bones. Normally the bone-soft-tissue interface is seen as a continuous, reflective, hyperechoic line. Acoustic shadowing is seen deep to the interface as a result of the high acoustic impedance of the bony cortex.[5] Sonographic evidence of a fracture includes disruption of this hyperechoic line and may be associated with an anechoic or hypoechoic collection near the cortical break, suggestive of a hematoma.[6] The diagnostic accuracy of ultrasound for fracture detection differs based on the location and severity of fracture. However, there is some evidence that ultrasound performs with similar sensitivity and specificity compared with plain radiography when used by experienced operators.[7] Of note, while our patient suffered a substantial patellar fracture, the sonographic diagnosis of subtle patellar sleeve fractures has also been described by Ditchfield et al,[8] Klerx-Melis and Watt,[9] and Grobbelaar and Bouffard.[10]

In addition to fracture detection, additional knee pathology may be diagnosed using ultrasound. Specifically, ultrasound can be used to identify the quadriceps tendon (by sliding the probe cephalad from the superior pole of the patella) and the patellar tendon (by sliding the probe caudad from the inferior pole of the patella) and to assess for tendon disruption. In addition, knee effusions[11] and meniscal[12] injuries may be accurately detected using ultrasound.

To our knowledge, this is the first description of the use of bedside ultrasound by emergency physicians to diagnose a patellar fracture. The identification of bony injury using portable ultrasound units may be useful in circumstances in which radiographs are not possible or when the provider wishes to avoid the use of ionizing radiation. In fact, portable ultrasound units have already been used in mass casualty situations for identification and triage of trauma victims.[13] The use of portable ultrasound for the detection of fractures could specifically affect the practice of wilderness medicine by determining whether splinting and/or medical evacuation are necessary following acute musculoskeletal trauma.

R. Gentry Wilkerson MD
Brooklyn, NY, USA

Michael B. Stone, MD, RDMS
Brooklyn, NY, USA

1. Christian SR, Anderson MB, Workman R, et al. Imaging of anterior knee pain. *Clin Sports Med.* 2006;25:681–702.
2. Weaver JK. Bipartite patellae as a cause of disability in the athlete. *Am J Sports Med* 1977;5(4):137–143.
3. Chen L, Kim Y, Moore CL. Diagnosis and guided reduction of forearm fractures in children using bedside ultrasound. *Pediatr Emerg Care.* 2007;23:528–531.
4. Tayal VS, Antoniazzi J, Pariyadath M, Norton HJ. Prospective use of ultrasound imaging to detect bony hand injuries in adults. *J Ultrasound Med.* 2007;26:1143–1148.
5. van Holsbeeck M, Introcaso J. *Musculoskeletal Ultrasound: Sonography of the Dermis, Hypodermis, Periosteum and Bone.* St. Louis, MO: Mosby; 2001.
6. O'Malley P, Tayal VS. Use of emergency musculoskeletal sonography in diagnosis of an open fracture of the hand. *J Ultrasound Med.* 2007;26:679–682.
7. Moritz JD, Berthold LD, Soenksen SF, et al. Ultrasound in diagnosis of fractures in children: unnecessary harassment or useful addition to X-ray? *Ultraschall Med.* 2008; 29:267–274.
8. Ditchfield A, Sampson MA, Taylor GR. Ultrasound diagnosis of sleeve fracture of the patella. *Clin Rad* 2000; 55:721–722.
9. Klerx-Melis F, Watt I. The mechanism and diagnosis of a sleeve fracture of the upper pole of the patella in children. *Eur J Rad Extra.* 2006;59:6–70.
10. Grobbelaar N, Bouffard JA. Sonography of the knee, a pictorial review. *Sem Ultrasound CT MRI.* 2000;21:231–274.
11. Hauzeur JP, Mathy L, De Maertelaer V. Comparison between clinical evaluation and ultrasonography in detecting hydrarthrosis of the knee. *J Rheumatol.* 1999;26:2681–2683.
12. Najafi J, Bagheri S, Lahiji FA. The value of sonography with micro convex probes in diagnosing meniscal tears compared with arthroscopy. *J Ultrasound Med.* 2006;25: 593–597.
13. Sarkisian AE, Khondkarian RA, Amirbekian NM, et al. Sonographic screening of mass casualties for abdominal and renal injuries following the 1988 Armenian earthquake. *J Trauma.* 1991;31:247–250.

Causes of Death From Avalanche

To the Editor:

In 2 recent studies McIntosh et al[1] and Hohlrieder et al[2] have focused on the causes of death from snow avalanches, putting the pathophysiology of avalanche burial in a new light. This has been acknowledged by Martin Radwin in the Editorial for a recent issue of *Wilderness and Environmental Medicine.*[3] We would like to add a comment related to the techniques of postmortem examination of avalanche victims and the study methodologies used in the cited publications.

We endorse the opinion that autopsy, strictly defined as a full postmortem examination of both external and internal organs, is the gold standard in establishing the cause of death. If autopsy is not conducted, then a documented full external examination and the review of any premortem clinical records, including radiology and computer imaging technologies, should be the required minimum for a reliable postmortem diagnosis. Otherwise, unreliable diagnoses are to be expected. Furthermore, the study sample should be representative and should minimize selection bias.

In this regard some of the often-cited studies should be critically reviewed, focusing particular attention on 1) the method of postmortem examination and 2) the reliability of the study sample. We have reviewed all studies dealing with the causes of avalanche deaths from 1970 to date.

The dissertation of Markwalder[4] in 1970 comprised a review of 66 Swiss avalanche accidents occurring from 1961 to 1967. Two of the 43 fatalities described underwent full autopsy, while the method of postmortem examination remained unclear in the remaining 41 cases. All 7 traumatic deaths occurred in buildings or vehicles, in contrast to the results of other studies involving investigations of victims hit in open areas. The author did not exclude a selection bias, as the sample was only a small fraction of the 171 avalanche fatalities documented in Switzerland in this time period.[5]

In 1972 Lugger and Unterdorfer[6] published a selection of 20 autopsies of avalanche victims in Tyrol, Western Austria; deaths occurred between 1964 and 1970. However, similarly, the authors did not indicate whether their sample represented the total number of fatalities in that area in that time period.

The authors of 2 French studies, Eliakis[7] in 1974 and Lapras[8] in 1980, did not specify how the cause of death had been determined. Eliakis reported 24 avalanche fatalities, quoting a Swiss investigator without description of the circumstances or the time period, and, therefore, additionally, this sample may not be representative.

In 1989, Stalsberg et al[9] reported 2 major snow avalanches with 18 fatalities in Norway in 1986 and 1987. Six victims underwent full external examination; 12 underwent full autopsy. Though all fatalities from these 2 investigated accidents were included, there was no reference to the total number of avalanche fatalities in this area, and since the sample only included 2 successive winters, the findings may not be representative.

In 1989 Grossman et al[10] reviewed all avalanche fatalities in Northern Utah from 1982 to 1987. Four out of 12 fatalities were apparently not subject to external examination, while 7 were subject to clinical examination during resuscitation, and only 1 victim was subject to autopsy. The official causes of death differed from the clinical records. The latter incorporated combinations of asphyxia, multiple trauma, and hypothermia.

Tschirky et al[11] did not present original data in their article about avalanche rescue devices in 2001, but they quoted a dissertation of Weymann,[12] published in 1999. This prospective study included all persons caught by avalanches in Switzerland from 1991 to 1996. In 91 of 99 fatalities the cause of death was determined using a standardized questionnaire. However, the author described only 4 autopsies and did not indicate how the remaining 87 causes of death were established.

In 1996, Locher and Walpoth[13] retrospectively analyzed the causes of cardiac arrest in 19 of 32 hospitalized avalanche victims in Switzerland from 1980 to 1987. During this time period, however, a total of 245 avalanche fatalities were documented in Switzerland,[14] and a selection bias therefore cannot be excluded.

In our opinion the above-mentioned studies[4,6–13] might not meet the requirements for a valid determination of cause of death because either samples were not representative or the method of postmortem examination was not adequate or clearly documented. Therefore, caution should be taken in including these investigations when analyzing causes of death in avalanche victims.

Only 3 studies (the Table) complied with the requirement that 1) the research was based on a representative sample and 2) either full external examination or full autopsy was performed to determine the cause of death.[1,2,15]

In 1993, Tough and Butt[15] presented all fatal accidents associated with backcountry skiing in Alberta, Canada, from 1980 to 1991, including 15 avalanche deaths. External examination was performed in 11 and autopsy in 4 cases.

The study of McIntosh et al[1] (2007) included all avalanche fatalities in Utah from 1989 to 2006. Of the 56 fatalities, 28 were subject to full autopsy, while 28 were subject to external examination alone.

Concurrently, Hohlrieder et al[2] analyzed all avalanche accidents in Tyrol, Western Austria, between 1996 and 2005; their data included 36 fatalities. In 30 cases autopsy was performed, while in the remaining 6 cases cause of death was determined by extensive clinical investigation.

In these studies we found no significant difference in the proportions of causes of death determined by external examination compared to autopsy ($P = .622$; χ^2 test) and between the countries in which the studies were conducted (ie, Tyrol, Austria; Alberta, Canada; and Utah, USA) ($P = .730$; χ^2 test). It should be emphasized, however, that as a result of the limited number of available studies with an overall rather-small study population, results might not be generally valid.

The resulting percentages of lethal trauma (5.6% in total, with 95% CI [2.3%, 12.3%]; 4.4% CI [1%, 16%] with external examination and 6.5% CI [2%, 16.5%] with autopsy) are also consistent with the survival function calculated by Falk and Brugger[16] and Brugger et al.[17] The initial course of the survival curve showed a 91% survival probability within 18 minutes after burial

Table. Causes of deaths from avalanche in relation to method of postmortem examination

	*External examination (%)**				*Autopsy (%)†*				*Both methods (%)*			
	Trauma‡	*Asphyxia§*	*HT*	*Subtotal*	*Trauma‡*	*Asphyxia§*	*HT*	*Subtotal*	*Trauma‡*	*Asphyxia§*	*HT*	*Total*
Tough and Butt, 1993[15]	1 (9.1)	10 (90.9)	0 (0)	11 (100) (73.3)	0 (0)	4 (100)	0 (0)	4 (100) (26.7)	1 (6.7)	14 (93.3)	0 (0)	15 (100) (100)
McIntosh et al, 2007[1]	1 (3.6)	27 (96.4)	0 (0)	28 (100) (50)	2 (7.1)	26 (92.9)	0 (0)	28 (100) (50)	3 (5.4)	53 (94.6)	0 (0)	56 (100) (100)
Hohlrieder et al, 2007[2]	0 (0)	6 (100)	0 (0)	6 (100) (16.7)	2 (6.7)	27 (90)	1 (3.3)	30 (100) (83.3)	2 (5.5)	33 (91.7)	1 (2.8)	36 (100) (100)
Total	2 (4.4)	43 (95.6)	0 (0)	45 (100) (42.1)	4 (6.5)	57 (91.9)	1 (1.6)	62 (100) (57.9)	6 (5.6)	100 (93.5)	1 (0.9)	107 (100) (100)

*Full external examination with or without review of in-hospital medical records.
†Full examination of external and internal organs.
‡Trauma as sole cause of death.
§Including cases presenting traumatic injuries not considered the primary cause of death. HT indicates hypothermia.

that would indicate a rate of trauma deaths immediately after burial of about 9% with CI (7.1%, 11.6%).

Traumatic injury leading to death within a few minutes needs substantial body impact during the passage of the avalanche. It is unlikely that snow masses alone could be strong enough to inflict lethal trauma to a human body. From the survival analyses,[16,17] such lethal trauma from the snow alone is not supported. External factors (eg, impacts with rocks or trees during the avalanche or impacts with man-made structures when hit in vehicles or buildings) are the logical causes of trauma. We would like to point out, however, that a theoretical incidence of traumatic deaths of 9% within the first 18 minutes does not preclude an overall higher rate of trauma. Victims suffering potentially lethal trauma may die first from asphyxia if their breathing is impaired.

Though we found no variation between the countries represented in these 3 studies, we agree with Radwin that trauma mortality may differ in relation to the local geography, not just between countries, but even within a mountain chain.

In our review, hypothermia (0.9% of cases, 0% with external examination and 1.6% with autopsy; the Table) appears to play a negligible role as the sole cause of death from avalanche. It has been assumed, however, that avalanche-related hypothermia emerges from prolonged snow burial in the presence of an air pocket and free airways and is associated with hypoxia and hypercapnia, the so-called triple H syndrome.[18] It is questionable whether this combination of slow asphyxia and hypothermia is detectable solely by external examination or autopsy without clinical data. Additional investigation is needed to clarify the significance of this recently designated pathology as a cause of death, paying attention to body temperature on extrication from the snow masses.

In conclusion, thanks to the studies of Hohlrieder et al and McIntosh et al on the European and American continents, we catch a new glimpse on the pathophysiology of avalanche burial. In these 2 well-performed studies asphyxia was overwhelmingly the most life-threatening factor, and this reflects its dominant role in avalanche burial, whereby hypothermia may act as a co-factor in some cases. Trauma remains an important but unresolved issue requiring further study, as stated by Radwin.

To avoid future misunderstanding, investigators should exercise caution with often-quoted older studies and seek those in which the cause of death is established by full external examination or the gold standard—full autopsy. Moreover, particular attention should be paid to the reliability of the sample by seeking a comprehensive series within a geographic area.

Hermann Brugger, MD
Bruneck, Italy

Hans Jürg Etter
Davos, Switzerland

Jeff Boyd, MD
Banff, Canada

Markus Falk
Bruneck, Italy

References

1. McIntosh SE, Grissom CK, Olivares CR, et al. Cause of death in avalanche fatalities. *Wilderness Environ Med.* 2007;18:293–297.
2. Hohlrieder M, Brugger H, Schubert H, et al. Pattern and severity of injury in avalanche victims. *High Alt Med Biol.* 2007;8:56–61.
3. Radwin MI. Unburying the facts about avalanche victim pathophysiology. *Wilderness Environ Med.* 2008;19:1–3.
4. Markwalder K. Medizinische Aspekte bei Lawinenunfällen, 66 Fälle aus den Schweizer Alpen von 1958 bis 1967. *Inaugural-Dissertation Universität Zürich.* City-Druck AG, Zurich; 1970.
5. Winterberichte. Eidgenössisches Institut für Schnee- und Lawinenforschung. Davos, Switzerland; 1961–1967;25–31.
6. Lugger L, Unterdorfer H. Obduktionsergebnisse bei Lawinenverunfallten. *Ärztliche Praxis.* 1972;24:28–31.
7. Eliakis E. La mort violente par avalanche. Mise au point médico-légale. *Méd. Légale Dommage Corporel.* 1974;7: 83–87.
8. Lapras A. Pathologie des ensevelis. *Nouv Presse Méd.* 1980;9:3124–3130.
9. Stalsberg H, Albretesen C, Gilbert M, et al. Mechanism of death in avalanche victims. *Virchows Arch A Pathol Anat Histopathol.* 1989;414:415–422.
10. Grossman MD, Saffle JR, Thomas F, et al. Avalanche trauma. *J Trauma.* 1989;29:1705–1709.
11. Tschirky F, Brabec B, Kern M. Avalanche rescue devices, state of the development, success and failure. In: *Jahrbuch 2001 der Österreichischen Gesellschaft für Alpin- und Höhenmedizin.* Austrian Society of Mountain and High Altitude Medicine; Innsbruck, Austria 2001:101–125.
12. Weymann A. Lawinenunfälle in den Schweizer Alpen. In: *Inauguraldissertation. Medizinische Fakultät Universität Basel.* Basel, Switzerland; 1999.
13. Locher T, Walpoth BH. Differential diagnosis of circulatory failure in hypothermic avalanche victims: retrospective analysis of 32 avalanche accidents [in German]. *Schweiz Rundsch Med Prax.* 1996;85:1275–1282.
14. Winterberichte. Eidgenössisches Institut für Schnee- und Lawinenforschung. Davos, Switzerland; 1980–1987;45–51.
15. Tough SC, Butt JC. A review of 19 fatal injuries associated with backcountry skiing. *Am J Forensic Pathol.* 1993; 14:17–21.
16. Falk M, Brugger H, Adler-Kastner L. Avalanche survival chances. *Nature.* 1994;368:21.
17. Brugger H, Durrer B, Adler-Kastner L, et al. Field management of avalanche victims. *Resuscitation.* 2001;51:7–15.
18. Brugger H, Sumann G, Meister R, et al. Hypoxia and hypercapnia during respiration into an artificial air pocket in snow: implications for avalanche survival. *Resuscitation.* 2003;58:81–88.

Skiing Injuries in Perspective

To the Editor:

Congratulations to Flores, Haileyesus, and Greenspan with regard to their excellent article on National Estimates of Outdoor Recreational Injuries Treated in Emergency Departments, United States, 2004–2005.[1] The article calls attention to recreational injuries, an important component in the need for injury control. However, when we first looked at their table 6, we thought "Where is skiing?" The omission of skiing in the table might leave the casual reader with the impression that skiing is not an important source of outdoor recreational injuries. The authors apparently excluded skiing injuries, as they were "concentrated in a few hospitals." It is not surprising that there are more skiing injuries in hospitals near ski areas and that the hospitals selected in the Consumer Product Safety Commission's sample do not provide a reasonable estimate of skiing injuries.

A major problem in measuring the importance of recreational injuries is the following: What is to be used as a denominator? The authors have used rates per 100 000 population, which gives an estimate of the societal importance of injuries resulting from each activity. Equally important is measuring the relative danger of persons exposed to the various activities. For skiing, the denominator is particularly difficult. Is it the number of people skiing? The days of skiing? Hours spent skiing? "Double black diamonds" as compared to hours on "bunny slopes"? Although the number of "ski visits" to the northeast areas decreased from 14.7 million in 1986–1987 to 11.8 million in 2006–2007, the number of skiers still exceeds the number of snowboarders.[2]

Although China does not seem a likely place for skiing injuries, the problem of ski injuries in the United States may be a forewarning of greater problems in China. Surprisingly, the number of people in China who skied went from 300 000 in 2000 to 3 million in 2005.[3] China has great opportunities for "extreme skiing,"[4] which is growing in popularity and should be of interest to the readers of *Wilderness and Environmental Medicine.* In conclusion, we call attention to an article on skiing injuries by William Haddon, Jr, "The father of