


# Biopsychosocial factors associated with complications in patients with frostbite

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## Abstract

Cold weather injuries can be devastating and life changing. Biopsychosocial factors such as homelessness and mental illness (especially substance use disorders [SUDs]) are known risk factors for incurring frostbite. Based on clinical experience in an urban level 1 trauma center, we hypothesized that complications following frostbite injury would be influenced by homelessness, SUDs, and other forms of mental illness. The aim of this study was to examine the relationship between biopsychosocial factors and both amputations and unplanned hospital readmissions after cold injuries. Patients admitted with a diagnosis of frostbite between the winters of 2009 and 2018 were included in this retrospective cohort study. Descriptive statistics and multivariable regression assessed factors associated with outcomes of interest. Of the 148 patients in the study, 40 had unplanned readmissions within 1 year. Readmitted patients were significantly less likely to have a stable living situation (48.7% vs 75.0%,  $P = .005$ ) and more likely to have an SUD (85.0% vs 60.2%,  $P = .005$ ) or other psychiatric disorder (70.0% vs 50.9%,  $P = .042$ ). Homelessness and SUDs were independent predictors of unplanned readmission. Overall, 18% of frostbite injuries resulted in amputation. Any history of drug and/or alcohol use independently predicted amputations. The study results suggest that additional hospital and community resources may need to be marshaled to prevent vulnerable patients with biopsychosocial risk factors from having complications after frostbite. Complications place a high downstream burden on healthcare systems. Clinicians caring for frostbite patients with comorbid conditions can use these findings to inform care and discharge decisions.

**Abbreviations:** CCI = Charlson Comorbidity Index, ED = emergency department, EHR = electronic health record, LOS = length of hospital stay, SUD = substance use disorder.

**Keywords:** amputation, frostbite, homeless, readmission, substance use disorder

## 1. Introduction

Exposure to cold weather can result in a range of injuries with central effects such as hypothermia or peripheral effects such as frostbite.<sup>[1]</sup> Typically, frostbite affects the extremities—primarily the hands, feet, and face. However, any part of the body exposed to cold conditions may be susceptible to frostbite injury.<sup>[2]</sup> Among the most dreaded complications associated with frostbite are tissue necrosis, gangrene, eschar formation, and full thickness tissue loss. These complications may require surgical interventions such as debridement, escharotomy, skin grafting, and even amputation.<sup>[3]</sup> Treatment for frostbite injuries can be costly, requiring specialized care and often long lengths of stay in the hospital for patients frequently lacking commercial health insurance coverage.<sup>[4,5]</sup> Preexisting medical conditions such as diabetes and peripheral vascular disease may put people at higher risk for poor outcomes following frostbite injury.<sup>[6]</sup> Severe cold

weather injuries are associated with increases in morbidity due to cardiovascular, cerebrovascular, and pulmonary effects leading to increased all-cause mortality.<sup>[7,8]</sup>

Several premorbid biopsychosocial factors are associated with risk of cold-weather injury; however, data in this area come primarily from single-center studies. Economic factors (such as poverty) leading to inadequately heated homes can predispose individuals to cold injury.<sup>[9]</sup> Acute intoxication is associated with many cases of frostbite and cold injury.<sup>[10]</sup> Finally, psychiatric disorders with accompanying cognitive impairment may play a role in cold injuries, particularly because they are strongly correlated with homelessness.<sup>[11]</sup>

We hypothesized that complications of frostbite would be influenced by biopsychosocial factors such as homelessness and mental illness with particular focus on substance use disorders (SUDs). The aim of this study was to examine the effects of these specific biopsychosocial factors on amputations and unplanned hospital readmissions.

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## 2. Methods

The institutional review board for human subjects research at our institution approved this research. All patients admitted to the hospital with a diagnosis of frostbite between the winters of 2009 and 2018 were included in analysis. Exclusion criteria included age < 18 years and those that opted out of research. Upon identification of the final cohort, the health records of individual patients located in the centralized electronic health record (EHR) system were used to identify the outcomes of interest and to gather additional information on relevant biopsychosocial factors.

The primary outcomes of interest were any unplanned readmission to a healthcare institution in the 1-year period following the index hospitalization and any amputation related to the initial frostbite injury. Hospital readmissions excluded emergency department (ED) visits without an associated hospitalization, as well as planned readmissions for surgical management. Demographic variables of interest were age, gender, race, and ethnicity. Variables from the patient's past medical history included any documented history of psychiatric disorders including SUDs, admissions related to substance use or other psychiatric disorders, and any hospital visits (ED and/or hospital admissions) in the year prior to the frostbite admission. In some cases, medical records, including "Problem Lists" in the EHR, contained entries for clinically relevant substance use prior to the index frostbite admission that may or may not reflect an SUD; for our analysis, such data were collected as a variable (history of drug and/or alcohol use) distinct from clearly documented SUDs. Social variables included from the index frostbite

admission were marital status and living situation. Additionally, we included variables related to the hospitalization: intoxication at the time of admission, treatment of frostbite injury with thrombolytics, treatment of frostbite injury with hyperbaric oxygen, length of hospital stay (LOS), any surgical intervention (debridement, grafting, and amputation), and the Charlson Comorbidity Index (CCI)<sup>[12]</sup> at the time of discharge. The CCI has been validated for large-scale national health databases and EHR data as a measure of illness burden and a predictor of mortality.<sup>[13,14]</sup> The CCI scores were grouped: 0; 1 or 2; 3 or 4; and  $\geq 5$ . These groupings have been associated with 1-year survival with level 0 corresponding to a 98% survival rate while survival for scores  $\geq 5$  was approximately 72%.<sup>[14]</sup>

Statistical analysis included Student *t* test for continuous variables and Fisher exact test for categorical variables. Univariable and multivariable analysis assessed factors associated with unplanned readmission and amputation. Analysis was conducted using Stata 15.1 (StataCorp, College Station, TX).

## 3. Results

Patients were divided into 2 cohorts for analysis—those with unplanned readmission (N = 40) and those without unplanned readmission (N = 108; Table 1). Age, gender, and marital status were similar between the 2 cohorts. The unplanned readmission group contained higher percentages of Black (27.5% vs 17.6%) and Native American patients (17.5% vs 6.5%), but these differences did not reach statistical significance (*P* = .078). Patients in the unplanned readmission cohort were significantly less likely to have

**Table 1**  
Patient characteristics.

	Cohort N = 148	No unplanned readmission within 1 yr N = 108	Unplanned readmission within 1 yr N = 40	P value
Age in years, mean (SD)	42.4 (15.6)	41.3 (16.6)	45.3 (12.3)	.162
Male gender, n (%)	120 (81.1)	88 (81.5)	32 (80.0)	.817
Race, n (%)				.078
White	91 (61.5)	70 (64.8)	21 (52.5)	
Black	30 (20.3)	19 (17.6)	11 (27.5)	
Hispanic	7 (4.7)	6 (5.6)	1 (2.5)	
Native American or Alaskan	14 (9.5)	7 (6.5)	7 (17.5)	
Other or unknown	6 (4.1)	6 (5.6)	0 (0)	
Marital status, n (%)				.507
Single	106 (71.6)	77 (71.3)	29 (72.5)	
Married or partnered	20 (13.5)	17 (15.7)	3 (7.5)	
Divorced or separated	15 (10.1)	9 (8.3)	6 (15.0)	
Widow	4 (2.7)	3 (2.8)	1 (2.5)	
Unknown	3 (2.0)	2 (1.9)	1 (2.5)	
Stable living situation, n (%)	97 (67.8)	78 (75.0)	19 (48.7)	.005
Intoxication on admission, n (%)	98 (66.2)	71 (65.7)	27 (67.5)	1.000
History of drug and/or alcohol use, n (%)	54 (36.5)	37 (34.3)	17 (42.5)	.442
Substance use disorder, n (%)	99 (66.9)	65 (60.2)	34 (85.0)	.005
Other psychiatric disorder, n (%)	83 (56.1)	55 (50.9)	28 (70.0)	.042
Charlson Comorbidity Index, mean (SD)	0.9 (1.6)	0.9 (1.6)	1.1 (1.5)	.625
Charlson Comorbidity Index 10-yr survival %, mean (SD)	90.0 (19.7)	90.0 (20.2)	90.0 (18.6)	.936
ED or hospital admissions in 1 yr prior to frostbite admission, n (%)	69 (46.6)	42 (38.9)	27 (67.5)	.003
History of frostbite injury, n (%)	15 (10.1)	9 (8.3)	6 (15.0)	.234
LOS days, mean (SD)	8.1 (8.7)	8.1 (9.6)	7.9 (6.1)	.867
Thrombolytics, n (%)	94 (63.5)	68 (63.0)	26 (65.0)	.850
Any surgical intervention, n (%)	62 (41.9)	36 (33.3)	26 (65.0)	.001
Amputation, n (%)	27 (18.2)	18 (16.7)	9 (22.5)	.474
Medical discharge disposition, n (%)				.016
Home or stable housing	74 (50)	59 (54.6)	15 (37.5)	
Homeless shelter	14 (9.5)	5 (4.6)	9 (22.5)	
Inpatient psychiatry	13 (8.8)	11 (10.2)	2 (5.0)	
Other healthcare facility	38 (25.7)	26 (24.1)	12 (30.0)	
Against medical advice (to various locations)	9 (6.1)	7 (6.5)	2 (5.0)	
Mortality in 1-yr follow-up, n (%)	4 (2.7)	0 (0)	4 (10.0)	.005

ED = emergency department, LOS = length of hospital stay, SD = standard deviation.

a stable living situation (48.7% vs 75.0%,  $P = .005$ ). Likewise, the unplanned readmission group was more likely to have an SUD (85.0% vs 60.2%,  $P = .005$ ) or other psychiatric disorder diagnosis (70.0% vs 50.9%,  $P = .042$ ). However, there were no differences between the groups with respect to presentation with acute intoxication on admission or a reported history of any prior drug or alcohol use not necessarily meeting criteria for an SUD.

The 2 groups had similar rates of comorbidities and 10-year survival risk using the CCI. The unplanned readmission group was more likely to have had an ED visit or hospital admission in the previous year (67.5% vs 38.9%,  $P = .003$ ), though the rates of previous frostbite injury were not significantly different between the 2 groups (Table 1). Hospital LOS and use of thrombolytics were similar between the cohorts. The unplanned readmission group was more likely to have been discharged to a homeless shelter as opposed to a stable living situation after the index frostbite admission (22.5% vs 4.6%,  $P = .016$ ). Rates of amputation within 1 year of injury were similar between the 2 groups (Table 1). However, the unplanned readmission group did have higher rates of any surgical intervention (65% vs 33.3%,  $P = .001$ ). The mortality rate was higher at 1 year in the unplanned readmission cohort (10.0% vs 0%,  $P = .005$ ).

Multivariable regression assessed factors associated with unplanned readmission in frostbite patients (Table 2). Age, gender, race, and marital status were not independent predictors of unplanned readmission. Substance use disorder was a significant independent predictor of readmission (adjusted odds ratio [OR] 3.19,  $P = .025$ ). Psychiatric disorder unrelated to substance use was not an independent predictor of unplanned readmission (Table 2). Discharge to a homeless shelter was associated with unplanned readmission in frostbite patients (adjusted OR 5.40,  $P = .009$ ). We also performed a multivariate regression analysis to look at predictors of amputation in frostbite patients (Table 3). Substance use disorder (adjusted OR 6.03,  $P = .033$ ), any documented history of drug and/or alcohol use (adjusted OR 1.40,  $P = .038$ ), treatment with thrombolytics (adjusted OR 3.38,  $P = .038$ ), and transfer to another healthcare facility (adjusted OR 3.94,  $P = .039$ ) were independent predictors of amputation.

#### 4. Discussion

Cold weather injuries are more common in people who have a higher probability of exposure to cold weather (mountain-seers, military personnel, winter athletes, and those living in cold

**Table 2**  
Variables associated with unplanned readmission.

	OR (95% CI)	P value	Adjusted OR (95% CI)	P value
Age	1.02 (0.99–1.04)	.163		
Male gender	0.91 (0.36–2.27)	.838		
Non-White race	1.67 (0.80–3.48)	.173		
Intoxication on admission	1.08 (0.50–2.34)	.841		
History of drug and/or alcohol use	1.42 (0.68–2.98)	.356		
Substance use disorder	3.75 (1.45–9.69)	.006	3.19 (1.15–8.81)	.025
Other psychiatric disorder	2.25 (1.04–4.88)	.040	1.70 (0.70–4.15)	.241
Charlson Comorbidity Index	1.06 (0.85–1.32)	.623		
History of frostbite injury	1.94 (0.64–5.86)	.239		
Thrombolytics	1.09 (0.51–2.33)	.819		
Amputation	1.45 (0.59–3.56)	.416		
Medical discharge disposition				
Home or stable housing	1		1	
Homeless shelter	7.08 (2.07–24.26)	.002	5.40 (1.53–19.09)	.009
Inpatient psychiatry	0.72 (0.14–3.58)	.683	0.44 (0.08–2.34)	.336
Other healthcare facility	1.82 (0.75–4.41)	.188	1.52 (0.58–3.98)	.392
Against medical advice (to various locations)	1.12 (0.21–5.97)	.891	0.79 (0.14–4.35)	.785

Univariable and multivariable logistic regression.  
CI = confidence interval, OR = odds ratio.

**Table 3**  
Variables associated with amputation.

	OR (CI)	P value	Adjusted OR (CI)	P value
Age	1.03 (1.00–1.06)	0.031	1.03 (0.99–1.07)	.196
Male gender	1.42 (0.45–4.50)	0.549		
Non-White race	0.62 (0.25–1.53)	0.297		
Intoxication on admission	0.69 (0.29–1.63)	0.399		
History of drug and/or alcohol use	4.91 (1.40–17.21)	0.013	1.40 (1.07–10.68)	.038
Substance use disorder	0.74 (0.30–1.82)	0.509	6.03 (1.16–31.46)	.033
Other psychiatric disorder	3.33 (1.26–8.83)	0.016	1.89 (0.60–5.93)	.275
Charlson Comorbidity Index	1.08 (0.84–1.39)	0.545		
History of frostbite injury	1.34 (0.30–4.34)	0.853		
Thrombolytics	2.30 (0.87–6.12)	0.095	3.38 (1.07–10.68)	.038
Medical discharge disposition				
Home or stable housing	1		1	
Homeless shelter	0.74 (0.08–6.50)	0.783	0.39 (0.04–3.75)	.416
Inpatient psychiatry	2.87 (0.64–12.96)	0.170	1.80 (0.34–9.57)	.492
Other healthcare facility	6.24 (2.26–17.22)	<0.001	3.94 (1.07–14.45)	.039
Against medical advice (to various locations)	1.20 (0.13–11.01)	0.874	0.70 (0.07–6.82)	.755

Univariable and multivariable logistic regression.  
CI = confidence interval, OR = odds ratio.

climates).<sup>[15–17]</sup> Recent studies show that frostbite is increasingly becoming a concern in civilian medical practice in urban areas.<sup>[18,19]</sup> The increased rates of cold weather injury in urban areas prompted us to assess biopsychosocial factors associated with complications following frostbite. In frostbite, common complications include amputation and unplanned hospital readmission. We sought to determine whether biopsychosocial factors might influence the rates of those complications in frostbite patients at our institution. We found that homelessness was associated with unplanned readmission following frostbite injury, while SUDs were an independent predictor of both unplanned readmission and amputation.

According to the National Coalition for the Homeless, cold weather injuries are more frequent in the homeless than in the population at large. In the United States, as much as a quarter of the homeless population carries a major mental illness diagnosis—a prevalence rate 3 to 4 times that of the population as a whole.<sup>[11]</sup> It is clear from other areas of medicine that preexisting psychiatric disorders can compromise patient outcomes. Hudson et al<sup>[20]</sup> found that burn patients with preexisting psychiatric disorders had more severe injuries, higher rates of in-hospital complications, higher mortality, and a lower likelihood of being discharged home. A meta-analysis by Davis et al<sup>[21]</sup> found that cancer patients with a preexisting psychiatric disorders were more likely to present with an advanced stage of cancer and die sooner after diagnosis. Haupt et al<sup>[22]</sup> examined orthopedic trauma patients with preinjury depression and anxiety, and found that those patients had a prolonged LOS and more days in the intensive care unit than patients without depression or anxiety. While we found that homelessness was an independent predictor of unplanned readmission after frostbite injury, psychiatric diagnosis unrelated to substance use was not associated with morbidity in the form of unplanned readmission or amputation.

High rates of SUDs may mediate the increased risk of both incidence and severity of cold weather injuries in the homeless.<sup>[23]</sup> Comorbid SUDs have already been shown to mediate risk and negative outcomes in other circumstances involving acute injury to the skin. Rehou et al<sup>[24]</sup> looked at SUDs in burn patients and found increased rates of bacteremia and sepsis, as well as increased average LOS compared to burn patients without SUDs. A meta-analysis of SUDs in burns showed that patients with these disorders had higher rates of multiple complications, including more intubations and ventilator days, increased rates of wound infection, and increased overall mortality.<sup>[25]</sup> We found that SUD diagnosis was a significant predictor of unplanned readmission and amputation, while even just a history of documented drug and/or alcohol use was associated with amputation. This is consistent with our anecdotal experience with these patients. Frostbite patients often need an extended period of outpatient care after their initial admission, including pain management and dressing changes. It is easy to imagine that a significant SUD could impact adherence with proper wound care, and that tolerance and addiction could complicate pain management (especially with narcotics), all leading to unplanned readmissions and subsequent amputation. More aggressive interventions for addictive problems may therefore be warranted to prevent complications and poor outcomes in frostbite patients with SUDs.

In our population of patients hospitalized with cold injury, those with unplanned readmissions after discharge had similar baseline demographics (largely single men in their fourth or fifth decade of life) compared to those without an unplanned readmission. But as expected, the unplanned readmission cohort had higher rates of homelessness, SUDs, other psychiatric disorders, and previous hospital admissions (in the year before their frostbite admission). Given those findings, it was not surprising that they had higher rates of surgical intervention and mortality, as well. Those patients were also less likely to be discharged

home after treatment for frostbite, and more likely, instead, to go to a homeless shelter or other healthcare facility. It should be noted that disposition to inpatient psychiatry after treatment for frostbite was associated with lower rates of hospital readmission within a year. Patients who underwent inpatient psychiatric stabilization may have had more durably effective treatment of their underlying SUDs and other mental illnesses, thereby improving adherence with outpatient medical care.

At first glance, it may seem unusual that amputation was not a predictor of unplanned readmission. It is very common for frostbite patients to have a planned readmission for amputation surgery, typically at least 6 weeks after their original frostbite injuries. We excluded these planned readmissions from our analysis. Thrombolytics have been shown to decrease need for amputation following frostbite injury.<sup>[26–30]</sup> They are only used in the setting of severe frostbite with demonstrable perfusion deficit. While use of thrombolytics is a predictor of amputation in this cohort, that is unsurprising since it is a marker of the severity of injury, and we did not limit our cohort to severe frostbite injury. After adjusting for other factors, age was not an independent predictor of amputation. However, older patients have a decrease in peripheral perfusion,<sup>[31]</sup> potentially increasing the severity of frostbite.

Limitations of this study include those associated with single-center, retrospective research. Categorical designation of biopsychosocial factors may be overly simplistic. Severity of psychiatric illness varies widely within the same diagnostic category, and thus the impact of those comorbidities in individual patients may vary, as well. Merely carrying a diagnosis of SUD does not account for the current state of the patient's substance use and its impact on health and behavior. As is often the case, documentation of SUDs in our patients' records may not have been diagnostically accurate, and the burden of illness conferred by having substance related problems at some point before frostbite is difficult to quantify. As noted, intoxication at the time of cold injury is common, but that episode may reflect everything from a 1-time misadventure to a manifestation of severely entrenched, life-threatening addiction. An unstable housing situation can be fluid as well and can even change over the course of a patient's treatment for frostbite and its sequel. Noting the complex illness burden in our disadvantaged patient population, one would also expect trauma and stressor-related disorders to be common and potentially impact frostbite outcomes via multiple mechanisms. We suspect that post-traumatic stress disorder was underreported in the medical records of study subjects, since only 1 individual (who did also have an unplanned readmission) had documented post-traumatic stress disorder. The influence of trauma in various forms with or without resulting mental illness is a clear area of need for future study in understanding patients with frostbite and identifying opportunities for improvement in care.

One other limitation relates to the problem of frostbite itself—the initial assessment of frostbite severity can be difficult. Although we are making strides using clinical assessment scores<sup>[32]</sup> and real-time imaging,<sup>[33]</sup> those recent clinical advancements were evolving over the decade covered by this study, and therefore not consistently applied into the care of all 148 patients. Therefore, the severity of frostbite could not be incorporated into our analysis but may have been a greater factor in producing complications in some cases compared to any of the biopsychosocial factors examined.

## 5. Conclusions

Cold weather injuries cause extreme pain and not infrequently result in acute and subacute complications with lasting disfigurement and morbidity. Biopsychosocial factors including SUDs and homelessness are independent predictors of unstable recovery trajectories in frostbite patients resulting in unplanned



readmission. SUDs and even a premorbid history of drug and/or alcohol use without clear evidence of disorder are independent predictors of amputations. Clinicians caring for frostbite patients with these conditions should consider these factors as part of their treatment planning and discharge decisions, with poor outcome prevention in mind. There may be a role for greater attention to psychiatric stabilization and substance use management during the early aftermath of a cold weather injury to improve adherence for the sake of better physical outcomes. Shoring up more stable disposition planning for homeless frostbite victims, even if just for the period of wound care, healing, and management of complications may decrease morbidity. Additional hospital, public health, and community resources may be needed to prevent these vulnerable patients from having significant complications and placing an even higher burden on healthcare systems.

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