Original Article

Understanding frostbite presentation and distribution of care in Ontario 2010–2018

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Abstract

Introduction: Frostbite is a cold-weather injury presenting a significant risk of functional morbidity due to amputation. There is a paucity of studies investigating the epidemiology and regional distribution of frostbite. We describe the characteristics of frostbite patients and their care in Ontario.

Methods: Data were collected from the Institute of Clinical and Evaluative Sciences for adults over 18 years presenting to an Ontario emergency department from 1 January 2010 to 31 December 2018. Patients were followed for 30-day readmission and additional treatments within 180 days of presentation.

Results: Five thousand three hundred and eleven patients presented with unique episodes of frostbite in Ontario. Most cases were classified as unspecified (n = 3775) or superficial (n = 1379) frostbite of the extremities, primarily in male patients with a mean age 40 and few comorbidities. Cases were seen across all income and marginalisation quintiles, with a trend towards more cases in greater Ontario Marginalization indices and a higher proportion of homelessness seen in deep frostbite presentations (10%) compared to superficial (4.4%) or unspecified (5.6%). Most cases (75%) presented to small or medium-sized non-academic hospitals. An increase in cases was seen in extreme cold winters in 2014 and 2015.

Conclusion: Frostbite patients presented to small and medium non-academic hospitals with increased cases during extreme cold weather. While there was a trend towards more cases in lower-income and marginalised populations, frostbite impacted all segments of society. Frostbite education initiatives involving patients and providers have the potential to positively impact patient outcomes.

Keywords: Amputation, comorbidities, frostbite, knowledge dissemination

Résumé

Introduction: L'engelure est une blessure liée au froid qui comporte un risque important de morbidité fonctionnelle en raison d'amputations possibles. Peu d'études se sont intéressées à l'épidémiologie et à la répartition régionale des engelures. Nous décrivons ici les caractéristiques des patients atteints d'engelures et leur trajectoire de soins en Ontario.

Méthodes: Les données proviennent de l'Institute for Clinical and Evaluative Sciences et concernent les adultes de 18 ans et plus ayant consulté à l'urgence en

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Ontario entre le 1er janvier 2010 et le 31 décembre 2018. Les patients ont été suivis afin d'évaluer les réadmissions dans les 30 jours et les traitements additionnels dans les 180 jours suivant la première consultation.

Résultats: Au total, 5 311 patients ont consulté pour un épisode unique d'engelure en Ontario. La majorité des cas concernaient des engelures des extrémités, classées comme non spécifiées (*n* = 3 775) ou superficielles (*n* = 1 379), principalement chez des hommes âgés en moyenne de 40 ans et présentant peu de comorbidités. Les cas ont été observés dans tous les quintiles de revenu et de marginalisation avec une tendance plus marquée dans les indices de marginalisation élevés de l'Ontario (ONMARG). Une proportion plus grande de personnes en situation d'itinérance a été relevée parmi les engelures profondes (10%), comparativement aux engelures superficielles (4,4%) ou non spécifiées (5,6%). La plupart des patients (75%) se sont présentés dans de petits ou moyens hôpitaux non universitaires. Une hausse des cas a été observée durant les hivers extrêmement froids de 2014 et 2015.

Conclusion: Les patients atteints d'engelures ont surtout été pris en charge dans de petits et moyens hôpitaux non universitaires, avec une incidence accrue lors des épisodes de froid extrême. Bien qu'une tendance à une plus grande incidence dans les populations à faible revenu et marginalisées ait été observée, l'engelure touche toutes les couches de la société. Des initiatives de sensibilisation auprès des patients et des professionnels de la santé pourraient améliorer les résultats cliniques.

Motsclés: Engelure, Amputation, Comorbidités, Diffusion des connaissances

INTRODUCTION

Frostbite is a subtype of thermal injury resulting from cold exposure, ranging from superficial cutaneous lesions to full-thickness necrosis of the skin and underlying tissues.[1-3] While historically associated with military operations, frostbite injuries are becoming more prevalent among the general population, particularly in northern countries and communities.[1,2,4-8] Older age, male sex, smoking, substance and alcohol abuse, psychiatric illness and homelessness have all been identified as risk factors for frostbite.[4,5,9,10] Risk factors for frostbite-associated amputations include duration of exposure, lack of proper attire and remoteness of location at the time of injury.[6] The current epidemic of homelessness, substance abuse and climate change all have the potential to further impact the landscape of cold-weather injuries.[7,11]

Severe frostbite injuries are associated with the potential for high morbidity, including amputation.[2,4,9] Rapid rewarming and pain management remain foundational principles of frostbite treatment, along with the introduction of vasodilator and thrombolytic therapy with the aim of digit salvage.[3,10,12,13] Early expert consultation and involvement of multidisciplinary teams including pharmacists, occupational therapists, nurses, physiotherapists and mental health professionals have also demonstrated positive impacts on patient outcomes.[3,14]

Current Canadian frostbite literature is dominated by single-centre case reports or series and is lacking large population-based studies investigating the demographics, presentation and treatment of frostbite.[8,12,15] Anticipated societal changes, including an increase in homelessness and substance abuse, may impact the epidemiology of frostbite injuries.[16-21] The relationship between the location of frostbite presentation, demographics and outcomes, particularly with respect to urban and rural settings, is also poorly understood. Our study aims to describe the characteristics of frostbite patients and the distribution of frostbite presentation and care in Ontario at the population level.

METHODS

Data were provided by the Institute for Clinical and Evaluative Sciences (ICES), an independent, non-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyse health care and

demographic data, without consent, for health system evaluation and improvement. The cohort was defined by the inclusion of all patients 18 years of age and older presenting to the emergency department (ED) with frostbite in the province of Ontario between 1 January 2010 and 31 December 2018. Individuals were excluded if they had missing demographic data. Ontario health care regional reporting changed from a local health integration network (LHIN) system in 2021 to an alternate system. Data collected and used in our study were attributed to the Ontario LHIN distribution, which was in place at that time.

Baseline descriptive data of the cohort population were reported for several variables including age, sex, region of patient residence, homelessness, location of presentation to ED and season of presentation. Incidence rates for first frostbite presentation per year were reported per 100,000 individuals at least 18 years of age or older in Ontario. All analyses were performed using SAS Enterprise Guide v7.1.

Patients were followed retrospectively within the health system for 30-day readmission and additional debridement, or amputation treatments related to frostbite within 180 days of frostbite. Open-source information was also used, including Environment Canada data, to identify environmental factors, including weather conditions.

Presentation with frostbite to the ED was defined using the Canadian Institute for Health Information's (CIHI) National Ambulatory Care Reporting System database with ICD-10 codes for frostbite. Also used were the Ontario health insurance plan claim base, Ontario mental health reporting system, Ontario Marginalization Index (ONMARG), registered persons database files, same day surgery database, Ontario Asthma Dataset, Ontario Congestive Heart Failure Dataset Ontario chronic obstructive pulmonary disease dataset (COPD), discharge Abstract database the ontario hypertension dataset (HYPER) and Ontario Healthcare Institution database (INST). These datasets were linked using unique encoded identifiers and analysed at ICES. Charlson comorbidity index was used as an established weighted index to represent patient comorbidity. Charlson scores were calculated using the Johns Hopkins ACG®System Version 10 software, as 32 ACG® system aggregated diagnosis groups (ADGs) and combined to define a singular ADG score. Charlson scores, ADG scores, ONMARG indices, as well as the demographic information, characteristics of frostbite and characteristics of the treating hospital were determined at the time of first frostbite presentation. The variable reported as drug exposure 'at the time of injury' refers to other diagnostic codes reported concurrently with the medical record of frostbite presentation. Repeat frostbite was defined as any frostbite occurring 180 days or more after the incident frostbite.

Our study received ethics approval through the Laurentian University research ethics board (File 6020977).

RESULTS

Table 1a summarizes demographic information including age, sex, location of residence, homelessness, hospital region, hospital size and rurality index. Five thousand three hundred and eleven patients presented with frostbite in Ontario from 2010 to 2018. Most cases were classified as unspecified (n = 3,775), followed by superficial (n = 1,379) and then deep (n = 160). Most patients were male (68.7%–74.4%), with a mean age of 40, presenting with unspecified or superficial frostbite. Those who presented with deep frostbite were slightly older, with a mean age of approximately 48. The highest proportion of homelessness was observed among individuals presenting with deep frostbite (10% homeless) compared to superficial or undefined (4.4% and 5.6%, respectively). Urban populations had higher numbers of frostbite presentations compared to rural populations. Individuals residing in Ontario LHIN regions 9 (Central East), 11 (Champlain) and 13 (Northeast) had the highest percentage of incident frostbite cases. Most cases are presented in the winter season, followed by spring and fall, with very few presenting in the summer. Most frostbite cases (75%) presented to small or medium-sized hospitals across Ontario, with only approximately 25% of cases presenting to larger academic hospitals.

The Charlson Comorbidity Score,[22] ADG scores and Marginalization Indices of frostbite patients were noted. Of patients with known

Charlson scores, most patients presenting with frostbite had low scores. Mean ADG scores for frostbite presentations were 7.61 for superficial frostbite and 7.78 for deep frostbite presentations. The number of patients with either superficial or deep frostbite trended towards greater marginalisation in ONMARG residential instability, dependency and material deprivation scores, though cases were present across all quintiles. There were no trends identified in ONMARG Ethnic Diversity scores in frostbite case presentations.

Table 1b shows the comorbidities of patients recorded at the time of frostbite presentation. The most common comorbidities were hypertension, followed by asthma, diabetes and COPD. Peripheral vascular disease, coronary artery disease, chronic heart failure, renal failure and dementia were present in very few patients.

Table 1c shows case presentations identified as occurring with recreational activity, drug exposure or alcohol exposure. Recreational activity was identified in 549 cases, alcohol exposure in 141 cases and drug exposure in 58–62 cases with distribution across superficial, deep (exact number of cases supressed due to low number of cases reported) and unspecified case classifications.

Table 2 shows the primary body part involved with frostbite injury. Patients presented most frequently with lower extremity injuries (42%),

Table 1a: Characteristics of patients presenting with frostbite in Ontario – demographics and location of presentation

	Superficial, *n* (%)	Deep (tissue necrosis), *n* (%)	Not specified, *n* (%)
Total patients (*n*)	1379	160	3775
Age at index			
Mean±SD	39.9±18.2	47.8±17.8	40.4±17.7
Median (IQR)	36 (23–53)	49 (33–59)	38 (24–54)
Sex			
Female	431 (31.3)	20 (12.5)	966 (25.6)
Male	948 (68.7)	140 (87.5)	2809 (74.4)
Homelessness (Y)	60 (4.4)	16 (10.0)	211 (5.6)
Distance between residence and site of index emergency visit categories (km)			
Missing	502 (36.4)	64 (40.0)	1264 (33.5)
≤20	644 (46.7)	76 (47.5)	1871 (49.6)
20–60	134 (9.7)	13 (8.1)	395 (10.5)
60–100	30 (2.2)	0	68 (1.8)
>100	69 (5.0)	7 (4.4)	177 (4.7)
Institution region			
Missing	15 (1.1)	1–5*	58 (1.5)
Central	358 (26.0)	56 (35.0)	1075 (28.5)
East	365 (26.5)	40 (25.0)	978 (25.9)
Northeast	212 (15.4)	21 (13.1)	428 (11.3)
Northwest	101 (7.3)	12 (7.5)	302 (8.0)
West	328 (23.8)	30 (18.8)	934 (24.7)
Season of frostbite			
Fall	88 (6.4)	1–5*	147 (3.9)
Spring	171 (12.4)	28 (17.5)	427 (11.3)
Summer	52 (3.8)	8–12*	91 (2.4)
Winter	1068 (77.4)	119 (74.4)	3110 (82.4)
Academic hospital (Y)	361 (26.2)	40 (25.0)	994 (26.3)
Hospital size			
Missing	47 (3.4)	6 (3.8)	141 (3.7)
Small (1–199 beds)	745 (54.0)	74 (46.3)	1965 (52.1)
Medium (200–399 beds)	475 (34.4)	74 (46.3)	1227 (32.5)
Large (≥400 beds)	112 (8.1)	6 (3.8)	442 (11.7)

*Cells with fewer than six visits were suppressed to protect patient privacy. RIO (rurality index for Ontario) score ranges from 0 to 100, where 0 is the most urban and 100 is the most rural. This score is generated for each census subdivision as the sum of a measure of population density, travel time to nearest basic referral centre and travel time to nearest advanced referral center. ONMARG: Ontario Marginalization, SD: Standard deviation, IQR: Interquartile range

followed by upper extremity (33.6%), the head (13%) and neck involvement (10%). Patients presenting with deep frostbite most commonly involved the distal extremities (wrist and hand, foot and ankle). In the small number of cases with torso involvement, none were classified as deep tissue injury. Few patients were classified as presenting with multiple or unspecified body sites.

Table 3 shows that 44.85% (n = 2382) of frostbite patients had at least one return visit to the ED for frostbite within 180 days of initial presentation. There was a trend towards increased number of mean return ED visits for deep frostbite (2.61) compared to unspecified (1.5) and superficial (1.32). Overall, 12% (n = 637) of frostbite patients required inpatient admission, with 40% of deep frostbite presentations requiring inpatient admission. Debridement and amputation associated with frostbite cases were investigated in the databases; however, <300 cases were identified with multiple categories of suppressed data due to low numbers.

Table 4 shows annual frostbite incidence in Ontario from 2010 to 2018. Notably, 2014, 2015 and to a lesser degree 2018, had a large increase in relative incidence compared to other years. The number of frostbite cases seen in the western region, representing southwestern Ontario as

Table 1b: Comorbidities by frostbite type

	Superficial, *n* (%)	Deep (tissue necrosis), *n* (%)	Unspecified, *n* (%)
Total patients	*n*=1379	*n*=160	*n*=3775
Comorbidities at index date			
Coronary artery disease	32 (2.3)	1–5*	98 (2.6)
Chronic heart failure	17 (1.2)	7 (4.4)	82 (2.2)
COPD	116 (8.4)	20 (12.5)	333 (8.8)
Dementia	23 (1.7)	6 (3.8)	73 (1.9)
Hypertension	253 (18.3)	37 (23.1)	720 (19.1)
Diabetes	155 (11.2)	24 (15.0)	394 (10.4)
Peripheral vascular disease	9 (0.7)	1–5*	23 (0.6)
Asthma	289 (21.0)	21 (13.1)	698 (18.5)
Renal failure	27 (2.0)	8 (5.0)	71 (1.9)

*Cells with fewer than six visits were suppressed to protect patient privacy. COPD: Chronic obstructive pulmonary disease

Table 1c: Characteristics of patients presenting with frostbite in Ontario – exposure, substance use and repeat/previous frostbite

	Superficial, *n* (%)	Deep (tissue necrosis), *n* (%)	Unspecified, *n* (%)	Total
Frostbite injury during recreational activity	173 (12.5)	20 (12.5)	356 (9.4)	549
Alcohol exposure at time of injury[a]	38 (2.8)	10 (6.3)	103 (2.7)	141
Drug exposure at time of injury	11 (0.8)	1–5*	46 (1.2)	58–62

*Cells with fewer than six visits were suppressed to protect patient privacy. [a]Variables recorded 'at the time of injury' refer to other diagnostic codes reported with the frostbite record. All individuals in these categories were intoxicated at the time of injury

Table 2: Primary body part involved

Location	Superficial, *n* (%)	Deep (tissue necrosis), *n* (%)	Unspecified, *n* (%)	Total
Foot, Knee and Lower Leg	544 (21.0)	68 (2.7)*	1969 (76.4)	2577
Head	204 (14.8)	11 (6.9)	587 (15.5)	800
Neck	28 (2.0)	1–5*	587 (15.5)	616–620
Arm, Wrist and Hand	528 (25.7)	73 (3.5)	1390 (67.5)	2058
Unspecified body site	35 (2.5)	1–5*	370 (9.8)	406–410
Abdomen Wall/Lower Back/Pelvis	23 (1.7)	0	49 (1.3)	72
Hip and Thigh	19 (1.4)	1–5*	49 (1.3)	69–73
Thorax	6 (0.4)	0	49 (1.3)	54
Multiple body sites	39 (2.8)	8 (5.0)	79 (2.1)	*

*Note that some frostbite cases span multiple body sites

Table 3: Repeat emergency room visits and inpatient admissions to hospital within 180 days of initial frostbite				
Hospital type	Overall	Superficial	Deep (tissue necrosis)	Unspecified
Any ED visit, *n* (%)	2382 (44.9)	596 (43.2)	85 (53.1)	1703 (45.1)
Number of ED visits - mean±SD	1.48±4.2	1.32±3.7	2.61±8.1	1.5±4.2
Any inpatient visit, *n* (%)	637 (11.0)	129 (9.4)	64 (40.0)	449 (11.9)

SD: Standard deviation, ED: Emergency department

the most temperate part of the province, had the greatest percentage increase in frostbite cases during 2014 and 2015 (from 22% to 28%) compared to other regions and all other years studied (2010 through 2013 and 2016 through 2019). Correlation with Environment Canada weather reports for these years identified extreme cold temperatures.

DISCUSSION

Frostbite was consistently present across Ontario over the period studied with presentations primarily in the winter and spring months and increased case numbers during years with severe cold episodes. Frostbite patients ranged in demographics and were most often middle-aged males in predominantly urban settings in southern Ontario. While patients were not highly comorbid, the most associated comorbidities were hypertension, followed by asthma, diabetes and COPD, with a low prevalence of peripheral vascular disease and cardiovascular disease. While smoking status was not identifiable within the dataset, asthma and COPD may be linked to smoking. The prevalence of HYPER, diabetes and possibly smoking in our study demonstrates the value of clinical trials in further understanding the impacts of vasodilator and antithrombotic medications in frostbite care, as vasoconstriction and small vessel disease may play more of a role than previously understood.[16,20]

Homelessness was connected to some frostbite presentations, with a higher proportion of deep frostbite cases seen in this population. Increasing material deprivation and residential instability showed a trend toward higher numbers of frostbite cases. This may be due to the risk of prolonged cold exposure in patients experiencing homelessness, or additional social determinants of health such as limited resources for cold-weather clothing or the necessity of working in cold conditions for prolonged periods. Recreational activity and alcohol were reported in frostbite presentations, though not in large numbers and drug use was rarely reported synchronously with frostbite presentations. Further research into social determinants of health in relation to frostbite presentation among marginalised populations including homeless, low-income and racialised communities, may prevent devastating impacts such as amputation in already vulnerable patients. Where homelessness, marginalisation, recreational activity and alcohol and drug use were present within our study population, it's important to note that frostbite was seen across all income, marginalisation and diversity quintiles. Broad public health education in frostbite prevention and treatment is needed across all segments of society to impact frostbite outcomes most effectively.

Most cases identified in this study were presented in the most populous southern and urban regions of the province, often to small and medium-sized non-academic hospitals where they may be less likely to have subspecialty multidisciplinary frostbite care, expertise or treatment protocols. Frostbite care is highly variable across Canada, and medical interventions such as tPA and Iloprost may be most beneficial when implemented early.[16] Provider education and treatment availability are critical in ensuring eligible patients are appropriately identified and treated in a timely fashion, highlighting the need for regional or national frostbite care resources to support provider education and timely access to modern frostbite care.[21]

The notable increase in frostbite cases in Ontario during unseasonably cold winters in 2014 and 2015, and to a lesser degree in 2018, particularly in the warmer southwestern regions of the province, could be related to lack of preparedness or prevention in a region where severe cold conditions and frostbite risk may be less common. This highlights the potential value of frostbite prevention and treatment

Table 4: Rate of yearly frostbite incidence in Ontario from 2010 to 2018

Calendar year	New frostbite case	Individuals in Ontario	Rate per 100,000 (95% CI)
2010	302	14,177,710	2.13 (1.9–2.4)
2011	404	14,352,514	2.81 (2.6–3.1)
2012	224	14,523,795	1.54 (1.4–1.8)
2013	518	14,685,464	3.53 (3.2–3.8)
2014	1126	14,830,973	7.59 (7.2–8.1)
2015	1069	14,961,703	7.14 (6.7–7.6)
2016	478	15,078,262	3.17 (2.9–3.5)
2017	453	15,181,318	2.98 (2.7–3.3)
2018	737	15,271,350	4.83 (4.5–5.2)

CI: Confidence interval

education in warmer regions of Ontario and Canada, particularly during extreme cold events. This may become increasingly important as the frequency of extreme climate events is anticipated to increase due to climate change.[17,18]

Limitations

The administrative data used in this study were limited to the ICD-10 codes identified by providers and administrators at the time of patient presentation. ICD-10 codes for frostbite were limited to classifications of unspecified, superficial or deep. The use of this categorisation is not reflective of modern frostbite grading systems and understanding of frostbite severity and may have contributed to the high number of cases classified as unspecified. While care was taken to holistically assess demographic factors such as comorbidities and decreased access to resources and care, the tools used, including the Charlson score or the ONMARG rankings, have their own intrinsic limitations. Limitations of hospital administrative data and billing information within the datasets were unable to clearly link frostbite presentation with procedural interventions such as debridement and amputation.

CONCLUSION

Frostbite patients presenting to EDs in Ontario, Canada, from 2010 to 2018 were seen primarily in small and medium-sized non-academic hospitals in southern Ontario, with a notable increase in cases in warmer parts of the province during extreme cold winter weather in 2014 and 2015. While there was a trend towards more frostbite cases in lower-income and marginalised populations with a higher proportion of severe frostbite cases seen in the homeless population, frostbite impacted all segments of society. The development of broader regional and national frostbite care education and research initiatives involving both patients and providers has the potential to positively impact future patient outcomes.

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