Review Article

Wilderness medicine

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BACKGROUND: Human activity in wilderness areas has increased globally in recent decades, leading to increased risk of injury and illness. Wilderness medicine has developed in response to both need and interest.

METHODS: The field of wilderness medicine encompasses many areas of interest. Some focus on special circumstances (such as avalanches) while others have a broader scope (such as trauma care). Several core areas of key interest within wilderness medicine are discussed in this study.

RESULTS: Wilderness medicine is characterized by remote and improvised care of patients with routine or exotic illnesses or trauma, limited resources and manpower, and delayed evacuation to definitive care. Wilderness medicine is developing rapidly and draws from the breadth of medical and surgical subspecialties as well as the technical fields of mountaineering, climbing, and diving. Research, epidemiology, and evidence-based guidelines are evolving. A hallmark of this field is injury prevention and risk mitigation. The range of topics encompasses high-altitude cerebral edema, decompression sickness, snake envenomation, lightning injury, extremity trauma, and gastroenteritis. Several professional societies, academic fellowships, and training organizations offer education and resources for laypeople and health care professionals.

CONCLUSIONS: The future of wilderness medicine is unfolding on multiple fronts: education, research, training, technology, communications, and environment. Although wilderness medicine research is technically difficult to perform, it is essential to deepening our understanding of the contribution of specific techniques in achieving improvements in clinical outcomes.

KEY WORDS: Wilderness medicine; High-altitude sickness; Dive medicine; Envenomation; Trauma; Hyperthermia; Hypothermia; Frostbite; Avalanche; Combat injuries; Search and rescue; Travel medicine; Disaster medicine

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INTRODUCTION

Wilderness medicine is a multifaceted field of medical practice with a long history.[1] Its definition must consider concepts of distance and time from typical hospital care, the activity in which an injured or ill person was engaged, the possibility of prolonged environmental exposure, a scarcity of resources, and the risks faced by rescuers and health care providers. A flexible approach to planning, patient assessment, and evacuation is mandatory.[2,3] Howard D. Backer, MD, a past-president of the Wilderness Medical Society, eloquently described wilderness medicine by its remoteness, physiology, need for improvisation, and dependence on clinical examination and judgment.[4] In stark contrast, "street" medicine benefits from an abundance of rescue personnel, technologic capability, and rapid ground and air transportation to facilities that can provide definitive care.

Ongoing basic research and epidemiology continue to define and refine wilderness medicine, reporting morbidity and mortality rates from diverse populations and regions. Data from U.S. National Parks indicate that the most common injuries treated by wilderness medicine specialists are soft-tissue lesions, sprains, strains, and lower-extremity fractures.[5–7]

Early development

In 1983, the Wilderness Medical Society (WMS) was founded by three physicians: Drs. Greer, Auerbach, and Kizer, from northern California. This non-profit organization is based in Salt Lake City, Utah, USA. Its objectives are to advance wilderness medicine health care, education, and research.[8] The society launched the *Journal of Wilderness Medicine* in 1987 as a peer-reviewed and indexed publication. As the journal matured, its name was changed to *Wilderness and Environmental Medicine*. It is published quarterly and contains articles on bench and clinical research as well as editorials. Other journals that address topics in wilderness medicine include *High Altitude Medicine and Biology*; *Military Medicine*; *Journal of Special Operations Medicine*; *Aviation Space and Environmental Medicine*; *Undersea and Hyperbaric Medicine*; *Diving and Hyperbaric Medicine*; *Journal of Applied Physiology*; *Medicine & Science in Sports & Exercise*; and the *Journal of Venom Research*. An additional resource is the quarterly newsletter *Wilderness Medicine Magazine* (www.wildernessmedicinemagazine.com), which started as a pamphlet and has developed into an online, interactive, hyperlinked publication.

Basic care recommendations were first published in *WMS Practice Guidelines for Wilderness Emergency Care*, edited by William Forgey, MD; the fifth edition of this book was published in 2006.[9] These practice guidelines are updated by subject matter experts, ranked by class of evidence, and published individually as the *Wilderness Medical Society Practice Guidelines*. They are indexed and published in the journal *Wilderness and Environmental Medicine*.

Paul Auerbach, MD, edits the primary textbook on the topic, *Wilderness Medicine*.[10] The sixth edition, published in 2012, contains 114 chapters.

Areas of interest

The field of wilderness medicine encompasses many areas of interest. Some focus on special circumstances (such as avalanches) while others have a broader scope (such as trauma care). Several core areas of key interest within wilderness medicine are discussed in this section.

High altitude

High-altitude travel is common and increasing. From ski resorts to mountaineering, the incidence of acute mountain sickness (AMS) is high, estimated to affect 25% of people who ascend to even moderate altitudes.[11] High-altitude pulmonary edema (HAPE) and high-altitude cerebral edema (HACE) are more serious life-threatening conditions and, thankfully, are less common.[12–15] The primary treatment for these conditions involves descent and administration of oxygen. Pharmacologic management usually begins with acetazolamide and glucocorticoid steroids.[16,17]

Dive medicine

Diving for recreation and technical purposes is increasingly popular worldwide. Dive-specific injuries include decompression illness and barotrauma. The incidence of decompression illness appears to be stable across recreational, professional, and scientific venues (0.003%–0.01%). Scientific diving has the lowest rate of injury.[18,19] Decompression illness is triggered by decompression stress and subsequent nitrogen bubble formation, possibly pro-inflammatory microparticle formation.[20] Interestingly, inner-ear decompression illness has been diagnosed more frequently in recent years.[21,22] Treatment includes recompression in a hyperbaric chamber; portable chambers for use in remote areas are being developed.[23] A number of descriptions of in-water recompression have been published.[24–27]

Envenomation

The toxicology and pathology of snake bites, arthropod stings, and marine envenomations vary widely, with significant differences in management based on location. This variation is related to local fauna as well as the availability (or lack) of anti-venoms.[28] Victims' reactions to envenomation are often self-limiting, but systemic reactions leading to coagulopathy or respiratory arrest induced by neurotoxins are certainly possible. Some envenomations, such as from Cubozoa jellyfish, can lead to massive adrenergic surge and cardiovascular collapse.[29–36]

Trauma

Trauma is a common cause of wilderness morbidity. A leading cause of trauma mortality is head injury after a fall from height during hiking, rock climbing, mountain biking, and snow-related activities. Although most traumatic injuries are "minor" and involve the lower extremities, they often end outdoor activities and extended trips. In rare events, trauma involves multiple systems and becomes life-threatening.

This category of wilderness medicine includes injuries sustained in motor vehicle crashes that occur during travel to and within remote areas.[6] Retrospective surveys have shed light on the nature and frequency of traumatic injuries sustained while climbing.[37–46]

Advances in cervical spine management and immobilization, opiate-based pain control, and invasive procedures are being discussed.[47–51] Advanced techniques such as shoulder reduction are being taught to lay providers.[52] Even such specialized injuries as prolonged harness suspension are being considered.[53]

Hyperthermia

Heat exposure and heat stress can cause a spectrum of illness, ranging from benign heat cramps to life-threatening heatstroke.[54] Heatstroke is a severe, sometimes fatal, disease that is defined as elevated core temperature accompanied by neurologic dysfunction. Heatstroke is a complex process that involves cellular dysfunction, cardiac conduction dysfunction, release of pro-inflammatory cytokines, concomitant intravascular depletion, and subsequent circulatory collapse.[55] The degree of dehydration varies. In contrast to classic heatstroke, exertional heatstroke can occur even in moderate temperatures, especially among endurance wilderness athletes.[56]

Removal from the heat stress and rapid whole body cooling are essential to mitigate encephalopathy, coagulopathy, and multi-organ failure.[57–59] The optimal cooling technique is total body immersion in ice or cold water, but this intervention is usually not practical in wilderness settings. Under these circumstances, skin wetting and aggressive fanning can be used in an attempt to lower the patient's temperature. This technique might induce shivering, but there is no evidence suggesting that the concomitant heat production conflicts with the attempt to lower the core temperature.[60,61]

Hypothermia

Accidental hypothermia is a common concern in wilderness medicine both as a primary condition and as a complication of illness or trauma. The mortality rate increases when the core temperature falls below 95 ˚F (35 ˚C) in association with trauma, resulting in acidosis, coagulopathy, and multiple organ dysfunction.[62,63] Hypothermia occurs when cold stress is not matched by heat production. Interestingly, hypothermia can even occur in temperate climates.[64]

Multiple physiologic and behavioral mechanisms work together to maintain euthermia; however, they can fail when certain temperature thresholds are reached. "Paradoxic undressing" is thought to be caused by cutaneous vasodilation and alterations in cognition; "terminal burrowing" might be a primitive reflex.[65–67]

The basics of hypothermia resuscitation include prevention of further heat loss, rewarming, and support of physiologic processes.[68,69] Field research with healthy subjects and invasive monitoring has clarified the physiology of cooling and afterdrop. Improvised and commercial methods for preventing further body heat loss are being developed.[70–75] Arteriovenous anastomoses rewarming with or without negative-pressure devices could offer a technique to rapidly rewarm severely hypothermic patients in the field.[76,77]

Resuscitation protocols for hypothermia and cardiac arrest have long engendered controversy, because of the resources that are required and the dismal recovery statistics. In some cases, prolonged resuscitation will be successful in achieving a positive neurologic outcome. But, in remote settings, the required resources are usually not available.[9,78] Nonetheless, the state of Alaska has had progressive emergency medical services (EMS) protocols in place for a long time to guide the pre-hospital response to victims hypothermia combined with cardiac arrest in remote settings.[79,80]

Frostbite

Frostbite is a complex process in which tissue cooling causes vasoconstriction, ischemia, and intracellular and extracellular ice crystal formation, leading to cell lysis and cell death. Reperfusion-ischemia injury is possible, and repeated thawing and refreezing is particularly damaging. Recent practice guidelines from the Wilderness Medical Society discuss the dichotomy between intentional field rewarming of a frozen body part, with maintenance of thawed tissue, and keeping the tissue frozen when the risk of re-freezing is significant.[81]

Basic field care includes administration of anti-prostaglandins, pain control, and placement of protective dressings in addition to treating concomitant hypothermia and injuries. Debridement of nonhemorrhagic blisters might be beneficial, but evidence is lacking. In medical facilities, advanced care with tissue plasminogen activator or prostaglandins/PG analogues has been documented. In the past, a "wait-and-see" approach was used to determine demarcation of the frozen area; now, tissue viability can be determined rapidly with advanced imaging such as magnetic resonance angiography or bone scintigraphy.[81]

Avalanche

Avalanches most commonly occur in mountainous terrain with 35% slope when a buried layer fails and releases an overlying slab of snow. Victims caught in an avalanche are subjected to tremendous traumatic forces and are at risk of suffocation and, eventually, hypothermia. The severity of avalanche injury is generally based on several factors: depth of burial, length of burial, airway obstruction, and concurrent trauma.[82–84] Avalanche rescue and resuscitation have been advanced by an improved understanding of snow burial physiology, including cooling, afterdrop, and the role of exhaled carbon dioxide.[85,86] Technologic advances designed to mitigate the risk of avalanche-associated injury and death include exhaled air diversion devices, flotation devices, and transceivers.[87] The science of avalanche forecasting has improved; detailed reports are available online.[88] Despite these advances, North American avalanche fatalities continue their upward trend.[89] Morbidity and mortality rates associated with non-avalanche snow burial (tree well and deep snow immersion asphyxia) are also being documented.[90]

Military medicine

Tactical/battlefield medicine has advanced dramatically in the past decade, including the development of tactical combat casualty care guidelines and training. Significant advances have been achieved in hemorrhage control with tourniquets and hemostatic agents, surgical cricothyroidotomy, intraosseous access, needle decompression, pain management, prophylactic antibiotics, and low-volume field resuscitation. These advances are now crossing over to civilian EMS systems, tactical units, and wilderness medicine.[91–98]

Epidemiology

Wilderness medicine epidemiology is a rapidly growing field that describes the incidence of morbidity and mortality in the wilderness. Detailed information is still being collected, but general trends can be described. The most common injuries are soft-tissue lesions (e.g., blisters), sprains, strains, and fractures. The most common causes of death are head trauma, cardiac arrest (males >55 years old), drowning, hypothermia, hyperthermia, and suicide.[5,6,10,99–106] These data are important for general educational programs, risk mitigation, trip planning, and medical kit stocking.[7]

Search and rescue

Search and rescue operations are conducted under many organizational structures, typically citizen volunteer groups, law enforcement agencies, or, in many localities, a blend of the two.[107] Participants' medical training ranges from basic first aid to wilderness first aid, wilderness first responder, wilderness emergency medicine technician, paramedic, mid-level provider, as well as physician. Search and rescue missions are often used for missing children, recreationalists, and individuals with developmental delay, autism, Alzheimer's disease, or dementia.[99–101,108–112] Search management has evolved to the point of using statistical models of subjects' behavior along with computer analysis and mapping.[113,114] Helicopters facilitate rapid identification and extrication when they are deployed under appropriate circumstances.[115–119]

Travel medicine

Travel medicine involves the epidemiology of travelers' diseases, education, and vaccination.[120] This specialty has become especially important in this era of easy long-distance travel.[121] A particularly important disease in travel medicine is malaria, which carries significant morbidity and mortality rates, especially among children.[122–124] Geosentinel monitoring is used to detect disease propagation and assist with management.[125,126]

Disaster medicine

Disaster medicine and wilderness medicine have significant overlap. Both are practiced under sudden, unexpected, difficult, and austere conditions and have an inherent delay in emergency response and evacuation. Disaster conditions can be created in urban, suburban, and rural locations and are all associated with delays in emergency response, extraction, and evacuation to medical resources. Diseases that are typical in wilderness or remote settings can emerge in the aftermath of disasters. Although dramatic scenarios such as crush injuries and amputations grab news media attention, the basics of hygiene and water sanitation are just as critical in disaster management as is the deployment of trained response personnel into devastated areas.[127–129]

Ultrasound

Small, portable ultrasound machines are being used as an extension of the physical examination of patients with a number of clinical conditions: trauma (Focused Assessment with Sonography in Trauma [FAST] and pneumothorax examination), HAPE (pulmonary examination), HACE (determination of the diameter of the optic nerve sheath), and obstetric emergencies (determination of the age of the fetus).[130,131] Increasing use of this technology is being reported by the US military, particularly by remote special forces medics in Afghanistan and at small remote receiving centers.[132,133] Disaster medicine has used ultrasound in the field and in hospitals when other resources are overwhelmed or unavailable.[134–138] These situations often employ ultrasound for the focused scans delineated in ACEP's Emergency Ultrasound Guidelines.[139] The use of ultrasound in conjunction with telemedicine is intriguing. Real-time ultrasound images have even been transmitted from the International Space Station.[140,141]

WMS practice guidelines

Formal recommendations for clinical care and decision-making were lacking until 1979, when Forgey published *Wilderness Medicine*.[142] Six editions have been published, the latest in 2006.[143]

Over the past several years, the evidence-based Wilderness Medical Society Practice Guidelines have been developed and published in several areas of wilderness medicine. The topics addressed in these guidelines include: high-altitude illness,[16] frostbite,[81] lightning,[144] eye injuries,[145] epinephrine,[146] use of extrication devices in crevasse rescue,[147] exercise-associated hyponatremia,[148] spine trauma management,[51] heat-related illness,[149] anesthesia and pain management (in press), wound management (pending), hypothermia (pending), drowning and immersion injuries (pending). They are based on case series and expert consensus, because, for many topics, research studies using randomized controls have not yet been conducted. The guidelines were developed in accordance with the templates suggested by the American College of Chest Physicians.[149]

Professional organizations

The Wilderness Medical Society (WMS) is the primary professional organization representing wilderness medicine physicians and other health care providers. It sponsors a variety of meetings in North America: an annual summer meeting, an annual winter meeting, and a fall specialty meeting (organized around themes such as travel medicine, desert medicine, or environmental health). The WMS has developed a series of online video recordings from past conferences for continuing medical education (CME). The World Congress in Wilderness Medicine has met every 10 years since 1991, providing a forum for the exchange of current ideas and concepts related to wilderness medicine. The International Society for Mountain Medicine sponsors the International Hypoxia Symposium and the Congress on High Altitude Medicine and Physiology. The Undersea and Hyperbaric Medical Society, the Divers Alert Network, and the South Pacific Undersea Medicine Society focus on dive medicine.

Several other professional societies play important roles in wilderness medicine. The International Society of Travel Medicine (www.istm.org), founded in 1988, focuses on travel-related disease, including immunization recommendations. ISTM is involved in global monitoring of infectious diseases. Together with the Centers for Disease Control and Prevention (CDC), ISTM manages Geosentinel, a global surveillance network for infectious diseases that provides nearly real-time data for analysis of evolving disease patterns. The International Commission for Alpine Rescue (www.ikar-cisa.org), founded in 1948 and based in Switzerland, represents European mountain rescue groups. ICAR publishes recommendations on both medical and technical issues for a variety of issues facing mountain rescue teams. The International Society for Mountain Medicine (http://ismmed.org), founded in 1985 and also based in Switzerland, publishes the journal *High Altitude Medicine and Biology*.

Fellowships

The purpose of wilderness medicine fellowships is to develop academic leaders in the specialty. Multiple postgraduate fellowships are based in emergency medicine and family medicine graduate medical education programs. Generally, they have a research component, a teaching component, and a field component. A typical pattern is 1 year of training, with part-time clinical attending duties and part-time wilderness medicine training. The program at the University of California, Fresno, has an optional 1-year extension to obtain a master's degree in public health. The program at George Washington University also offers the opportunity to complete a master of science or a master of public health degree. The original and best known wilderness medicine fellowship is based at Stanford University in Palo Alto, California. The Society for Academic Emergency Medicine lists eight other wilderness medicine fellowships associated with emergency medicine residency programs. They are located at Baystate Medical Center; the University of California, San Francisco-Fresno; the Medical College of

Georgia; the University of Utah; Massachusetts General Hospital; the University of Colorado; the State University of New York; and Loma Linda University. Additionally, the Madigan Army Medical Center hosts an Austere and Wilderness Medicine fellowship for military physicians.

Several family medicine programs also host wilderness medicine fellowships: the Montana Family Medicine Program (www.riverstonehealth.org), the family medicine residency of Idaho (www.fmridaho.org), and Saint Vincent Wilderness Medicine Track (www.stvincenthealth.com).

Academy of wilderness medicine

Under the auspices of the Wilderness Medical Society, the Academy of Wilderness Medicine offers a fellowship that provides rigorous education through a 100-hour core curriculum as well as requirements for service, teaching, research, and experience. As of June 2013, the Academy recognizes more than 260 fellows as well as more than 700 fellowship candidates.

Master's degree

The Wilderness Medical Society opened its master's degree program (http://wms.org/fawm/acad_information.asp) in 2009. This program offers advanced, post-fellow certification in the participant's chosen sub-discipline within the scope of wilderness medicine. The master's program is developed by the student and a mentor and must meet requirements in education, scholarly activity, and experimental activity. For example, a master's program in the subspecialty of dive medicine could focus on the clinical management of decompression illness. Most participants fulfill the requirements of their program within 2 to 5 years.

Diploma in mountain medicine

In collaboration with the University of Utah and the University of Colorado, the Wilderness Medical Society also awards diplomas in mountain medicine, certifying academic and advanced skills in mountain rescue techniques (http://wms.org/education/dimm.asp). Started in 1997, the diploma program is co-sponsored by the Union Internationale Des Associations D'Alpinisme, the International Committee for Alpine Rescue, and the International Society for Mountain Medicine. The program is open to physicians, nurses, and paramedics who work in or aspire to work in austere environments. The 100 hours of coursework blend didactic and practical education in wilderness medicine, technical rescue, and self-sufficiency in the backcountry. This skill set crosses a number of disciplines, including expedition medicine, search and rescue operations, mountain guiding, ski patrol, and mountain recreation. The program consists of four week-long sessions that should be completed within 2 or 3 years. Participants must pass written and skills examinations to complete the program.

Student interest groups

The Wilderness Medical Society supports student interest groups that sponsor lecture series, workshops, and outdoor trips in conjunction with their sponsoring medical schools and faculty advisors. The events are organized by medical students, often in their second year of training. As of July 2013, approximately 43 of these interest groups, most of them in the United States and Europe, were active and operational. In addition, a number of emergency medicine and family medicine training programs in the United States offer 1- to 4-week electives in wilderness medicine for medical students and residents (see below).

Schools of wilderness medicine

Training in wilderness medicine is decentralized. Several organizations (based primarily in North America) teach wilderness medicine courses and skills throughout the world:

• Stonehearth Open Learning Opportunities (SOLO), Conway, New Hampshire, USA

• National Outdoor Leadership School, Wilderness Medicine Institute, Lander, Wyoming, USA

• Wilderness Medical Associates International, Portland, Maine, USA; Haliburton, Ontario, Canada; Tsukubamirai, Ibaraki, Japan (runs courses in China regularly)

• National Ski Patrol, Lakewood, Colorado, USA (outdoor emergency care)

• Advanced Wilderness Life Support, University of Utah, Salt Lake City, Utah, USA

• Aerie Backcountry Medicine, Missoula, Montana, USA

Their programs include basic introductory courses for the general public and pre-hospital care providers, such as wilderness first aid (WFA), a 2-day course; advanced wilderness first aid (AWFA), a 4-day course; wilderness first responder (WFR), a 9-day course; and wilderness emergency medical technician (WEMT), a 4-week course. Wilderness medicine courses for advanced care providers are available as well, e.g., Advanced Wilderness Life Saving.

Table 1. Grants offered by the Wilderness Medical Society in Support of Health Research in Wilderness Medicine (www.wms.org/research).

Grants
Charles S. Houston Award
Audience
Medical students
Article by recent recipients
• Fischer MD, Willmann G, Schatz A, Schommer K, Zhour A, Zrenner E, Bartz-Schmidt KU, Gekeler F. Structural and functional changes of the human macula during acute exposure to high altitude. PLoS One 2012; 7: e36155.
Research-in-Training Award
Audience
Residents and fellows of accredited graduate medical education programs or PhD candidates
Articles by recent recipients
• Graves JM, Whitehill JM, Stream JO, Vavilala, MS, Rivara FP. Emergency department-reported head injuries from skiing and snowboarding among children and adolescents, 1996–2010. Inj Prev, March 19, 2013 [Epub ahead of print].
• Muller MD, Mast JL, Patel H, Sinoway LI. Cardiac mechanics are impaired during fatiguing exercise and cold pressor test in healthy older adults. J Appl Physiol 2013; 114: 186–194.
• Muller MD, Gao Z, Mast JL, Blaha CA, Drew RC, Leuenberger UA, Sinoway LI. Aging attenuates the coronary blood flow response to cold air breathing and isometric handgrip in healthy humans. Am J Physiol Heart Circ Physiol 2012; 302: 1737–1746.
Herbert N. Hultgren Award
Audience
Members of the Wilderness Medical Society
Article by recent recipients
• Chang CY, Trehan I, Wang RJ, Thakwalakwa C, Maleta K, Deitchler M, Manary MJ. Children successfully treated for moderate acute malnutrition remain at risk for malnutrition and death in the subsequent year after recovery. J Nutr 2013; 143: 215–220.
Peter Hackett-Paul Auerbach Research Grant
Audience
Young investigators, physicians or non-physicians, with projects that will improve wilderness medicine practice
WMS Adventure Travel Research Grant
Audience
Investigators conducting field research associated with the WMS Adventure Travel Experiences

Medical direction

In the United States, street-based emergency medical services (EMS) systems are regulated by state agencies and the Department of Transportation at the federal level. Wilderness EMS does not have such a defined system of regulation. If present, medical oversight varies by jurisdiction. Only a few states have wilderness medicine integrated into their EMS protocols. In Pennsylvania and Maryland, two states with such integration, wilderness medicine practitioners are considered an extension of the pre-hospital system and have medical direction, follow wilderness specific protocols, and have quality assurance programs. In other states, wilderness medicine providers are not directly subservient to pre-hospital systems.

Many medical directors of EMS systems are unfamiliar with the practice of wilderness medicine, particularly its logistical limitations. To facilitate understanding and the integration of wilderness medicine into pre-hospital protocols, the Wilderness Medicine Society and the National Association of EMS Physicians (www.naemsp.org) have designed a Wilderness Medicine EMS Director Course, which is designed to support physicians who provide medical oversight to EMS systems with jurisdictions that cover wilderness environments.[150,151] Topics include search and rescue teams, technical rescue teams, ski patrols, and disaster response teams.

Wilderness research and grants

The Wilderness Medical Society offers a number of grants intended to support health-related research projects in outdoor and wilderness activities. Examples are listed in Table 1.

Future

The future of wilderness medicine is unfolding on multiple fronts: education, research, training, technology, communications, and environment. A wide range of individuals is showing an interest in learning wilderness medicine skills. Although wilderness medicine research is technically difficult to perform, it is essential to deepening our understanding of the contribution of specific techniques in improving clinical outcomes.

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