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Clinical paper

Burial duration, depth and air pocket explain avalanche survival patterns in Austria and Switzerland☆

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ABSTRACT

Aim: To calculate the first Austrian avalanche survival curve and update a Swiss survival curve to explore survival patterns in the Alps.
Methods: Avalanche accidents occurring between 2005/06 and 2012/13 in Austria and Switzerland were collected. Completely buried victims (i.e. burial of the head and chest) in open terrain with known outcome (survived or not survived) were included in the analysis. Extrication and survival curves were calculated using the Turnbull algorithm, as in previous studies.
Results: 633 of the 796 completely buried victims were included (Austria $n = 333$, Switzerland $n = 300$). Overall survival was 56% (Austria 59%; Switzerland 52%; $p = 0.065$). Time to extrication was shorter in Austria for victims buried ≤60 min ($p < 0.001$). The survival curves were similar and showed a rapid initial drop in survival probability and a second drop to 25–28% survival probability after burial duration of ca. 35 min, where an inflection point exists and the curve levels off. In a logistic regression analysis, both duration of burial and burial depth had an independent effect on survival. Victims with an air pocket were more likely to survive, especially if buried >15 min.
Conclusion: The survival curves resembled those previously published and support the idea that underlying survival patterns are reproducible. The results are in accordance with current recommendations for management of avalanche victims and serve as a reminder that expedient companion rescue within a few minutes is critical for survival. An air pocket was shown to be a positive prognostic factor for survival.

Introduction

An avalanche survival curve is a graphical representation of the cumulative survival probability during complete avalanche burial as a function of time.[1] The step-wise decrease of survival probability with increasing duration of burial was first recognized in the original curve in 1994 using avalanche data from Switzerland.[1] Four distinct phases could be distinguished in the curve, which reflected patterns of death in victims extricated within that time period: trauma is the major cause of death in the first ("survival") phase, asphyxia in the second ("asphyxia") phase and a combination of severe hypothermia, hypoxia and hypercapnia in the third ("latent") and fourth ("long-term survival") phases. Characterising avalanche survival in this manner had a lasting practical impact on avalanche rescue. For example, these curves offered a way to quantify the importance of rapid extrication by companion rescuers, i.e. a victim must be extricated within ca. 15 min for a survival chance of >90%. Secondly, a threshold was identified at the end of the asphyxia phase (ca. 35 min) after which survival without a patent airway is unlikely. These aspects were later integrated into international guidelines on the management of avalanche victims[2,3] and resuscitation guidelines.[4]

To understand whether these survival patterns pertained to other regions, the first comparative study of survival curves was published in 2011 using data from Switzerland and Canada.[5] For the first time it was shown that these four phases in the survival curve seem to be universal, but that their duration and contribution to survival are modified by local factors. In this comparison,

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the incidence of fatal injuries and snow climate were decisive for survival in the early phase of burial, whereas response time of rescue services and transport time seem to influence survival after prolonged burial. However, because this was the only comparative study published to date, it is unclear which local factors affect survival patterns in other regions or how they contribute to understanding survival patterns in similar regions. The aim of this study was to calculate the first avalanche survival curve for Austria and compare it to an updated curve for Switzerland as a step towards exploring survival patterns in the Alps.

Methods

Data were collected from all reported avalanche accidents occurring in open areas between the winter season 2005/06 and 2012/13 from databases in Austria (Austrian Alpine Police) and Switzerland (WSL Institute for Snow and Avalanche Research SLF). Accidents involving completely buried victims (i.e. burial of the head and chest) with known outcome (survived or not survived) were included. *Survival* in these datasets refers to the victim's status either upon extrication from the snow or at hospital admission or discharge. Accidents occurring in buildings or on transport routes were excluded because survival patterns are not comparable to those of victims buried in open terrain. The variables included year, duration of burial, burial depth, presence of an air pocket (i.e. any space no matter how small in front of the mouth and nose with a patent airway) and survival. Accident data are compiled from different sources, including persons who witnessed the accident, rescue organizations and other authorities responsible for reporting accidents in these countries.

The Mann–Whitney *U* test was used to compare burial depth between countries and the Fisher's exact test to compare survival and extrication rates between countries. Extrication curves were compared using the Log-rank and Breslow tests for cases with burial ≤360 min. Survival curves were calculated with the estimation procedure of Turnbull[6] for doubly-censored data and compared using the procedure of Dümbgen et al.[7] Logistic regression was used to describe the effect of duration of burial, burial depth and winter season on survival for victims buried ≤180 min using a combined dataset from both countries. The analysis was limited to victims extricated within ≤180 min to reduce the influence of exceptionally long burial cases on the regression analysis, which (in contrast to survival analyses) addresses only final outcome. In a subsequent analysis, logistic regression was used to further investigate the association of burial depth on survival; this analysis included cases with at least two victims in the same avalanche but at least one victim buried ≤80 cm and at least one buried >80 cm (i.e. median burial depth as a cut-off). Burial duration and depth were entered into the model as ordinal (not continuous) variables. Tests were two-sided and $p < 0.05$ was considered statistically significant. SPSS (Version 23.0, SPSS Inc., Chicago, IL) was used for the analyses.

Results

There were 406 completely buried avalanche victims between the winter season 2005/06 and 2012/13 in Austria; 73 cases were excluded from further analysis because of missing information on duration of burial or survival. There were 390 completely buried avalanche victims between the winter season 2005/06 and 2012/13 in Switzerland; 90 cases were excluded from further analysis because of missing information on duration of burial or survival. The remaining 633 cases (Austria $n = 333$, Switzerland $n = 300$) were included in the analysis.

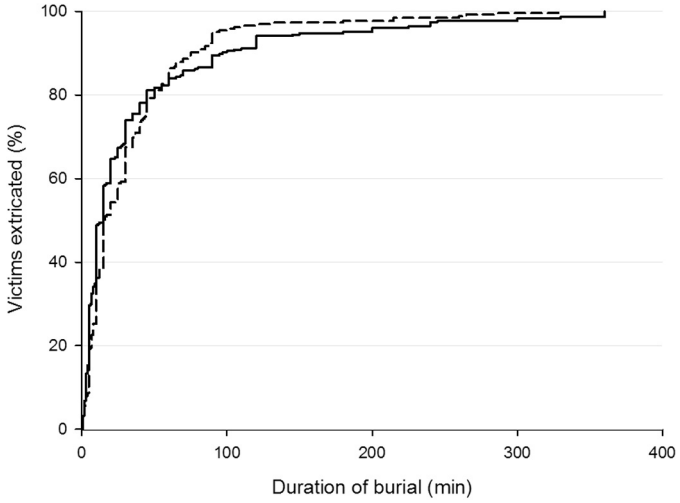

Fig. 1. Extrication curve shown as the proportion of victims extricated as a function of duration of burial in Austria (solid line) and Switzerland (dashed line) for completely buried victims between 2005 and 2013.

Duration of burial

Overall median time between burial and extrication was 15 min (25–75th quartile: 5–50 min) in Austria and 25 min (25–75th quartile: 10–60 min) in Switzerland. The proportion of all victims extricated as a function of duration of burial is shown in Table 1. The extrication curves are not proportional and intersect at ca. 60 min (Fig. 1). In Austria, 54% of victims were extricated within the first 15 min of burial and 78% within 60 min. In Switzerland, 44% of victims were extricated within the first 15 min of burial, significantly less with respect to Austria ($p = 0.021$), and 76% within 60 min, which is comparable to Austria ($p = 0.777$). Median time between burial and extrication for victims extricated within 60 min was 10 min in Austria and 15 min in Switzerland (Log-rank $p < 0.001$, $n = 487$); for victims extricated after 60 min median time between burial and extrication was 225 min in Austria and 330 min in Switzerland (Log-rank $p = 0.079$, $n = 146$). This was not due to differences in burial depth for victims buried ≤60 min ($p = 0.640$) or >60 min ($p = 0.335$).

Survival probability

Overall survival was 56% (Austria 59%; Switzerland 52%; $p = 0.065$). The survival curves, i.e. survival probability as a function of duration of burial, are shown in Fig. 2. In the Austrian curve, the major drop in survival probability occurs (i) within 7 min of burial

Table 1
Number of avalanche victims extricated in Austria and Switzerland.

Duration of burial (min)	Extricated (Austria)			Extricated (Switzerland)			*p*-value (Austria vs. Switzerland)
	n	%	Cumulative %	*n*	%	Cumulative %	Cumulative %
≤15	179	53.8%	53.8%	133	44.3%	44.3%	0.021
16–35	53	15.9%	69.7%	52	17.3%	61.7%	0.036
36–60	26	7.8%	77.5%	44	14.7%	76.3%	0.777
>60	75	22.5%	100.0%	71	23.7%	100.0%	
Total	333	100.0%		300	100.0%		