



Frostbite injuries: independent predictors of outcomes

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ABSTRACT

Objective: Frostbite injuries are important causes of morbidity and mortality after trauma. Epidemiology, injury patterns, and outcomes after frostbite among patients presenting to trauma centers are incompletely defined. The purpose of this study was to delineate patient demographics, clinical characteristics, and independent predictors of outcomes after frostbite.

Material and Methods: Patients with frostbite injury were identified from the National Trauma Data Bank (NTDB) (2007-2014). Demographics, clinical/injury data, and outcomes were collected. Patients were dichotomized into study groups based on intensive care unit (ICU) admission. Univariate analysis was performed with the Mann-Whitney U, Fisher's exact, or Chi-Square test as appropriate. Multivariate analysis using logistic regression determined independent predictors of outcomes.

Results: Over the study period, 241 patients were identified. Median body temperature on admission was 36.3°C (IQR 33.4-36.7). Mortality was 3% (n=7). ICU admission was required in 101 (42%) patients and 48 (20%) underwent surgical intervention. On multivariate analyses, mortality was predicted by lower admission GCS (p=0.027) and amputation by higher HR (p=0.013). Need for ICU admission was predicted by older age (p=0.010), male gender (p=0.040), higher HR (p=0.031) and ISS (p<0.001), and lower GCS (p=0.001). Prolonged hospital LOS was predicted by higher heart rate (p<0.001) and ISS (p<0.001).

Conclusion: Frostbite injuries are uncommon but can necessitate surgical intervention and cause mortality. Lower GCS and higher heart rate, but not body temperature, portend poor outcomes. These findings can be used to triage patients appropriately upon admission and to better inform prognosis after frostbite injuries.

Keywords: Frostbite, thermal injuries, hypothermia

INTRODUCTION

Frostbite injuries are infrequent but important causes of morbidity and mortality after trauma. In part because of their rarity, frostbite injuries are incompletely defined by the current literature (1). Knowledge of predictors of outcomes, such as mortality and need for amputation, would be useful for prognostication and to anticipate resource utilization after this uncommon mechanism of injury.

The primary objective of this study was to define independent predictors of outcomes [mortality, need for surgical intervention, need for intensive care unit (ICU) admission, ICU length of stay (LOS), and hospital LOS] after frostbite injuries using a large, nationwide patient population from the National Trauma Data Bank (NTDB) (2). The secondary objectives were to define the epidemiology and clinical characteristics of patients who sustain frostbite injuries. Our hypothesis was that worsened physiologic status on presentation to hospital [e.g. lower body temperature, tachycardia, hypotension, diminished glasgow coma scale (GCS) score] would be predictive of poor outcomes after frostbite.

MATERIAL and METHODS

In this retrospective observational study, all patients with frostbite injuries (AIS codes 915000, 915002, 915004, 915006) between January 1, 2007 and December 31, 2014 were identified from the NTDB. The NTDB, run by the American College of Surgeons (ACS), is the largest trauma registry in existence and is comprised of aggregate data from centers across the United States (2). There were no exclusion criteria. Ethics committee approval by the Institutional Review Board of the University of Southern California was obtained. Informed consent was waived due to the study's retrospective observational design of deidentified patient data.

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After patient identification, demographics (age, gender), clinical data [admission heart rate (HR), systolic blood pressure (SBP), temperature, and GCS score], and injury data [Injury Severity Score (ISS)] were collected from the NTDB. Primary outcome was mortality. Secondary outcomes included need for surgical intervention (debridement, amputation), need for ICU admission, ICU LOS, and hospital LOS.

Statistical Analyses

Patients were dichotomized into study groups based on the need for ICU admission or not. Continuous variables are represented as median [interquartile range (IQR)] and categorical variables are given as number (percentage). Univariate analysis was used to compare patient demographics, clinical/injury characteristics, and outcomes between study groups using the Mann-Whitney U test, Fisher's exact test, or Chi-square test as appropriate. Multivariate regression with the enter method included all clinically relevant predictor variables. Data were collected and analyzed using SPSS version 20.0 (IBM Corporation, Armonk, NY). Statistical significance was defined as $p < 0.05$.

RESULTS

Patient Demographics, Clinical Data, Injury Data, and Outcomes

Overall, 241 (< 0.01%) patients with frostbite injury were identified from the NTDB (Figure 1). ICU admission was required

in 101 (42%) patients. Median age was 44 years [interquartile range (IQR) 29-58] and 184 (76%) patients were male (Table 1). Median temperature on arrival to the emergency department was 36.3°C (IQR 33.4-36.7). In general, patients were hemodynamically normal and intact neurologically. Median ISS was 8 (IQR 2-14). Overall mortality was 3% ($n = 7$) (Table 2). Surgical intervention was required in 20% of the patients ($n = 48$). Overall median hospital LOS was 5 days (IQR 2-10).

Patients Who Required ICU Admission vs. Those Who Did Not

Patients who were admitted to the ICU ($n = 101$, 42%) tended to be older (48 vs. 41 years, $p = 0.008$), have a lower admission body temperature (34.1 vs. 36.6°C, $p < 0.001$), and a lower admission GCS (13 vs. 15, $p < 0.001$) than patients who were not admitted to the ICU ($n = 140$, 58%) (Table 1). Patients admitted to the ICU had a higher mortality (7% vs. 0%, $p = 0.004$), greater need for amputation (9% vs. 3%, $p = 0.047$), and longer hospital stay (8 vs. 3 days, $p < 0.001$) than patients not admitted to the ICU (Table 2).

Independent Predictors of Outcomes

Mortality: On multivariate logistic regression, only lower admission GCS was independently predictive of mortality ($p = 0.027$) (Table 3).

Need for surgical intervention: No independent predictors of the need for debridement were identified. Higher admission HR was independently predictive of the need for amputation ($p = 0.013$).

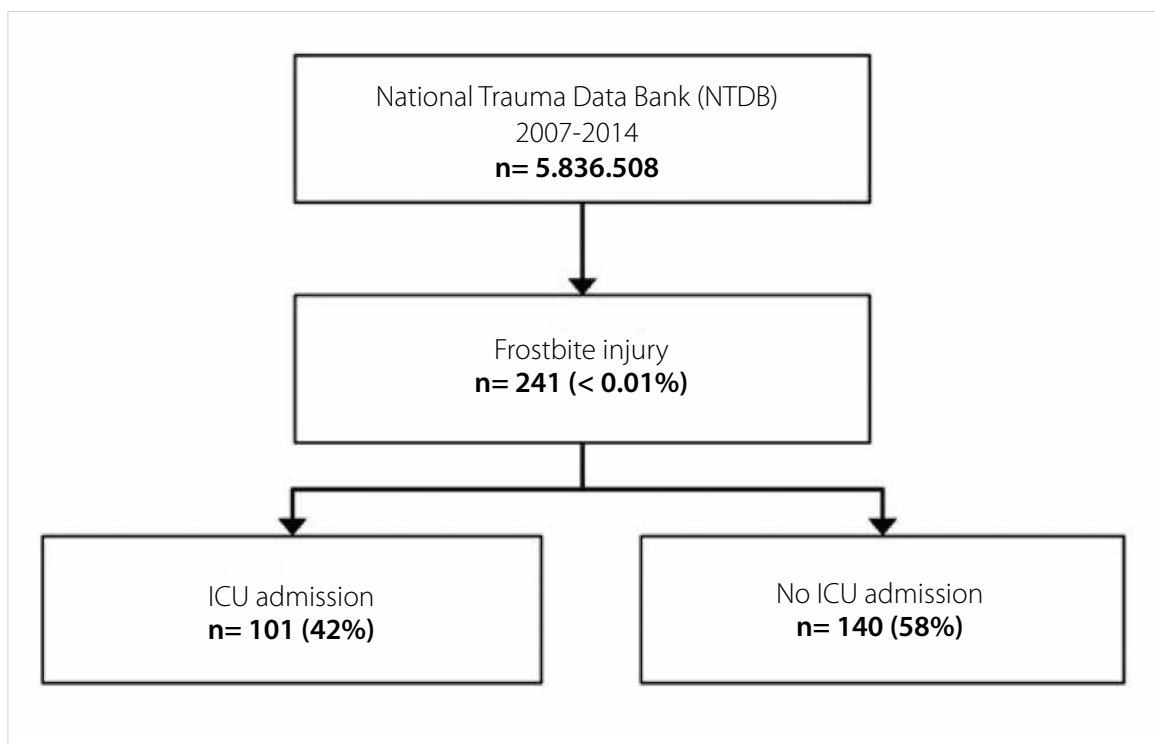


Figure 1. Study algorithm.
ICU: Intensive care unit.

Table 1. Baseline patient demographics, clinical data, and injury data

	Total patients (n= 241)	ICU admission (n= 101, 42%)	No ICU admission (n= 140, 58%)	p
Age (years)	44 (29-58)	48 (37-63)	41 (28-55)	0.008
Gender (male)	184 (76%)	81 (80%)	103 (74%)	0.283
HR (bpm)	96 (84-108)	95 (83-108)	96 (85-95)	0.546
SBP (mmHg)	133 (117-149)	130 (111-149)	134 (122-149)	0.165
Temperature (°C)	36.3 (33.4-36.7)	34.1 (30.6-36.3)	36.6 (34.1-35.9)	< 0.001
GCS	15 (13-15)	13 (6-15)	15 (15-15)	< 0.001
ISS	8 (2-14)	14 (7-21)	5 (1-9)	< 0.001

ICU: Intensive care unit; patient was admitted to ICU after presentation to the emergency department, HR: Heart rate, Bpm: Beats per minute, SBP: Systolic blood pressure, GCS: Glasgow Coma Scale score, ISS: Injury Severity Score.
Continuous variables expressed as median [interquartile range]; p-value calculated with Mann-Whitney U-test. Categorical variables expressed as number (%); p-value calculated with Fisher's Exact Test or Pearson Chi Square Test as appropriate.

Table 2. Univariate analysis of outcomes

	Total patients (n= 241)	ICU admission (n= 101, 42%)	No ICU admission (n= 140, 58%)	p
Mortality	7 (3%)	7 (7%)	0 (0%)	0.004
Need for surgical Intervention	48 (20%)	23 (23%)	25 (18%)	0.414
Debridement	43 (18%)	19 (19%)	24 (17%)	0.737
Amputation	13 (5%)	9 (9%)	4 (3%)	0.047
Upper extremity	4 (2%)	3 (3%)	1 (1%)	0.312
Lower extremity	11 (5%)	8 (8%)	3 (2%)	0.056
Hospital LOS	5 (2-10)	8 (4-16)	3 (2-6)	< 0.001
ICU LOS	0 (0-3)	3 (2-7)	-	-

ICU: Intensive care unit; patient was admitted to ICU after presentation to the emergency department, LOS: Length of stay in days.
Continuous variables expressed as median [interquartile range]; p-value calculated with Mann-Whitney U-test. Categorical variables expressed as number (%); p-value calculated with Fisher's Exact Test or Pearson Chi Square Test as appropriate.

ICU admission and LOS: The need for ICU admission was predicted by older age ($p= 0.010$), male gender ($p= 0.040$), higher admission HR ($p= 0.031$) and ISS ($p< 0.001$), and lower admission GCS ($p= 0.001$). Longer ICU LOS was predicted by older age ($p< 0.001$); male gender ($p= 0.030$); higher HR ($p< 0.001$) and ISS ($p< 0.001$); and lower SBP ($p= 0.003$) and GCS ($p< 0.001$) (Table 4).

Hospital LOS: Higher admission HR ($p< 0.001$) and ISS ($p< 0.001$) were independent predictors of prolonged hospital LOS.

DISCUSSION

Frostbite, wherein skin is exposed to freezing temperatures and injured by cold thermal energy, is relatively common in some parts of the world, with a lifetime incidence in colder climates of approximately 10% (1,3,4). Most of the available data on frostbite injuries originate from small case series from the military or from adventurers (5-10). The generalizability of these studies, particularly in terms of their applicability to the general population, remains unclear. Existing literature is scarce on patient epidemiology and severity of illness after frostbite

injury among civilians. Additionally, independent predictors of outcomes, such as the need for surgical intervention, ICU admission, and mortality, are undefined.

This study examined a nationwide patient population sustaining frostbite injuries and found that frostbite is an infrequent cause of presentation to American hospitals. Patients who suffered from these injuries tended to be middle aged men. Despite exposure to freezing temperatures, most were normothermic upon presentation to the Emergency Department. Mortality in this population was low but surgical intervention, either with debridement or amputation, was required in 20% of the patients. These data would suggest that systemic sequelae after frostbite injuries are infrequent but that local complications such as tissue necrosis and infection are relatively common.

Elevated heart rate and lower GCS on presentation to hospital were almost uniformly associated with poorer outcomes, including mortality, need for surgical intervention, need for ICU admission, and prolonged hospital stay. Other risk factors

Table 3. Multivariate analysis of outcomes (categorical variables)

	OR	95% CI	P
Mortality			
Age (years)	1.039	0.979-1.103	0.211
Gender (male)	< 0.001	< 0.001-> 999.999	0.997
HR	1.019	0.979-1.060	0.355
SBP	0.991	0.967-1.014	0.432
Temperature (°C)	1.056	0.812-1.373	0.683
GCS	0.776	0.620-0.971	0.027
ISS	1.052	0.962-1.150	0.266
Debridement			
Age (years)	0.981	0.960-1.002	0.074
Gender (male)	1.045	0.444-2.458	0.920
HR	1.012	0.994-1.030	0.184
SBP	1.011	0.997-1.025	0.116
Temperature (°C)	0.994	0.843-1.173	0.947
GCS	1.000	0.885-1.131	0.995
ISS	1.016	0.973-1.060	0.471
Ambulation			
Age (years)	1.002	0.967-1.038	0.916
Gender (male)	3.949	0.467-33.390	0.207
HR	1.040	1.008-1.073	0.013
SBP	0.995	0.973-1.017	0.662
Temperature (°C)	1.314	0.941-1.834	0.110
GCS	0.853	0.702-1.037	0.110
ISS	1.030	0.960-1.105	0.411
ICU admission			
Age (years)	1.028	1.007-1.050	0.010
Gender (male)	2.736	1.048-7.146	0.040
HR	1.021	1.002-1.040	0.031
SBP	0.996	0.963-1.010	0.613
Temperature (°C)	0.935	0.774-1.128	0.481
GCS	0.764	0.651-0.897	0.001
ISS	1.130	1.071-1.192	< 0.001

OR: Odds ratio, CI: Confidence interval, ICU: Intensive care unit; patient was admitted to ICU after presentation to the emergency department. HR: Heart rate in beats per minute. SBP: Systolic blood pressure in mmHg, GCS: Glasgow Coma Scale score, ISS: Injury Severity Score, LOS: Length of stay in days. Multivariate analysis was performed using logistic regression.

for worse outcomes identified by the present study were older age, male gender, lower SBP on admission, and higher ISS. Interestingly, body temperature on admission was not predictive of any study outcome. Taken together, these findings suggest that many of the clinical parameters known to portend worse outcomes among trauma patients, such as tachycardia, hypotension, depressed neurological status, and older age, also herald worse outcomes among the subset of trauma patients with frostbite injuries.

Limitations of the present study must be acknowledged. Retrospective studies are inherently limited by their design. Additionally, the NTDB lacks sufficient granularity to identify the depth or

severity of the frostbite injury, information which may be useful in prognostication after injury (11). Finally, nonsurgical treatment strategies, such as the type of rewarming employed or the use of thrombolytics, are not coded by the NTDB. Therefore, the effect of management strategy on outcomes after frostbite is not captured by this study.

CONCLUSION

Frostbite injuries are infrequent among the American civilian population. Despite having a very low mortality rate, approximately half of the patients with frostbite will require ICU admission and one fifth will require surgical intervention. Although a number of independent predictors of poor outcomes were

Table 4. Multivariate analysis of outcomes (continuous variables)

	RC	95% CI	p
ICU LOS			
Age (years)	0.010	0.004-0.015	< 0.001
Gender (male)	0.248	0.024-0.472	0.030
HR	0.008	0.004-0.013	< 0.001
SBP	-0.005	-0.009 - -0.002	0.003
Temperature (°C)	0.015	-0.029-0.058	0.506
GCS	-0.078	-0.111 - -0.045	< 0.001
ISS	0.043	0.032-0.055	< 0.001
Hospital LOS			
Age (years)	0.004	-0.003-0.011	0.318
Gender (male)	0.163	-0.133-0.459	0.278
HR	0.011	0.005-0.017	< 0.001
SBP	-0.003	-0.008-0.001	0.162
Temperature (°C)	0.012	-0.046-0.069	0.693
GCS	-0.020	-0.064-0.023	0.358
ISS	0.050	0.035-0.065	< 0.001

RC: Regression coefficient, CI: Confidence interval, ICU: Intensive care unit; patient was admitted to ICU after presentation to the emergency department. HR: Heart rate in beats per minute, SBP: Systolic blood pressure in mmHg, GCS: Glasgow Coma Scale score, ISS: Injury Severity Score, LOS: Length of stay in days. Multivariate analysis was performed using logistic regression.

identified, higher heart rate and depressed GCS on admission in particular portended worse outcomes. Clinicians should be especially vigilant with patients who arrive to the ED with these clinical features after frostbite injury. The knowledge of patient epidemiology, clinical characteristics, and predictors of outcomes imparted by this study may be useful in planning resource utilization and to better inform conversations with patients and families about prognosis after frostbite injury.

Ethics Committee Approval: Ethics committee approval by the Institutional Review Board of the University of Southern California was obtained (Approval granted January 28, 2019; Approval number is: HS-19-00015).

Informed Consent: Informed consent was waived due to the study's retrospective observational design of deidentified patient data.

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ORİJİNAL ÇALIŞMA-ÖZET

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Donuk travmaları: gidişatın bağımsız belirleyicileri

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ÖZET

Giriş ve Amaç: Donuk travmaları travma alanının önemli mortalite ve morbidite nedenlerinden biridir. Travma merkezlerine başvuran hastaların epidemiyoloji, yaralanma şekilleri ve donukların gidişatı yeterince bilinmemektedir. Bu çalışmanın amacı, hastaların demografik ve klinik özellikleri ile birlikte donuk travması sonrası bağımsız gidişat belirleyicilerini ortaya koymaktır.

Gereç ve Yöntem: Donuk travması olan hastalar, ulusal travma veri bankası (2007-2014) kullanılarak belirlendi. Hastalar yoğun bakım ünitesi (YBÜ) yatışlarına göre çalışma gruplarına ayrıldı. Tek değişkenli analiz, uygun görüldüğü şekilde Mann-Whitney U, Fisher's Exact veya ki-kare testleri ile uygulandı. Lojistik regresyon kullanılan çok değişkenli analiz, bağımsız gidişat belirleyicilerini belirledi.

Bulgular: Çalışma dönemi içerisinde toplam 241 hasta bulunmuştur. Başvuru esnasındaki ortalama vücut ısısı 36,3°C idi (IQR 33,4-36,7). Mortalite %3 olarak saptanmıştır (n= 7). 101 (%42) hasta YBÜ'ye kaldırılırken 48 (%20) hastada cerrahi müdahale gerekmiştir. Çok değişkenli analizde mortalite, daha düşük başvuru GKS (p= 0,027) ve amputasyonla birlikte olan yüksek kalp hızı (KH) ile (p= 0,013) ilişkisi gösterilmiştir. YBÜ yatış gereksiniminin ileri yaş (p= 0,010), erkek cinsiyeti (p= 0,040), yüksek KH (p= 0,031) ve İSS (p< 0,001) ve düşük GKS (p= 0,001) ile ilişkisi gösterilmiştir. Uzamış hastanede yatış süresi ise, daha yüksek KH (p< 0,001) ve İSS (p< 0,001) ile birlikte görülmektedir.

Sonuç: Yaygın olmamakla birlikte donuk yaralanmaları cerrahi müdahale gerektirebilir ve mortalite ile sonuçlanabilir. Vücut ısısından çok düşük GKS ve yüksek KH kötü prognoza işaret etmektedir. Bu bulgular, başvuru esnasında hastaların triyajlarını uygun şekilde yürütmek ve donuk yaralanmaları sonrası prognozu daha iyi öngörmek için kullanılabilir.

Anahtar Kelimeler: Donuk, termal yaralanmalar, hipotermi

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