WILDERNESS MEDICAL SOCIETY PRACTICE GUIDELINES

Wilderness Medical Society Practice Guidelines for Prevention and Management of Avalanche and Nonavalanche Snow Burial Accidents

Christopher Van Tilburg, MD; Colin K. Grissom, MD; Ken Zafren, MD; Scott McIntosh, MD, MPH; Martin I. Radwin, MD; Peter Paal, MD; Pascal Haegeli, PhD; William “Will” R. Smith, MD; Albert R. Wheeler, MD; David Weber, FP-C; Bruce Tremper, MS; Hermann Brugger, MD

From the Occupational, Travel, and Emergency Medicine Departments, Providence Hood River Memorial Hospital, Hood River, OR (Dr Van Tilburg); Mountain Rescue Association, San Diego, CA (Drs Van Tilburg, Zafren, Smith, and Wheeler); the Division of Pulmonary and Critical Care Medicine, Intermountain Medical Center and the University of Utah, Salt Lake City, UT (Dr Grissom); Department of Emergency Medicine, Stanford University School of Medicine, Stanford, CA (Dr Zafren); International Commission for Mountain Emergency Medicine (Drs Brugger, Paal, and Zafren); the Division of Emergency Medicine, University of Utah, Salt Lake City, UT (Drs McIntosh and Wheeler); Iasis Healthcare Physician Group of Utah, Salt Lake City, UT (Dr Radwin); Barts Heart Centre, St Bartholomew’s Hospital, Barts Health NHS Trust, Queen Mary University of London, London, United Kingdom (Dr Paal); the Department of Anesthesiology and Critical Care Medicine, University Hospital, Innsbruck, Austria (Dr Paal); the School of Resource and Environmental Management, Simon Fraser University, Burnaby, BC (Dr Haegeli); the Department of Emergency Medicine, St. Johns Medical Center, Jackson, WY (Drs Smith and Wheeler); the Clinical WWAMI Faculty, University of Washington School of Medicine, Seattle, WA (Dr Smith); the Utah Avalanche Center, Salt Lake City, UT (Mr Tremper); Denali National Park & Preserve, Talkeetna, AK (Mr Weber); Intermountain Life Flight, Salt Lake City, UT (Mr Weber); and the EURAC Institute of Mountain Emergency Medicine, Bolzano, Italy (Dr Brugger).

To provide guidance to clinicians and avalanche professionals about best practices, the Wilderness Medical Society convened an expert panel to develop evidence-based guidelines for the prevention, rescue, and medical management of avalanche and nonavalanche snow burial victims. Recommendations are graded on the basis of quality of supporting evidence according to the classification scheme of the American College of Chest Physicians.

Keywords: airbags, air pocket, avalanche, hypothermia, rescue, resuscitation, snow burial, wilderness medicine

Introduction

Snow and ice avalanches are widespread in mountainous regions of the world. Worldwide avalanche-related morbidity and mortality are difficult to estimate due to the lack of reporting systems in many countries. Europe and North America have relatively accurate systems for capturing data on avalanche fatalities. Approximately 150 fatalities occur annually in Europe and North America.1-4 During the 31 winter seasons between 1983 and 2015, Europe and North America recorded 5123 avalanche fatalities,5 about 165 deaths per year; most are from Europe, about 130 per year. In the same period an average of 24 people died in avalanches each winter in the United States and 12 in Canada.5 Avalanche fatalities in mountain regions of other locales—for example, the Andes and the Himalaya—are not systematically recorded. However, the number of fatalities per year may be many times higher than fatalities officially recorded in Europe and North America. Catastrophic avalanches that killed over 10 persons, for example, include the serac fall in Nepal in 2014 and the earthquake in Nepal in 2015. Nonfatal avalanche events are extremely difficult to quantify because many accidents are not reported and organized search and rescue teams are not activated.

Most documented North American and European avalanche fatalities occur in recreational user groups such as snowmobilers, skiers, snowboarders, mountain-eers, and snowshoers. Occupational-related avalanche
fatalities among ski patrollers, mountain rescuers, mount-
tain guides, and transportation workers occur less fre-
quently, although job requirements may place these
personnel at higher and more prolonged risk.1

Avalanche avoidance should be the main method to
mitigate risk of injury and death. If an avalanche incident
occurs, rescue by one’s companions—including appro-
riate resuscitation and advanced life support measures
—are critically important to reduce avalanche morbidity
and mortality.

Methods
The Wilderness Medical Society convened an expert panel
to develop evidence-based recommendations for 3 primary
aspects of avalanche accidents: prevention, rescue, and
resuscitation. Nonavalanche deep snow and tree-well burial
were included as related conditions with pathophysiology
and recommendations similar to avalanche burial.

The PubMed database was searched using keywords
including avalanche, snow burial, snow asphyxiation,
and nonavalanche-related snow immersion death. Sec-
ondary references were also included. The panel mainly
considered peer-reviewed randomized controlled trials,
observational studies, case series, and case reports for
inclusion. Only a limited number of studies of avalanche
accidents have been published in the peer-reviewed
academic literature, so conference proceedings, aval-
anche center data, letters to the editor, review articles,
and books were included for background information.
When no studies existed to provide evidence, the
recommendations of the panel were based on review
articles, textbooks, patient-care experience, and firsthand
knowledge of equipment and techniques.

The panel developed recommendations by consensus.
The panel graded recommendations based on the
strength of the recommendation and the quality of
evidence using the classification scheme of the American
College of Chest Physicians (see online supplementary
Table 1).6 When no evidence existed, the panel made
recommendations based on expert consensus.

Pathophysiology
Avalanche morbidity and mortality largely depend on
duration of burial, patency of the airway, air-pocket
volume, depth of burial, and traumatic injuries. The term
air pocket is defined as a patent airway and any space in
front of mouth and nose.3,4,7–11 The chance of survival
after complete burial (head and chest below the snow)
for an uninjured victim is about 50%.1–4 If only partially
buried (head and chest out of the snow), chance of
survival is nearly 100% if trauma is not a contributing
factor.1,2,12 Asphyxia is the most common cause of death
during avalanche burial. About 75% of avalanche deaths
are due to asphyxia, 25% are due to trauma, and few are
due to hypothermia.9,12–18

ASPHYXIA
Asphyxiation during avalanche burial occurs by 3
primary mechanisms: physical blockage of the upper
airway caused by inhaled snow, ice mask formation, and
oxygen deprivation due to rebreathing expired air. In
addition, the weight and compaction of snow may limit
chest expansion and impair ventilation, especially with
heavy, dense snow, which is more common in a
maritime snow climate and during spring conditions.14

Complete obstruction of the upper airway by snow or
debris results in hypoxia in <10 minutes and acute
asphyxiation during the first 30 to 60 minutes of
avalanche burial. If the airway is patent, ice mask
formation occurs when water vapor in exhaled air
condenses and freezes on the snow in front of the face,
forming an impermeable barrier that prevents airflow.
Because asphyxia is the major cause of death during
avalanche burial, time to extrication is a foremost
determinant of survival. According to Swiss data, com-
pletely buried avalanche victims had >90% chance of
survival if they were extricated within about 15 minutes,
but only a 30% chance of survival if they were extricated
after approximately 30 minutes (Figure 1).3,7,12

Survival of a buried victim after more than 30 minutes
requires a patent airway and the presence of an air
pocket. The larger the volume of the air pocket, the
longer the duration of possible survival after burial.
Inspired air contains 21% oxygen (O2) and less than
0.03% carbon dioxide (CO2). Expired air contains about
16% O2 and 5% CO2. Rebreathing expired air during
avalanche burial results in a progressive decrease in the
fraction of inspired oxygen (FIO2) and a progressive
increase in the fraction of inspired carbon dioxide
(FICO2).8,19,20 Hypoxia and hypercapnia eventually cause
death by asphyxiation unless an adequate air pocket exists
or the victim is extricated before asphyxia can occur. A
larger air pocket volume provides greater surface area for air
flow, allowing expired CO2 to diffuse from the air pocket
into the snowpack and O2 to diffuse from the snowpack into
the air pocket. Snow density and porosity surrounding the
air pocket also is a factor in the diffusion of gases, but their
impact on survival is still not fully understood.19 If the air
pocket is large enough, asphyxiation is delayed and an
avalanche victim may survive for many hours.5,20

TRAUMA
Trauma accounts for less than 25% of avalanche deaths
in North America and Europe in avalanches that are
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