

Epidemiology and mortality of glacier crevasse accidents



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ARTICLE INFO

Article history:

Accepted 7 July 2014

Keywords:

Crevasse
Emergency Medical Services
Epidemiology
Hypothermia
Mountain Medicine
Trauma

ABSTRACT

Introduction: Crevasse accidents can lead to severe injuries and even death, but little is known about their epidemiology and mortality.

Methods: We retrospectively reviewed helicopter-based emergency services rescue missions for crevasse victims in Switzerland between 2000 and 2010. Demographic and epidemiological data were collected. Injury severity was graded according to the National Advisory Committee for Aeronautics (NACA) score.

Results: A total of 415 victims of crevasse falls were included in the study. The mean victim age was 40 years (SD 13) (range 6–75), 84% were male, and 67% were foreigners. The absolute number of victims was much higher during the months of March, April, July, and August, amounting to 73% of all victims; 77% of victims were practicing mountaineering or ski touring. The mean depth of fall was 16.5 m (SD 9.0) (range 1–35). Overall on-site mortality was 11%, and it was higher during the ski season than the ski offseason (14% vs. 7%; $P = 0.01$), for foreigners (14% vs. 5%; $P = 0.01$), and with higher mean depth of fall (22 vs. 15 m; $P = 0.01$). The NACA score was ≥ 4 for 22% of the victims, indicating potential or overt vital threatening injuries, but 24% of the victims were uninjured (NACA 0). Multivariable analyses revealed that depth of the fall, summer season, and snowshoeing were associated with higher NACA scores, whereas depth of the fall, snowshoeing, and foreigners but not season were associated with higher risk of death.

Conclusion: The clinical spectrum of injuries sustained by the 415 patients in this study ranged from benign to life-threatening. Death occurred in 11% of victims and seems to be determined primarily by the depth of the fall.

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Introduction

Mountaineering activities attract numerous people and confer a relatively high mortality rate compared to other sport or leisure activities [1]. Activities with a risk of crevasse accidents include mountaineering or ski touring, as well as off-piste skiing or snowboarding on glaciers, which are practised in several alpine countries in Europe or North America [2]. The spectrum of injuries sustained by victims is broad, from minor lesions to life-threatening

trauma or severe hypothermia [3,4]. However, the medical literature on crevasse accidents is sparse, and the largest case series contains only 95 cases [5]. The goal of our retrospective study was to review helicopter-based emergency services (HEMS) rescue missions for crevasse victims in Switzerland, focusing on the epidemiology and mortality of these accidents. As the patient data studied was anonymous (i.e., the identity of the victims did not appear in the registry), we were granted a waiver for formal review by our institutional ethics committee.

Patients and methods

All HEMS rescue missions for crevasse accidents in Switzerland from January 1, 2000, to December 31, 2010, were included in the study. Data were extracted from the Swiss Alpine Club registry,

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which prospectively collects information about mountain accidents in Switzerland, and to which we were granted access. This registry is used for statistics and accident prevention purposes and does not include in-hospital data. The following data were available: victim age, gender, and nationality (Swiss vs. foreigner), the month and year of the accident, the type of activity practised at the time of the fall, and in some cases the depth at which the victim had fallen into the crevasse. For our analyses, we defined the ski season as December to May and the ski off-season from June to November. Injury severity was graded using the eight-level National Advisory Committee for Aeronautics (NACA) gravity score [6]. This score was assigned by the emergency doctor at the end of the pre-hospital rescue mission and represents the most serious clinical state occurring at any given time during the mission (Table 1).

We used ordinal logistic regression analysis to assess the associations between NACA score and patients' characteristics (age, gender, nationality), type of activity (mountaineering, ski touring, off-piste snowboarding, off-piste skiing, snowshoe touring), season (winter, spring, summer, autumn), and depth of fall. When the outcome was on-site death, we used logistic regression analysis instead. As there were only 18% complete cases (see Appendix 1), we imputed missing values to limit selection bias (due to data not missing completely at random). To proceed, we used the method of multiple imputation by chained equations and imputed 40 values for each missing data point [7]. To assess sensitivity of the results to the number of imputed values we considered various numbers from 5 to 40. In the imputation procedure, dichotomous variables were modelled by ordinary logistic regression, ordered polytomous variables by ordered logistic regression, and unordered polytomous variables by multinomial logistic regression. Age was modelled by linear regression, whereas depth was modelled by interval censored regression with lower and upper boundaries set at 1 and 50 m. For each variable, Kernel density plots of observed, imputed, and completed distributions were used to assess the performance of the imputation method [8]. Statistical analyses were performed using Stata Statistical Software Release 13.1 (Stata Corporation, College Station, TX, USA).

Results

A total of 415 victims of crevasse falls were included in this study. The average number of victims per year was 37.7 (SD 10.1) (range 21–57). No difference was found in the number of victims over the years ($P = 0.54$). The mean victim age was 40 years (SD 13) (range 6–75). Most of the victims (84%, $n = 346$) were male, with a male to female ratio of 5.3:1; 67% (248 out of 371) were foreigners.

Table 1
Injury severity according to the National Advisory Committee for Aeronautics (NACA) score.

| NACA | Description |
|------|--|
| 0 | No injury or disease |
| 1 | Injuries/diseases without any need for acute physician care |
| 2 | Injuries/diseases requiring examination and therapy by a physician but hospital admission is not indicated |
| 3 | Injuries/diseases without acute threat to life but requiring hospital admission |
| 4 | Injuries/diseases that can possibly lead to deterioration of vital signs |
| 5 | Injuries/diseases with acute threat to life |
| 6 | Injuries/diseases requiring resuscitation |
| 7 | Lethal injuries or diseases (with or without resuscitation attempts) |

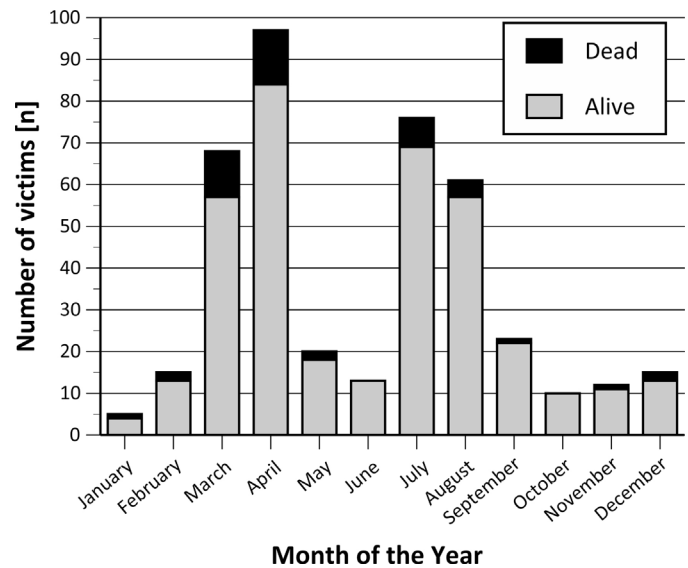


Fig. 1. Monthly count of glacier crevasse victims in Switzerland 2000–2010.

Of the 415 victims, 220 (53%) were injured during the ski season and 195 (47%) during the ski off-season. The majority (73%) of the victims were injured during the months of March, April, July, and August (Fig. 1). The most frequent activities practised by the victims were mountaineering (42%) and ski touring (35%). The mean depth of the fall in the 75 cases (18%) for which this information was available was 16.5 m (SD 9.0) (range 1–35).

Overall on-site mortality was 11%, representing a mean of four people each year. No difference in mortality was found over the years ($P = 0.23$). The results of the univariate analysis are shown in Table 2. Mortality was not associated with age or gender, but it was higher during the ski season, for foreigners, and depended on the activity and mean depth of the fall, which was higher for people who died than for survivors ($P = 0.02$).

Table 2
Characteristics of the study population and according to survival status.

| | Overall (n = 415) | Alive (n = 371) | Dead (n = 44) | P value |
|------------------------------|-------------------|-----------------|----------------|---------|
| Outcome (%) | 100 | 89 | 11 | – |
| Age [SD] (n) | 40 [13] (373) | 40 [13] (332) | 41 [12] (41) | 0.47 |
| Gender (%) (n) | | | | 0.66 |
| Male | 84 (346) | 90 (310) | 10 (36) | |
| Female | 16 (65) | 88 (57) | 12 (8) | |
| Season (%) (n) | | | | 0.02 |
| Ski season | 53 (220) | 86 (189) | 14 (31) | |
| Ski off-season | 47 (195) | 93 (182) | 7 (13) | |
| Nationality (%) (n) | 100 (371) | | | 0.01 |
| Swiss | 33 (123) | 95 (117) | 5 (6) | |
| Foreigner | 67 (248) | 86 (214) | 14 (34) | |
| Activity (%) (n) | 100 (414) | | | 0.01 |
| Mountaineering | 42 (172) | 94 (161) | 6 (11) | |
| Ski touring | 35 (145) | 89 (129) | 11 (16) | |
| Off-piste snowboarding | 14 (56) | 88 (49) | 13 (7) | |
| Off-piste skiing | 9 (38) | 82 (31) | 18 (7) | |
| Snowshoe touring | 1 (3) | 33 (1) | 67 (2) | |
| Depth of fall (%) (n) | 100 (75) | 85 (64) | 15 (11) | 0.02 |
| Metres of fall (SD) [range] | 17 (9) [1–35] | 16 (9) [1–30] | 22 (8) [12–35] | |

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