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Brief Reports

Avalanche Accidents Causing Fatalities: Are They Any Different in the Summer?

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Abstract

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Aims: This retrospective study investigated the epidemiology of summer avalanche accidents that occurred in Switzerland and caused at least one fatality between 1984 and 2014. Summer avalanche accidents were defined as those that occurred between June 1st and October 31st.

Results: Summer avalanches caused 21 (4%) of the 482 avalanches with at least one fatality occurring during the study period, and 40 (6%) of the 655 fatalities. The number of completely buried victims per avalanche and the proportion of complete burials among trapped people were lower in summer than in winter. Nevertheless, the mean number of fatalities per avalanche was higher in summer than in winter: 1.9 ± 1.2 (standard deviation; range 1–6) versus 1.3 ± 0.9 (range 1–7; $p < 0.001$). Trauma was the presumed cause of death in 94% (33 of 35) in summer avalanche accidents. Sixty-five percent of fully buried were found due to visual clues at the snow surface.

Conclusions: Fatal summer avalanche accidents caused a higher mean number of fatalities per avalanche than winter avalanches, and those deaths resulted mostly from trauma. Rescue teams should anticipate managing polytrauma for victims in summer avalanche accidents rather than hypothermia or asphyxia; they should be trained in prehospital trauma life support and equipped accordingly to ensure efficient patient care.

Keywords: avalanche; cardiac arrest; hypothermia; season; snow burial; trauma

Introduction

Most avalanche accidents occur during leisure activities in winter (Techel and Zweifel, 2013). Asphyxia from snow burial is the most common cause of death, and the prognosis for avalanche victims with unwitnessed asystolic cardiac arrest is poor (Brugger et al., 2013; Boué et al., 2014; Mair et al., 2014; Truhlar et al., 2015). Companion rescue is of utmost importance, and prehospital organized rescue teams must intervene promptly, have specific training for avalanche rescue, and carry appropriate safety and medical equipment (Brugger et al., 2013; Mair et al., 2013). Although rare, some of the most lethal recreational avalanche accidents in the European Alps occurred in summer (Jarry, 2012; Harvey et al., 2013). Most research and prevention efforts have focused primarily on winter avalanche. This study aimed to address this knowledge gap by focusing on the epidemiology of summer avalanche accidents.

Patients and Methods

We investigated avalanche accidents that occurred in Switzerland in unsecured terrain, which caused at least one fatality, from 1984 to 2014. We retrieved data from the registry of the WSL Institute for Snow and Avalanche Research SLF Davos (hereafter SLF), which prospectively collects information about all avalanche accidents in Switzerland. Accidents resulting in fatalities are systematically reported to SLF by rescue organizations and police, and the registry also includes accidents when the victim dies at a later stage in the hospital. For the vast majority of cases, the SLF is granted access to the police reports. In this study, summer was defined as the period between June 1st and October 31st. During these months, the leisure activity of accident parties is mainly dedicated to hiking and alpine climbing, whereas the winter period is mostly dedicated to backcountry touring and off-piste riding. Thus, we use a definition of summer based on

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the main alpine recreational activities rather than the calendar months usually considered as summer months.

The following data were collected in the registry: date of the avalanche; activity engaged when the avalanche occurred; the elevation and slope of the avalanche start zone; the slope (except for strictly east- and west-facing slopes) was categorized as north- or south-facing slopes; the avalanche path parameters, including the change in elevation between start and end zones, the distance covered, the avalanche type (slab or loose), and snow wetness (dry or wet) (EAWS, 2016). The terrain features in the avalanche path were considered as unfavorable when it consisted of single trees or forest, rock gullies or rock cliffs, single large rocks, or glacier seracs. Complete burial was defined as burial of both the head and chest (Brugger et al., 2013). The depth, duration of the burial, and the means of discovery were also collected. The presumed cause of death was recorded for most summer avalanche accidents. Trauma was assumed to be the cause of death when the victim had patent airways (not fully buried). In addition, two of the authors (M.P. and A.K.) reviewed accident descriptions for completely buried individuals and independently judged the cause of death (asphyxia, trauma, or undetermined). In cases of disagreement, the cause of death was considered ''undetermined.'' Data of the medical chart were available for some patients through an ethics committee-approved registry that included victims between 2013 and 2014.

Statistical analyses

Categorical data are expressed as counts and percentages. Continuous variables are expressed as mean and standard deviation or as median and interquartile range. Comparisons between summer and winter avalanche features were performed using the Wilcoxon rank-sum test for continuous variables, the Chi-square test for categorical variables (Boslaugh and Watters, 2008), and the two-sample test for equality of proportions with continuity correction (R Core Team, 2016). Two-sided *p* values <0.05 defined statistical significance.

Results

Summer avalanches accounted for 21 (4%) of 482 avalanches with at least one fatality occurring during the study period, and 40 (6%) of 655 fatalities attributed to avalanches. The main activity of 38 people who died was alpine climbing (95%) (38 of 40) in summer.

Summer avalanches more frequently occurred in southern-aspect start zones and at higher elevations than similar avalanches occurring in the winter (Table 1). The elevation drop and the proportion of unfavorable terrain conditions in the avalanche path were almost twice as high in summer than in winter. Avalanches were predominantly dry snow slab avalanches in winter and wet snow avalanches in summer.

The mean number of fatalities per avalanche accident involving at least one fatality was higher in summer than in winter (Table 2). The burial type was available in most cases, but the depth and duration of the burial and the means of discovery were only partially available. Ninety-one percent (557 of 614) of fatalities occurred after complete burial in winter, compared with 36% (14 of 39) in summer. In winter, among the completely buried individuals, 40% (274 of 684) were found using signals from an avalanche transceiver; 35% (237 of 684) were located by companions. In summer, all the completely buried individuals who were found were located by organized rescue teams, generally by detecting materials visible on the snow surface (65%, 10 of 16); none were detected with an avalanche transceiver.

Trauma was the cause of death in 94% (33 of 35) of summer avalanche accidents, when cause could be determined. Details of all summer avalanche accidents are pre-

Table 1. Characteristics of Avalanches Involving at Least One Fatality According to the Season (Switzerland, 1984–2014)

No. of avalanche accidents, n *(%)*	*Winter; 461 (96)*	*Summer; 21(4)*	p
Aspect[a], *n* (%)			0.03
North (WNW-ENE)	242 (53)	11 (52)	
South (ESE-WSW)	80 (17)	8 (38)	
West or East	136 (30)	2 (10)	
Slope angle, *n* (%)			0.2
<36°	53 (14)	2 (14)	
36–40°	178 (46)	3 (21)	
>40°	154 (40)	9 (64)	
Avalanche type, *n* (%)			
Slab	441 (98)	14 (70)	<0.001
Loose	7 (2)	6 (30)	
Dry	297 (93)	4 (25)	<0.001
Wet	23 (7)	12 (75)	
Start zone elevation [*m*], mean (SD; range)	2454 (464; 725–3800)	3383 (512; 2160–4000)	<0.001
Elevation difference from start to run-out zone [*m*], median (IQR; range)	190 (103–350; 15–1260)	473 (278–590, 60–1220)	0.002
Path distance (avalanche length) [*m*], median (IQR; range)	372 (222–707; 32–2615)	644 (359–873, 106–1658)	0.07
Unfavorable avalanche path[b], *n* (%)	215 (56)	18 (100)	<0.001

[a]E, East; N, North; S, South; W, West.
[b]The avalanche path was defined as unfavorable when it consisted of single trees or forest, rock gullies or rock cliffs, single large rocks, or glacier seracs.
IQR, interquartile range; SD, standard deviation.

Table 2. Epidemiological Characteristics of Avalanche Accidents Involving at Least One Fatality According to the Season (Switzerland, 1984–2014)

	Winter	*Summer*	p *values*
No. of avalanche accidents, *n* (%)	461 (96)	21 (4)	<0.001
No. of involved persons, *n* (%)	1124 (95)	58 (5)	<0.001
Caught persons per avalanche accident, median (IQR; range)	2 (1–3; 1–23)	2 (2–3; 1–14)	0.16
Multiperson avalanche accidents, *n* (%)	253 (55)	17 (81)	<0.001
Complete burials			
Complete burials among caught individuals, *n* (%)	687 (61)	16 (28)	<0.001
Completely buried victims per avalanche accident, median (mean, IQR; range)	1 (1.5; 1–2; 0–12)	1 (0.8; 0–1; 0–4)	<0.001
Duration of burial (min) for all complete burials, median (IQR)[a]	60 (30–195)[b]	1170 (47–1500)[c]	0.04
Depth (cm) of all complete burials, median (IQR)[d]	100 (50–150)[e]	90 (60–105)[f]	0.79
Mortality among completely buried victims, *n* (%)	558 (81)	14 (88)	0.75
Fatalities			
No. of fatalities, *n* (%)	615 (94)	40 (6)	<0.001
Proportion of fatalities among involved persons, *n* (%)	55	69	0.04
Fatalities per avalanche accident, mean (SD; range)	1.3 (0.9; 1–7)	1.9 (1.2; 1–6)	<0.001

Complete burial was defined as the burial of at least the head and chest (Brugger et al., 2013); multiperson accidents were defined as accidents where more than one person was caught.

[a]The median duration of burial for completely buried victims who survived was of 50 (30–90) in the winter and of 10 and 15 minutes for the two victims who survived complete burial in the summer.

[b]$n = 646$.

[c]$n = 12$.

[d]The median depth of burial for completely buried victims who survived was 15 (8–43) cm in the winter (depth of burial was not available for the two victims who survived complete burial in the summer).

[e]$n = 593$.

[f]$n = 8$.

sented in Table 3. Death was pronounced by the prehospital physician on site for all but one of the fatalities.

Discussion

This study was the first to present summer avalanche accidents as a distinct entity. We showed that, compared with winter, summer avalanche accidents with at least one fatality resulted in a higher mean number of fatalities per avalanche, and the deaths mostly resulted from trauma.

Several factors may have contributed to the high mean number of fatalities per avalanche. The first is the larger mean number of individuals involved per avalanche, although the numbers involved in summer and winter avalanches were not significantly different in our study. A second factor is the burial type, which was shown previously to be the strongest single factor for survival from winter avalanches (Brugger et al., 2001). As a significantly lower proportion of individuals were completely buried per avalanche accident in summer than in winter in our study, burial type, however, could not explain the high summer fatality rate. The third factor is the avalanche terrain. The main summer activity was alpine climbing, which takes place on exposed terrain, enhancing the risk of sustaining a life-threatening trauma (Hohlrieder et al., 2007). This hypothesis is a plausible explanation for our findings and is supported by the significant vertical drops and the unfavorable avalanche paths observed in most, if not all, summer avalanches.

We also found that the cause of death in summer avalanches was almost exclusively attributed to trauma, which was closely linked to summer activities. Although reliable information about the cause of death is not always available for winter avalanches, several studies have shown that avalanche deaths were mostly caused by asphyxia (Hohlrieder et al., 2007; McIntosh et al., 2007; Brugger et al., 2013; Truhlar et al., 2015). Also, two studies showed that trauma accounted for only 5.6% and 16%, respectively, of fatalities from avalanche accidents in a population and setting comparable to ours, in the European Alps (Hohlrieder et al., 2007; Moroder et al., 2015).

Our findings have some potentially important practical implications. Although infrequent, summer avalanches accounted for about 6% of fatalities associated with avalanches. Therefore, as repeatedly emphasized, mountaineers should include avalanche danger in their risk management for summer outings (Harvey et al., 2012; ICAR, 2015). Indeed, a careful evaluation of the avalanche situations in summer is as necessary as in winter because even small avalanches may result in falls, which can cause severe injuries.

In summer avalanche accidents, and particularly in those where people experience falls over a great height and/or unfavorable terrain, rapid response by medical teams is of utmost importance. This is in contrast to winter avalanche accidents, when companion rescue is extremely important (Hohlrieder et al., 2005; Mair et al., 2013). Two reasons may explain these differences: first, in summer, severe traumatic injuries are more frequent than full burial, and hence rapid extraction by companions is often of lesser importance than rapid administering of first aid by response teams. Second, the location of the victim is often only accessible by helicopter, as frequently very steep and exposed terrain (Table 1) make the access to the avalanche run-out zone very time consuming and dangerous.

Some important implications for organized rescue teams also emerged from our findings. First, the high mean elevation of summer avalanche accidents—coupled with the high summer temperatures—will negatively impact helicopter performance. This may become crucial, including if winching procedures are required, which is not uncommon in

Table 3. Detailed Overview of the 21 Fatal Avalanche Accidents that Occurred During the Months of June to October (Switzerland, 1984–2014)

Elevation (m.a.s.l.)	*Slope orientation*[a]	*Slope (°)*	*Elevation difference (m)*	*Avalanche distance (m)*	*Activity*	*No. of fatalities*	*Burial type*	*Burial duration (min)*	*Burial depth (cm)*	*Located by*	*Cause of death*[b]
3300	NNE	na	140	201	climber	2	c, n	840	60	vis	tr, tr
3040	NE	41–45	520	813	climber	1	p	nr	nr	nr	tr
3540	NNW	na	260	325	climber	1	c	55	50	vis	tr
2500	N	na	na	na	climber	1	c	1500	na	vis	tr
3790	S	36–40	540	794	climber	3	p, n, n	nr	nr	nr	tr, tr, tr
3540	E	na	350	532	climber	3	c, c, p	1500, 1500	80, 60	vis, vis	un, tr, tr
3420	N	na	60	108	climber	2	c, p	1500	250	vis	un[c], tr
3600	N	>45	1220	1658	climber	2	c, n	na	na	na	tr, tr
3080	N	>45	780	1022	climber	2	c, c	1740, 1680	100	dog, dog	un, un
3880	S	>45	760	1166	ski	1	n	nr	nr	nr	tr
3800	NE	>45	600	757	climber	2	p, p	nr	nr	nr	tr, tr
3340	SSE	na	120	168	climber	2	c, n	na	100	vis	tr, tr
2900	W	>45	na	na	climber	1	n	nr	nr	nr	tr
2160	SSE	36–40	60	106	hiker/ fisherman	1	nr	nr	nr	nr	drowning
4000	SE	41–45	1150	1568	climber	6	p, p, p, p, p, p	nr	nr	nr	tr, tr, tr, tr, tr, tr
3770	SE	41–45	425	532	climber	3	p, p, p	nr	nr	nr	tr, tr, tr
2520	N	31–35	330	461	climber	1	n	nr	nr	nr	tr
3950	NE	na	na	na	climber	1	c	na	na	na	un[c]
3460	N	>45	560	883	climber	2	c, c	40, 50	na	vis, na	tr[d], tr[d]
3760	S	36–40	530	843	climber	2	c, p	na	na	na	asph[d], tr
3690	S	31–35	390	520	climber	1	n	nr	nr	nr	tr

[a]E, East; N, North; S, South; W, West.
[b]The inter-rater agreement was substantial, with a kappa of 0.72, for the cause of death classifications for the 14 completely buried individuals.
[c]Undetermined after divergent adjudication.
[d]Medical chart available.
asph, asphyxia; cb, complete burial (burial of at least the head and chest); dog, search and rescue dogs; m.a.s.l., meters above sea level; n, not buried; na, not available; nr, not relevant; p, partial burial; tr, trauma; un, undetermined; vis, visible parts.

avalanche rescues (Hohlrieder et al., 2007; Pasquier et al., 2012). Second, in contrast to winter fatalities, we found that trauma was the predominant cause of death; this finding may also have potentially important consequences in medical management. Traumatic cardiac arrest indeed requires specific treatment, which would support early dispatch to the avalanche site of rescue teams trained in advance trauma care in difficult terrain (Mair et al., 2013; Truhlar et al., 2015). Finally, we found that a large proportion of these avalanche accidents involved multiple casualties. Although this scenario is not specific to summer accidents, the rescue operation should be prepared to send extra resources and provide on-site triage (Bogle et al., 2010; Mair et al., 2013; Truhlar et al., 2015).

Our study has some limitations. First, we included only avalanche accidents with at least one fatality that occurred in unsecured terrain. This subset only represented 10%–15% of all reported avalanche accidents in Switzerland (Techel et al., 2015). These strict selection criteria must be considered when comparing our results to results based on all reported avalanche accidents, particularly mortality rates among individuals completely buried. However, as shown by Techel and Zweifel (2013), the reporting rate of avalanche accidents depends on the severity of the accident, and varies over time and region. Therefore, limiting the analysis to the dataset of accidents, which can be considered complete, are generally well investigated, and documented reduced bias in time. We applied the same criteria to summer and winter avalanche accidents; thus, comparisons made between these two groups were valid. Another limitation was the reliability of the cause of death. The database we analyzed cannot be considered a medical registry. However, fatal avalanche accidents are consistently investigated in depth, and they are generally documented by police and rescue services; thus, a detailed description of each avalanche accident was nearly always available (Techel and Zweifel, 2013). This recurrent problem in avalanche research has, however, been addressed as best as possible for the 14 completely buried fatalities. Furthermore, in our pragmatic approach, the cause of death was considered traumatic for the 63% (25 of 40) fatalities that were not or partially buried, which is consistent with other studies (Moroder et al., 2015). Finally, the small number of summer avalanche accidents included in this study may have led to spurious findings; thus, our results must be confirmed in other registries.

Conclusions

Fatal avalanche accidents that occur in summer have specific characteristics. Some of these, notably the higher mean number of fatalities per avalanche and the predominance of trauma as the cause of death, pose specific logistic and operational challenges for the rescuers. The involved rescue teams and rescue systems should be trained, prepared, and equipped adequately for these specific features to ensure safe and efficient patient care.

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Author Disclosure Statement

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