

## ORIGINAL RESEARCH

# Causes of Death Among Avalanche Fatalities in Colorado: A 21-Year Review

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**Introduction**—A better understanding of the nature of morbidity and mortality in avalanche accidents helps direct both rescue efforts as well as preventive strategies to reduce fatalities.

**Methods**—We reviewed all avalanche fatalities from the avalanche years beginning in 1994 to 2015 in the state of Colorado, United States, using the database maintained by the Colorado Avalanche Information Center. For each fatality, we obtained the coroner's official determination of cause of death, and autopsy records if one was performed. We used these records to determine cause of death. Injury severity scores (0–75 scale) were calculated for those victims who underwent autopsy.

**Results**—Mortality information was available for 110 fatalities occurring during the 21-year study period. Of these, 64 underwent autopsy. Asphyxia was the cause of death in 65% of fatalities (72/110). Trauma was the cause of death in 29% of the fatalities (32/110). Of these, the primary cause was multiple system trauma in 38% (12/32), head trauma in 31% (10/32), and spinal injuries in 19% (6/32). Of the victims who died of asphyxia and had autopsy, only 10% (4/42) also had significant trauma, defined as an injury severity score greater than 15. There were 6 fatalities from other causes, including hypothermia, drowning, and primary cardiac arrest. There was no correlation between trauma and mode of travel, avalanche type, or starting zone elevation.

**Conclusions**—Asphyxia was the primary cause of death in avalanche fatalities in Colorado during our study period. The incidence of fatal trauma was 29% and did not correlate with user group demographics or avalanche characteristics.

*Keywords:* trauma, asphyxia, accidents, snow, wilderness

## Introduction

Snow avalanches and the fatalities they cause have plagued mountain communities the world over. In the United States, the state of Colorado has historically led the country in human deaths from avalanches (Figure 1). Although mining contributed to the majority of fatalities before World War II, recreationalists have been the victims in the majority of cases since 1950.<sup>1</sup> Over the past 21 years, from 1994 to 2015, avalanches have been the cause of 124 deaths in the state of Colorado, with nearly all of them (117/124) associated in some way with recreational activities. Of the 7 nonrecreational deaths, 4 were residents and 3 were working ski patrollers. Current

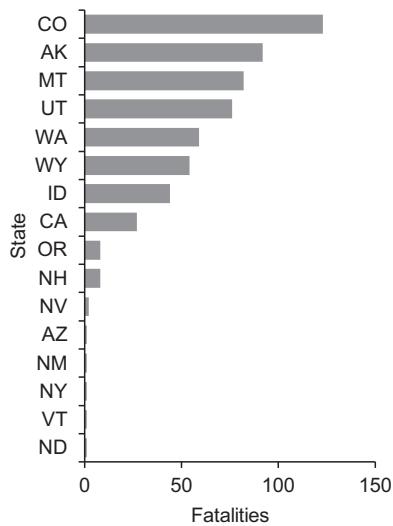
avalanche safety education and prevention strategies emphasize avoidance; nonetheless, avalanche accidents continue to occur. As asphyxia has been identified as the leading cause of death if caught in an avalanche,<sup>2</sup> techniques and equipment to improve survival focus on reducing time under the snow. These include using safety devices such as airbags designed to reduce complete burial, transceivers to locate a buried subject quickly, and shoveling techniques to dig them out rapidly. Other causes of fatalities in avalanche accidents have not been as well addressed, with many cases unrelated to asphyxia. Previous studies have found rates of fatal traumatic injury as high as 24% in Canada<sup>3</sup> and as low as 5.6% in Europe.<sup>4</sup> A better understanding of the nature of morbidity and mortality in avalanche accidents will enhance prevention, as well as response when accidents occur.

Our primary goal was to determine the cause of death in avalanche fatalities in Colorado during the study period and to examine the frequency and severity of

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**Figure 1.** Avalanche fatalities by state, 1994 to 2015.

traumatic injuries. A secondary goal was to investigate whether the incidence of fatal trauma in avalanches correlated with avalanche characteristics or user groups.

## Methods

### POPULATION

We reviewed all snow avalanche deaths in the Colorado Avalanche Information Center database for the avalanche years 1994 to 2015.<sup>5</sup> We excluded incidents in which avalanche was not a primary contributor to the fatality. We also excluded the 3 avalanche fatalities that resulted from slides off a roof or building, as they did not occur in a wilderness or mountain environment.

### DATA COLLECTION AND ABSTRACTION

Avalanche data was abstracted from Colorado Avalanche Information Center records by a single investigator (SL) who was blinded to the cause of death. Fields included elevation, date, group size, demographic information about victims, mode of travel, and avalanche characteristics.

We contacted individual county coroners to obtain records including the official cause of death and, if performed, the autopsy report. In total, we requested records for 124 fatalities from 26 separate county coroners in the state of Colorado.

A single investigator (AS) abstracted mortality data. For all cases, the investigator assigned cause of death based on the coroner's official determination of the principal cause of death. Other data abstracted included organ systems involved and type of injury sustained,

if any. If an autopsy was performed, the investigator calculated an injury severity score (ISS).

The ISS<sup>6</sup> is an anatomical scoring system for injured patients based on the abbreviated injury scale. An abbreviated injury scale is assigned to each of 6 body regions, and the 3 highest scoring regions are individually squared and then added together to produce the ISS score. The values range from 0 to 75, with severe trauma being defined as a score greater than 15.

## STATISTICAL ANALYSIS

We examined the incidence of traumatic fatalities for correlation with avalanche characteristics and some demographic data of the victims. We used  $\chi^2$  tests to assess possible correlation of trauma with avalanche type or with victim's primary travel mode. We used Mann-Whitney U tests to assess possible correlation of trauma with avalanche starting zone elevation or with victim age.<sup>7</sup>

## Results

We identified 121 eligible avalanche fatalities during the specified 21-year study period. Through the study period, the number of avalanche fatalities by calendar year ranged from 3 to 11, with a mean of 6.1 and standard deviation of 2.1. All fatalities occurred in the months of October through May. Mortality data was available for 110 of these; 64 had complete forensic autopsies performed.

The primary cause of death was determined to be asphyxia in 65% (72/110) of cases. Trauma was determined to have been the cause of death in 29% (32/110) of the fatalities. Of these traumatic fatalities, the primary cause was multiple system trauma in 38% (12/32), head trauma in 31% (10/32), and spinal injuries in 19% (6/32) of victims. There were 6 fatalities from other causes, including hypothermia, drowning, and primary cardiac arrest (Table 1).

We calculated ISS scores for all 64 victims who had forensic autopsies performed. Injury types for scores

**Table 1.** Primary cause of avalanche fatalities

Cause of death	n (Total = 110)	Percent (%)
Asphyxia	72	65
Trauma	32	29
Hypothermia	4	4
Drowning	1	1
Primary cardiac	1	1

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