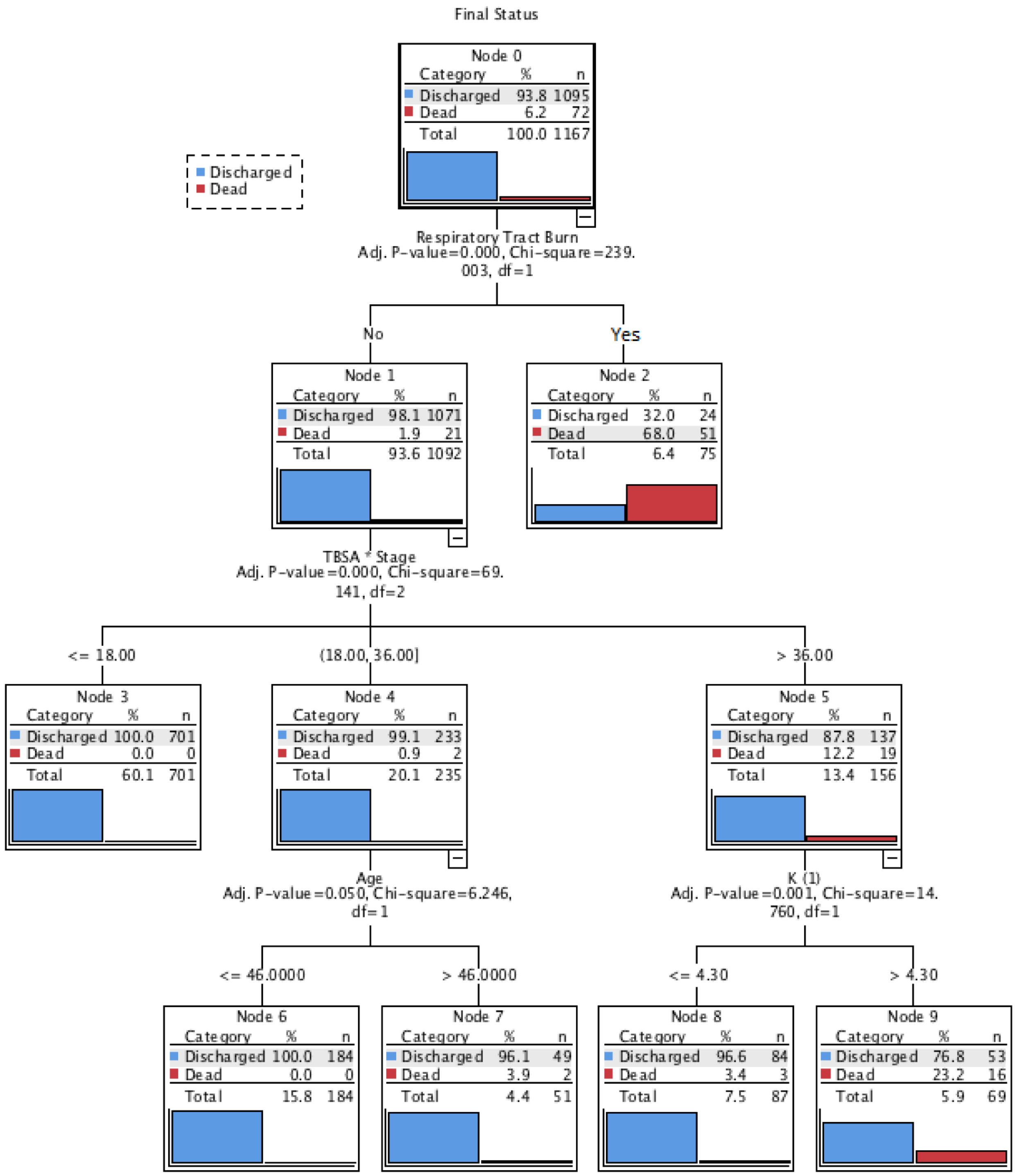

Figure 3. Decision tree extracted using CHAID analysis of the data; Correct prediction in 97.8% of discharged cases, 70.8% of expired cases, and 96.1% overall prediction correctness.

limitations—this study involved evaluation by an experienced associate professor of plastic surgery at the time of admission. Given the challenges of assessing burn depth within the first 48 *hr*, the surgeon re-evaluated the degree and extent of burns during hospitalization and documented these observations. The findings of the present study revealed no significant changes in the degree of burns during the hospital stay or prior to reconstructive surgery, affirming the accuracy of the initial evaluations.

While histological examination provides the most precise assessment of burn depth, it is not routinely performed in emergency or specialized centers. Instead, expert clinical opinion remains the trusted standard for initiating treatment. Although the absence of histological evaluation may be a limitation of this study, plastic surgeon's expertise ensured accurate assessments upon which treatment decisions were based.

The literature also suggests that female sex is associated with increased mortality in burn patients[15-17]. However, in the present study, this trend may be attributed to a higher admission rate among men. Additionally, thrombocytopenia has been previously reported as a predictor of sepsis and poor prognosis in pediatric patients, but few studies have evaluated its role in broader burn populations. By analyzing a large and heterogeneous sample, thrombocytopenia was identified as a potent predictor of poor outcomes in burn patients. This parameter is influenced by fluid administration, as larger volumes can lead to dilutional thrombocytopenia. The correlation between fluid volume and thrombocytopenia was not directly assessed in this study, which represents a potential limitation.

Clinicians can assess injury severity using both patient history and laboratory tests, both before and during admission, to minimize mortality risk. While several laboratory parameters were reported as indicators of poor prognosis, it is important to note that their predictive utility may diminish in the terminal stages of burn patients, who often experience multi-organ failure.

Conclusion

Nonetheless, unlike factors that tend to worsen during the hospital stay, the VI was identified as a practical and accurate predictor of mortality. VI, which is significantly easier to calculate, demonstrates predictive power comparable to the well-established ABSI. Since VI can be calculated immediately upon admission, it offers a convenient tool for early risk assessment.

It is strongly recommended that future studies compare VI with other indices, such as the Baux score, episodes of sepsis, the number of failing organs, and the types of drugs administered to manage organ failure. These comparisons could further validate VI's utility and provide a more comprehensive understanding of its role in predicting patient outcomes. VI and thrombocytopenia are novel and effective indices of poor prognosis among burned patients.

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Ethical approval

This study was registered and approved by the institutional review board of the Tabriz University of Medical Sciences (registration code: 64367) and the national committee of ethics (registration code: IR.TBZMED.REC.1398.1162).

Informed consent

Constants to participate and publication were obtained from the patients at the time of their admission.

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Conflict of Interest

The authors declare no conflict of interest.

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