An AvaLung-associated avalanche survival

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Abstract

Background: In controlled experiments the AvaLung, using air contained within snow, maintains buried persons' oxygenation adequately for 60 minutes or longer. **Objective**: To document an AvaLung-associated survival from a fatal avalanche that fully buried 3 helicopter skiers. **Methods**: Interviews with the company's senior guide, the survivor (a co-author),and a coroner's employee. **Results**: British Columbia,10 Feb 02: a guided group partially skied a leeward treeless bowl. Then Guest B observed a skier-triggered avalanche starting about 100 m above him (hard slab,1.5 m crown face, 90 m width, 450 m run). He inserted his AvaLung mouthpiece before being struck. Tumbling, his hands were forced away from his face, but his teeth tightly held the mouthpiece. After 200 m he stopped in a seated position, immobilized (except one hand), head buried 1.5-2 m. Snow tightly packed his nose and ears, but his oral airway remained clear. He breathed easily through the AvaLung without pressure on his chest. Initially confident, he worried as time passed without rescue. Choosing asphyxial over hypothermic death, he decided to spit out the mouthpiece if he became too cold. Transceiver searchers uncovered him after 20-40 minutes (estimates varied), unconscious but breathing, without the mouthpiece in his mouth. He awoke immediately upon exposure, recovering fully after treatment for mild hypothermia. Guest A (uncovered first) and a guide (uncovered last), buried nearby and at least 1.5 m deep, died of asphyxia. **Discussion Points**: successful mouthpiece deployment and retention; AvaLung breathing maintaining a snow-free oral airway; easy respiratory movements and AvaLung-supported breathing post-immobilization; possible reasons for final unconsciousness.

Keywords: Asphyxia, suffocation, ski, tree wells

1. Introduction

Air comprises about half the volume of even densely-packed avalanche debris. The AvaLung is a device intended to permit backcountry travelers buried in snow to breathe that air until rescue occurs. It consists of a small hollow chamber strapped to the front of the skier's chest and a flexible breathing tube connecting the chamber to a mouthpiece near the skier's face. One surface of the chamber, covered only by porous fabric, allows air but not snow to enter the chamber. With the mouthpiece in the skier's mouth inhalation draws air across the filter from the snow into the chamber, and thence through the tubing to the mouth. One-way check valves shunt exhaled air from the mouthpiece through another tube to the snow behind the skier, separating exhaled from inhaled air.

The AvaLung, first described at ISSW (Crowley 1996; Margid et al 1998), was used in pioneering studies of snow-burial physiology (Scholand et al 2000; Radwin et al 2000). As reported in the Journal of the American Medical Association, AvaLung-wearing volunteers buried in snow maintained excellent blood oxygenation, while showing a gradual increase of blood carbon dioxide concentrations (Grissom et al 2000). In that study burials were terminated (a) for potentially dangerous changes in blood gases, or (b) for subject discomfort, or (c) after 60 minutes; the ten subjects' burial times averaged 58 minutes with, and only 10 minutes without, the AvaLung.

1.1 Predictions of AvaLung function

Falk et al (1994), reporting that only 35 percent of avalanche victims survive 35 minutes' burial, called for "self-help techniques to facilitate

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creation of a life-saving air pocket ". Crowley (1996) suggested that the AvaLung could serve that purpose. While recognizing that the AvaLung could not help the third of avalanche victims who die of trauma, he also suggested that the AvaLung could address three other serious risks to victims (Crowley 1996):

1) Victims tumbling in running avalanches inhale a mixture of air and snow, and that snow often tightly packs the airway, making further breathing very difficult. Breathing through the AvaLung as the slide runs should filter the snow out of the inhaled mixture, preventing airway packing.

2) For buried victims who can move sufficient air volumes, each inhalation draws back into the body the CO_2 -loaded, O_2 -depleted air just exhaled, similar to breathing repeatedly into and out of a plastic bag. However, the AvaLung separates inhaled from exhaled air by drawing inhaled air from snow in front of the victim, while depositing exhaled air into snow behind the victim.

3) At the skin of the buried face condensed water vapor from exhaled air, together with melted and refrozen snow, often eventually forms an "ice mask " that may block further inhalation. However, the AvaLung extracts air from snow at the chamber on the anterior chest, distant from both facial skin and the rearward point where exhaled air enters the snow, so no ice mask should block inhalation.

Despite these theoretical advantages, and scientific reports of numerous test burials, some commentators (e.g., Fink 2000; Willi 2000; Zafren 2000) expressed concerns. Those included the following:

1) The AvaLung might provide a false sense of security to backcountry travelers, encouraging them to take greater risks in avalanche-prone terrain.

2) When sliding movements stop, avalanches immobilize buried victims. Thus, the victim must place the mouthpiece in the mouth before being hit by, or while tumbling in, the moving slide. Either panic or the mechanical force of the slide might make that impossible.

3) During tumbling, the snow might tear the AvaLung from the victim 's body.

4) After immobilization, respiratory movement of the chest might be very difficult due to pressure from surrounding snow.

5) Snow pressures might also collapse the AvaLung 's breathing tubes or air-exchange chamber.

6) The AvaLung does not aim to prevent burial, while an inflatable airbag in a backpack does, so the risk of trauma may be reduced by the airbag, but not by the AvaLung.

1.2 Purpose of this report

Reports of accidental burials could clarify these issues. The AvaLung's manufacturer did hear of two accidental burials in which ski guides wearing AvaLungs reportedly survived, but coherent reports of those incidents remain unavailable. However, we recently obtained detailed information on a third incident. We examine the above predictions in light of that incident.

2. Methods

Two authors (TJC, DA) extensively interviewed a survivor of the avalanche accident, starting 18 days after the accident; the survivor is a co-author of the report. In addition 10 days after the accident TJC interviewed a Senior Guide from the involved helicopter ski company by telephone. That guide was not present at the rescue, but debriefed the survivor later in the day. The Kamloops, B.C., Regional Coroner's Office provided preliminary cause-of-death information on the accident's two fatalities.

3. Results

In 2001 a very fit and experienced 44 year-old recreational backcountry telemark skier (Guest B) requested and received an AvaLung II as a Christmas present from his girlfriend. He skied with it in the Colorado backcountry about 5 times in early 2002, where he repeatedly practiced inserting the mouthpiece. Then, in February 2002 he and friends traveled to British Columbia to ski with a helicopter company with which he had frequently skied in the past.

After lunch on their first day, February 10, they were part of a well-organized group with lead and tail guides. Only Guest B wore an AvaLung. At the top of a large, leeward-facing, mostly-treeless, funnel-shaped bowl the guides dug a hasty pit. Guest B recalls discussion of a layer of buried surface hoar at about 1.8 m depth that had not produced avalanche releases during the season. The group then descended the bowl. After the group collected again at the "mouth " of the funnel, the lead guide and some others began descending the next pitch.

Before he could join them Guest B thought he saw "a cloud" about 100 m above him on the bowl. Then he realized that it was an avalanche, later described as "skier-triggered, hard slab, 1.5 m crown, 90 m width, 450 m run ". He called out a warning.

Unlike his practice sessions in Colorado, Guest B now was wearing a shell parka with a high collar that partially blocked his mouth, so it took

several tries to place the AvaLung mouthpiece into his mouth. Then the slide hit hard. He was immediately submerged and could not reach the surface. Guest B did not know that his friend, Guest A, enjoying his first day of helicopter skiing, and the tail guide also were swept down. Guest B, tumbling repeatedly, lost his poles, but his telemark skis remained attached. His hands were forced away from his face, but he held the mouthpiece firmly with his teeth.

After being swept about 200 m Guest B and the others passed over a small rock band and were deposited near its base. The slide continued flowing another 100 -150 m, entering a small forest. Guest B was buried in an upright sitting position, his head 1 – 1.5 m deep. His left hand, while over his head, was well below the surface. Guest A was horizontal and face down about 30 m away. The guide was horizontal and on his side about 10 m from B, and about 4 m deep.

Except for some movement in his left hand, Guest B was completely immobilized. There was no air space in front of his face. Cold snow tightly and uncomfortably packed his ears and nose, which he could not clear by blowing. However, his mouth and throat were free of snow, and he found that he could easily breathe through the AvaLung mouthpiece. He felt no constricting pressure on his chest. He said, "I could breathe; there was no snow in my mouth … The fact that I could sit and breathe comfortably, and knowing that I could breathe, helped me remain calm". He added that "I could calmly wait and that gave me a positive attitude".

Immobilized, Guest B of course could not measure the passage of time. Despite his initially positive attitude, he gradually became concerned that his whole party had been buried, and that no one was searching for him. He had lost his hat in the slide and was lightly dressed in polypropylene undergarments and a shell parka. Preferring death by asphyxiation to death by hypothermia, he resolved to spit out the mouthpiece if he became too cold, and he even tried that briefly to see if he could. However, he recalls no final rejection of the mouthpiece.

Fortunately, other members of the party were searching with transceivers. However, before the slide the lead guide had descended below the burial site, the tail guide now was buried, and in most helicopter ski groups guests have only limited experience with beacon searches and do not carry shovels or probes.

Guest A was extricated first. His nose and mouth were heavily snowpacked, and resuscitation efforts were unsuccessful. A few minutes later a rescue hole was dug to the head of Guest B. He was said to be unconscious but not blue, taking "baby breaths" with the mouthpiece out of his mouth. He awoke as soon as the rescue hole reached him, and he recalls a friend crying and yelling down the hole to him. A short time later the tail guide was found. Again, resuscitation efforts failed.

The Senior Guide estimated that the burials lasted about 20 minutes. However, Guest B's friends who were at the site told him that he was buried 35 to 40 min. The coroner's preliminary finding for both Guest A and the tail guide was "asphyxial death". Guest B recalls that recovery personnel thought that the tail guide also had leg fractures. The coroner's final report is not available at this writing.

After being dug free Guest B stood up and immediately fell down. He felt very cold for hours after his rescue, but he recalls no shivering during the experience. He felt ready to ski again a couple of days later. After the event he did not experience sleeping problems or mental flashbacks, but he did get very sweaty palms once while watching a video with vivid avalanche images. About two months after the accident he and some friends again made reservations to ski in 2003 with the same company.

4. Discussion

This is the first documented report of an avalanche accident involving an AvaLung-wearing victim. Although not the first to be dug free, he survived. Tragically, two others simultaneously buried nearby without AvaLungs died. The survivor 's story sheds light on eight claims and concerns about the AvaLung's function.

4.1 Issues of function

1) The incident provides no evidence that possessing an AvaLung encouraged riskier skiing in this survivor. Of course, backcountry skiing is always risky; a good way to avoid avalanches is to stay on a ranch in Texas. But after accepting that baseline risk, the survivor was doing what he often had done before owning an Avalung; he was skiing under the guidance of highly trained, well-equipped, certified professionals who were very familiar with local terrain and snow conditions.

2) Despite some fumbling due to a high collar, neither panic nor other problems prevented the victim from properly positioning his AvaLung mouthpiece before the avalanche struck.

3) Although the slide forced the victim's hands away from his face, he did hold the mouthpiece in place with his teeth, and the snow did not tear the AvaLung from his torso.

4) After tumbling in the avalanche, deceased Guest A's nose and mouth were said to be tightly packed with snow, and surviving Guest B had snow packed into his nose and ears. However, as predicted,

breathing through the AvaLung's mouthpiece while the avalanche ran delivered snow-free air to Guest B's oral airway, which remained unblocked.

5) The size of the AvaLung's air-intake filter permitted easy extraction of air from the surrounding snow. As in our burial tests, inhaling was not difficult for the victim.

6) In this incident pressure from the surrounding snow neither restricted the victim's respiratory movements nor collapsed the AvaLung's breathing tubes or air-exchange chamber.

7) Zafren (2000) asserted that risk of mechanical trauma is greater with the AvaLung than with a backpack airbag because the latter may prevent complete burial. However, in this incident a buoyant object, not buried below the rock band, would have been carried into an open forest by the continuing slide, risking serious injury. Assertions of which device best prevents trauma are, at this time, completely unsubstantiated.

8) As predicted, for some minutes the victim breathed comfortably, so apparently the AvaLung at least partially separated inhaled from exhaled air. However, none of our test burials produced unconsciousness, and some exceeded 60 minutes, so this survivor's unconsciousness when first reached is puzzling. We consider three possible explanations:

8a) Vasovagal syncope ("fainting") may occur with severe anxiety in
situations where the normal response to an acute emotional stimulus would be vigorous physical activity (Katon et al 1995). Vagal tone increases, the heartbeat slows, blood pools in muscles, cerebral blood flow drops, and unconsciousness ensues.

8b) Rising CO_2 levels in inhaled air reduce the O_2 concentration in that air, producing hypoxia and unconsciousness. CO_2 levels might rise, for example, if forces of the slide had moved clothing so that it channeled some air from the exhalation port to the inhalation port. The observation that the victim awoke immediately upon breathing atmospheric air supports this view. However, arguing against it is that the survivor described no "air hunger", that "I can't get enough air" sensation produced by elevated concentrations of CO_2.

8c) The survivor may have spit out his mouthpiece purposely as he had considered, but later was amnesic about that decision.

Studies of future accidents may clarify the relative roles of Explanations 8a-b-c.

In summary, in this incident the AvaLung generally functioned as intended, although the victim's eventual unconsciousness remains puzzling. Of course in future incidents with other circumstances, such as snow packed with high pressure against the chest, victims may have very different experiences. The AvaLung clearly will not always protect against all of the destructive actions of avalanches.

4.2 A life saved by the AvaLung?

The simultaneous, nearby burial of one skier with, and two without, AvaLungs made this accident a tragic kind of controlled experiment. Several factors suggest that the AvaLung may have saved Guest B's life. First, he survived longer than Guest A, who had no AvaLung but was dug out first. Second, for Guest B the AvaLung maintained a snow-free oral airway during tumbling, allowing easy breathing when the slide stopped. Guest A's airways were snowpacked. Third, Guest B had no air pocket, except for the artificial one of the AvaLung, and an air pocket is thought to be essential for surviving longer snow burials (Falk et al 1994). Without an air pocket few victims survive as long as Guest B did. Fourth, finding that he could breathe easily, Guest B initially could maintain a positive attitude, which may contribute to better outcomes in emergencies.

On the other hand, we recognize that without AvaLungs about one-third of avalanche victims survive a 35 min burial, and those are the statistics of this accident. Moreover, Guest B's seated position may have been more favorable for survival than the prone positions of Guest A and the guide. Clearly, one survival cannot establish the efficacy of a device, although this accident did demonstrate that the AvaLung can function as intended. Of course, as always, transceivers and skilled, well-equipped companions were essential to this survival.

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6. Patent information

The AvaLung is protected by US Patent 5490501, issued February 13, 1996.

7. Conflict of interest statement

Atkins, Grissom, and Radwin have received research support or remuneration, and Crowley receives royalties, from the manufacturer of the AvaLung.