Avalanche survival chances

SIR — The risk of triggering an avalanche makes ski touring the most dangerous winter sport, claiming about 150 lives annually in the Alps alone[1]. Using data[2] on all avalanche disasters in Switzerland from 1981 to 1991, we have calculated survival probability in relation to the length of time buried under the snow. At 15 min the survival probability (92%) is markedly higher than previously assumed, but the survival function then drops precipitously to only 30% at 35 min, representing deaths through acute asphyxiation. Thereafter, survival is impossible without an air pocket. After 90 min, victims gradually succumb to hypoxia and hypothermia unless the air pocket is open to the outside. This reassessment of survival probability has far-reaching implications for recommended rescue strategies, emphasizing the importance of rapid and efficient help by uninjured companions and explaining the low success rate achieved by organized rescue parties.

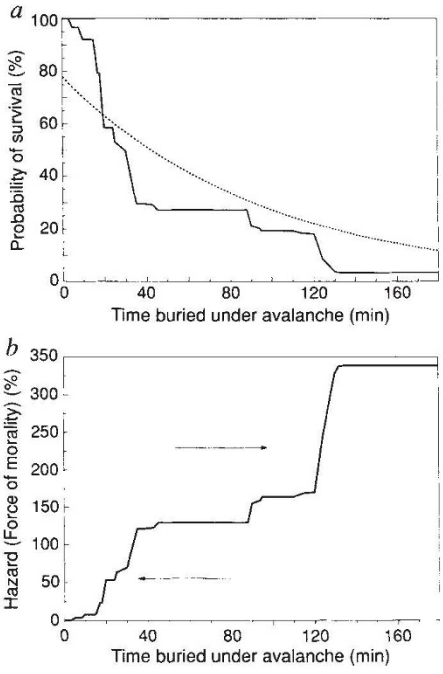
We have analysed precise, minuted rescue data[2]. Of 422 buried skiers, 241 (57%) were dead on extrication. The mean depth of burial under the snow (head) was 105±85 cm (s.d.). An analysis of the relationship between rescue outcome, depth of burial and time of extrication (data not shown) indicates that there is no direct influence of depth of burial on survival, and so the poor results on extrication of deeply-buried skiers merely reflect the generally prolonged rescue time involved.

All rescue directives to date are based on the survival function proposed by Schild[3]. But Brugger and Falk's[4] computer-assisted procedure[5] applied to the avalanche rescue data[2] allows estimation of survival probability with far greater accuracy. The fundamental difference in survival function (*a* in the figure) lies in the steep drop of the present curve at 15 min until 35 min, with a further dip commencing at about 90 min, as compared with the gradual exponential decrease in survival probability assumed by Schild.

The only finding giving grounds for optimism is that the initial survival probability is much higher than previously assumed. Indeed, of the 123 skiers extricated within 15 min, only 8 were dead and, moreover, only 2 had died of asphyxia (extrication times 10 and 15 min), whereas the remaining 6 skiers had all sustained fatal injuries during descent of the avalanche. The survival probability then plummets from 92% at 15 min to only 30% at 35 min, in contrast to the hitherto-accepted gentle decrease from 67 to 55% (ref. 3) over the same period. The corresponding pronounced increase in cumulative hazard function (*b* in the figure) is comparable with the well-known observation of rapid decline in probability of successfully resuscitating acutely asphyxiated patients. This fatal drop in survival function probably results from acute asphyxiation of all victims without an air pocket.

The virtually constant survival (*a* in the figure) and cumulative hazard (*b*) functions between 35 and 90 min indicate that for skiers still alive in a fortuitous or self-created air pocket at the beginning of this phase, the risk of dying is minimal for the next 55 min. It is known that the snow cover prevents rapid hypothermia (maximally 3 °C per hour)[6] and that oxygen consumption decreases significantly with lowering of the body temperature and loss of consciousness[7].

The survival probability then falls from 27% at 90 min to only 3% at 130 min (*a* in the figure), mirrored by the increase in hazard function (*b*). Hence, victims with a 'closed' air pocket eventually succumb between 90 and 130 min after descent of the avalanche. Death is due to a combination of "slow asphyxia" and hypothermia. (The decrease in body core temperature appears to be greatly slowed down if oxygenation is adequate, especially with an 'open' air pocket.) Thus, in the absence of fatal injuries, speed of extrication from the avalanche and existence of an air pocket are the decisive factors determining survival. The fact that there was no decline in the annual mortality rate between 1981 and 1991, despite increasing standards of professional rescue techniques and medical emergency back-up services, is largely explained by the difficulties in mobilizing mountain rescue teams within the brief optimum survival time.



a, Survival function and *b*, cumulative hazard function, of totally buried avalanche victims, 1981–91. The survival function (solid line) is shown in comparison with the hitherto-accepted function proposed in ref. 3 (dashed line). Both show the cumulative probability of survival under the snow in relation to time since burial. Our assessment of the survival function was based on a non-parametric estimation procedure in ref. 5, whereby the extrication times are entered as double-censored data (dead: left censored; alive: right censored). *b*, The cumulative hazard function, −log(survival function), shows the force of mortality in relation to duration of burial. The two phases of increase in cumulative hazard function are indicated by arrows and represent the prognosis for groups without (lower arrow) and with an air pocket (upper arrow).

Reduction of the present high mortality rate depends on increasing the proportion of skiers freed within 15 min, which, realistically, means by uninjured companions. Professional help should be sought immediately after, but not during, this critical phase. We believe that mountaineering organizations should teach skiers mandatory safety precautions, as well as the basic techniques of finding, extracting and resuscitating avalanche victims. At present, many skiers carrying search appliances (transceivers) are insufficiently familiar with their use, with fatal consequences. Another essential step would be to develop self-help techniques to facilitate creation of a life-saving air pocket, which would give the skier a relatively safe haven for about 90 min which is the new time goal set for professional rescue. However, optimal equipment and experience provide no life guarantee, and may induce a false sense of security. Prophylaxis remains the only reliable safeguard for the individual.

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