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CONCEPTS

Ultrasound and Ski Resort Clinics: Mapping Out the Potential Benefits

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Background.—Skiing and snowboarding are popular activities that involve high kinetic energies, often at altitude, and injuries are common. As a portable imaging modality, ultrasound may be a useful adjunct for mountainside clinics. This review briefly discusses skier and snowboarder injury profiles and focuses on the role of ultrasound for each injury type.

Methods.—Twenty-two sources including 17 reviews and observational studies were obtained describing skier and snowboarder injuries. Forty-nine studies were identified defining ultrasound applications for these injuries, including 38 reviews and observational studies, 6 case reports or case series, 3 cross-sectional studies, and 2 randomized, blinded studies.

Results.—Approximately 200 000 rider injuries are evaluated in the Unites States seasonally. Musculoskeletal injuries are the most common, and head, face, neck, and abdominal injuries are also prevalent, as are exacerbations of preexisting disease. Ultrasound has been shown to be useful and accurate for evaluating the aforementioned injury types, including joint, ligament, tendon, and fracture evaluation. Ultrasound has not been extensively studied in the prehospital setting, and only limited data address the utility of how it might influence management in a mountainside clinic setting.

Conclusions.—Ultrasound has the potential to be a useful diagnostic modality in ski resort clinics. The most promising areas for future, applied studies include evaluation of musculoskeletal injuries (especially injuries to joints and tendons and ruling out fractures), assessing for elevated intracranial pressure in minor head injuries and symptoms of altitude illness, and focused assessment with sonography for trauma and extended focused assessment with sonography for trauma examinations for cases of chest and abdominal trauma of unknown significance.

Key words: bedside ultrasound, skier injury, snowboarder injury, prehospital ultrasound, mountainside clinic

Introduction

Skiing and snowboarding are popular wintertime recreational activities. Participants are prone to a variety of injures, many of them consequential owing to the high kinetic energy involved with the sports. Injured parties are usually first evaluated by ski patrol and local ski resort clinics. These clinics manage thousands of patients every year and are frequently faced with difficult patient-management decisions as a result of lack of access to equipment, facilities, and certain expertise. In an effort to more efficiently and effectively manage patients in this setting, the introduction of portable ultrasound is an attractive idea. This manuscript will briefly review the number and types of injuries and presentations most commonly seen at ski resort clinics and describe ultrasound applications that may have a realistic role in improving patient management, with the intent of providing a basis for future, applied ultrasound studies. Both well-established and relatively novel ultrasound applications will be reviewed in an attempt to provide an in-depth yet practical view of the potential for ultrasound in mountainside clinics.

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Background

The National Ski Area Association (NSAA) estimates that more than 57 million skier and snowboarder days were logged in the United States during the 2008–09

season at 481 ski resorts open during that time. They report that approximately 2.1% of the US population participates in skiing and 1.9% of the population participates in snowboarding.[1]

While on the slopes, skiers and snowboarders are susceptible to a variety of different injuries. Speeds of 30 miles per hour are commonly reached and sometimes exceeded.[2] Most studies and data agree that the rate of "injury severe enough to require immediate medical attention" is approximately 3 per 1000 skier and snowboarder visits.[3,4] A quick calculation estimates that in a given season there are around 200 000 skier and snowboarder injuries evaluated by medical professionals, although estimates range from 170 000 to 500 000 because a significant number of injuries may be evaluated at other healthcare facilities. These injuries span a variety of processes, ranging from musculoskeletal injury and major trauma to complications of visiting high altitude such as acute mountain sickness and high altitude pulmonary edema (HAPE). Resort clinics therefore need to be prepared to recognize and address a wide range of presentations and injuries.[5–7] Several studies and reports from individual ski resorts help to break down injury rates and patterns further.

The Mount Buller Ski Patrol 2009 Annual Report, from a resort in Australia similar to many smaller, lower elevation ski resorts in the United States, showed that 679 (0.385% of total skiers and snowboarders) patients were evaluated for injury in their clinic during the 2009 season. Skiers and snowboarders made up a similar proportion of total accidents (45% and 49% of injuries, respectively), although with slightly different injury profiles. Skiers were more likely to suffer knee, lower leg, and ankle injuries, whereas snowboarders were more likely to suffer wrist, hand, and shoulder injuries. Both groups suffered a significant number of head, face, and neck injuries, and each group experienced injuries in every injury category.[3]

An epidemiological study by Willick et al[8] found that an average of approximately 2 injuries were evaluated in their mountainside resort clinic in Utah for every 1000 skier and snowboarder days, with slightly higher rates at the beginning and end of the ski season. Upper extremity musculoskeletal injuries were more common in snowboarders, whereas lower extremity injuries were more common in skiers. A total of 1636 patients were evaluated in their single clinic from November 2006 to April 2007.[8] A mountainside clinic from a large ski resort in Lake Tahoe, CA, showed the skier injury rate to be 3.2 per 1000 skier days and snowboarder injury rates to be 12.7 per 1000 snowboarder days.[4]

Regarding severely injured patients, a study through the Alberta Trauma Registry identified skiers and snowboarders who were traumatically injured and had an Injury Severity Score of 12 or greater. They found that within this group, head injuries were most common, followed by chest, spinal, extremity, and abdominal trauma.[9] Additionally, this study quantified that ski- and snowboard-related injuries accounted for 2.3% of traumas seen at their medical center during a 10-year period.

According to the NSAA, the number of fatalities attributable to skiing and snowboarding has averaged 39.8 people per year in the United States during the past 10 years.[1] The 2008–09 season brought with it 39 skier and snowboarder deaths, of which 30 were skiers and 9 were snowboarders. The rate of deaths per million skier and snowboarder visits is approximately 0.68, and the most common clinical scenario leading to death is loss of control and running into a tree.[4]

Ultrasound appears to be a potentially beneficial tool for resort mountainside clinics for several reasons. It has been shown to be a robust and versatile diagnostic modality for acute and chronic injuries and disease processes, including head trauma, abdominal trauma, chest injury, vascular compromise, and evaluation of the musculoskeletal system, among others, and is increasingly being used at the bedside.[7,10] Specific examination techniques are readily available to evaluate cases of trauma of unknown significance, which are commonly seen at ski resorts, and may aid in transfer decisions.[11] Ultrasound also has an excellent safety profile and been used successfully in isolated, remote, and austere environments.[12] Additionally, resort clinics have varying resources at their disposal. Many, although not all, have the ability to perform plain-film radiography; however, onsite computed tomography (CT) and magnetic resonance imaging are rarities.

Methods

Based on the number, types, and trends of skier and snowboarder injuries seen at ski resort clinics reported in prior medical literature, a PubMed search was performed to evaluate the role, potential role, or lack of role for ultrasound in the initial evaluation and management of the patient and injury type. The search included results for ultrasound applications ranging from backcountry to intensive care unit settings, and from well-established uses to novel, lesser-known applications.

Results

LITERATURE

Regarding skier and snowboarder injuries, 22 sources were gathered to characterize injury type, frequency, and

presentation. These include 17 reviews and observational studies on skier and snowboarder injury, 2 cross-sectional studies on risk factors and incidence, 1 case-control study, a ski-patrol yearly injury report, and the NSAA website. Regarding ultrasound applications for injury types, 49 studies were identified, including 38 reviews and observational studies, 6 case reports or case series, 3 cross-sectional studies, and 2 randomized, blinded studies.

CATEGORIES OF SKIER AND SNOWBOARDER INJURIES AND THE ROLE OF ULTRASOUND FOR EACH

Head injury

Head injuries occur as a result of falls and collisions with manmade and natural objects as well as other skiers and snowboarders, and can result in traumatic brain injuries, facial and cranial fractures, and lacerations.[13,14] Although helmet use is on the rise and bringing the number of significant head injuries down, traumatic brain injury remains the highest cause of catastrophic injury in skiers and snowboarders.[15]

Ultrasound has several potential roles in the management of head injuries. First, there is significant evidence that optic nerve ultrasonography (ONUS) is effective in assessment and monitoring of elevated intracranial pressure (EICP) through measurement of optic nerve sheath diameter (ONSD). Definition of EICP varies from study to study and ranges from invasive measurements greater than 20 mm Hg to noninvasive estimates based on head CT findings.[16–19] The ultrasound technique involves measuring the ONSD 3 mm proximal to the globe in both sagittal and axial planes. A prospective, observational study by Goel et al[17] of 100 patients with traumatic closed head injury found the sensitivity of ONUS in detecting EICP that ultimately required neurosurgical intervention to be 98.6%, specificity 92.8%, positive predictive value 97.26%, and negative predictive value 96.3%. Girisgin et al[20] performed a prospective, observational study that compared the results of 56 patients who received both head CT and ONUS for the evaluation of both traumatic and atraumatic EICP. They found a statistically significant difference in ONSD measurements concordant with head CT findings. In cases of EICP apparent on head CT, the mean ONSD was 6.4 mm vs 4.6 mm in those with a normal head CT. Although the number of patients in the study is relatively small, the results were convincing enough for them to suggest that ultrasound be used as a first-line tool in any head trauma scenario because it may be more sensitive than head CT for detecting EICP. As directly quoted from their study, "In detection and follow-up of EICP cases . . . ONUS is a practical, risk-free, inexpensive, convenient and, if performed by experts, reliable method. As a result, although CT may be more useful in finding a specific diagnosis, ONUS may be more efficient in detecting EICP." This may be particularly relevant in a resource-limited setting. An important consideration at this point in time regarding ONUS is the likely baseline elevation of ONSD in asymptomatic healthy travelers to high altitude. In the setting of acute mountain sickness (discussed later), there is a statistically significant increase in ONSD above the baseline that corresponds with symptom severity, but studies remain to be performed that analyze ONSD in the setting of closed head injuries at high altitude.[18] Ocular ultrasound may also have a role in resort clinics for the diagnosis or exclusion or retinal detachment by visualization of the hyperechoic detached retina within the globe. A recent, blinded study of a convenience sample of 48 patients performed in an emergency department found bedside ocular ultrasound to be 100% sensitive and 83% specific for this diagnosis.[21]

Ultrasound has also been found to be helpful in diagnosing facial and nasal fractures through finding discontinuity or irregularity along the cortex. A study published in 2007 evaluating a systematic tool for the evaluation of facial fractures with ultrasound using 6 predefined scanning areas showed it to be "reliable" in its small sample size of 10 patients, although the scan results were equivocal in 3 of 10 fractures confirmed by CT.[22] A review article published in 2011 that analyzed 17 articles on ultrasound diagnosis of maxillofacial fractures found it to be comparable to CT.[23] Studies by Lee et al[24] and Gürkov et al[25] found ultrasound to be not only effective in diagnosing nasal bone fractures but the imaging modality of choice over both CT and plain x-ray. Nasal bone fractures are, however, usually a clinical diagnosis, and this application is likely not beneficial in the mountainside clinic setting. The diagnosis of medically significant, complicated nasal fractures such as a naso-orbito-ethmoid fractures by ultrasound have not been studied, further limiting the use of nasal bone ultrasonography at this time, although this may be an area for further research.

Spinal column injuries

Neck, back, and spinal cord injuries represent a significant number of serious skier and snowboarder injuries. Most result from trauma and occur at a rate of roughly 1 injury per 100 000 skier and snowboarder days. A minority of these results in death or permanent neurological sequelae (approximately one in a million rider days).[26]

The evaluation of neck, back, and spinal cord injuries by ultrasound has not been well studied, and the role of ultrasound in managing these types of injures is not well characterized. There is a small amount of evidence that ultrasound may be useful in defining unstable vertebral burst fractures through visualization of the posterior ligamentous complex.[27] This may or may not be helpful if an isolated burst fracture has been diagnosed in the mountainside clinic setting. There is also good evidence that ultrasound is useful in guiding difficult lumbar punctures, which, again, may or may not be useful in a resource-limited clinic under routine circumstances.[28]

Chest injuries

Chest trauma in skiers and snowboarders can result in fractured ribs, pneumothorax, and hemothorax, as well as pulmonary and cardiac contusions, among others.[13] The EFAST (extended focused assessment with sonography in trauma) examination has been shown to be very useful in the evaluation of trauma and is in fact recommended as standard protocol in ATLS (Advanced Trauma Life Support) algorithms. The standard focused assessment with sonography in trauma (FAST) examination is discussed in further detail under the abdominal injury section. The "extended" portion of the EFAST examination uses assays for pneumothorax and hemothorax.[29,30] In the assay for pneumothorax, lung sliding of the visceral pleura along the parietal pleura is assessed, and, if absent, the test is considered positive. The lung point, corresponding to the edge of the pneumothorax, has been shown to be accurate in defining the size of pneumothorax as well, correlating to CT findings in the hands of an experienced sonographer.[31] M-mode (motion-mode) scanning can also be helpful to detect the presence or absence of lung sliding, as are B-lines, also knows as comet-tail artifacts. When B-lines are absent, the suspicion for pneumothorax is increased. Numerous studies to date have demonstrated that ultrasound is a robust method for diagnosing pneumothorax, with sensitivities and specificities of 86% to 98% and 97% to 100%, respectively.[31,32] It is paramount to remember, however, that tension pneumothorax is a clinical, lifesaving diagnosis and should be intervened on immediately when suspected. In the detection of hemothorax or pleural effusion, views just cephalad to the standard right upper and left upper quadrant FAST views are obtained by looking above the diaphragm and have a sensitivity of around 95%.[33,34] The standard FAST also involves a view of the heart from the subxiphoid position, parasternal-long position, or both to assess the heart's ejection fraction and for pericardial effusion, both of which are accurate when performed at the bedside by trained physicians.[35,36]

Evaluation of the bony thoracic cage by ultrasound has been well established. You et al[37] found in a blinded study of 36 consecutive blunt chest trauma patients with sternal tenderness that ultrasound has both a sensitivity and specificity of 100% in diagnosing sternal fractures, compared with 70% and 75%, respectively, for chest radiographs. It is also useful for rib fracture. A prospective study by Wüstner et al[38] that compared ultrasound with chest radiograph findings in the evaluation of blunt chest trauma in 100 patients suggested that ultrasound had nearly twice the sensitivity for diagnosing rib fracture and more than thrice the sensitivity for pleural effusion. Indeed, ultrasound has been found to provide a wide range of useful diagnostic information about the chest. Of clinical significance is the substantial time required to perform an ultrasound evaluation of the entire thoracic cage. Information gleaned from the history, patient symptoms, and physical examination findings would likely need to direct these ultrasound examinations.

Abdominal injuries

Abdominal trauma is common with skier and snowboarder injuries. The most frequently encountered serious complications are splenic laceration, liver laceration, and diaphragm rupture.[9] Snowboarders tend to incur more cases of medically significant abdominal trauma than skiers and are particularly prone to splenic laceration (aka "boarder belly").[39] A retrospective study by Wasden et al[13] that captured all skiers and snowboarders evaluated in their emergency department for 5 consecutive ski seasons reports that 22.4% of the snowboarders evaluated suffered abdominal injuries, including injury to the spleen, liver, and kidneys, making it the third most common presenting injury category in the emergency department setting behind head and lower extremity injuries. Notably, they reported that significant abdominal injury was rarely found in skiers.

The FAST examination is the primary ultrasonographic examination for the abdomen and includes 4 components: a subxiphoid (or parasternal-long) view to assess the pericardium for effusion and tamponade, right upper and left upper quadrant views to assess the potential spaces of the hepatorenal recess (Morrison's pouch) and the perisplenic space, respectively, and a suprapubic view to assess the pelvis for free fluid. Sensitivity and specificity for intraperitoneal free fluid are reported to be around 80% and 100%, respectively, according to several large studies.[40,41] It is not sensitive, however, for the detection of solid organ, bowel, or bladder injury.[41]

Serial FAST examinations may increase the sensitivity for intraperitoneal free fluid, and may aid in management or transfer decisions in a resource-limited clinic. With a suspicious mechanism or examination, however, the early decision to transfer may be potentially lifesaving, even in the absence of ultrasonographic findings, because of the low sensitivity for certain injuries.

Upper and lower extremity injuries

Musculoskeletal injuries to the extremities are by far the most common injury types in skiers and snowboarders as a whole.[3,13] Approximately 50% of snowboarder injuries affect the upper extremities, with the wrist being the most common site.[5] The shoulder, hand, elbow, and forearm are also routinely injured. Additionally, snowboarders are prone to a unique type of ankle injury, dubbed "snowboarder's ankle," which refers to a fracture of the lateral process of the talus occurring with forceful dorsiflexion of the ankle.[42] In skiers, injury to the ulnar collateral ligament, or skier's thumb, is the most common injury to the upper extremity, but any other part of the upper extremity can also be injured.[43] Lower extremity injuries overall are more common in skiers than snowboarders.[8,13] They include knee and ankle injury, as well as fractures of the femur, tibia, fibula, and bones of the foot.

Extremity and musculoskeletal examination by ultrasound has proven an effective tool. Evaluation for fracture uses a technique that visualizes the cortex of the bone looking for irregularities or discontinuities. In a retrospective, observational study of 44 patients by McNeil et al,[44] ultrasound yielded an overall sensitivity of 100% and a specificity of 94% in evaluation of suspected closed fractures of the fifth metatarsal, fibula, radius, ulna, fifth metacarpal, and distal phalanx using a digital handheld device. They concluded that "use of ultrasound by an experienced clinician . . . can be performed accurately and can possibly prevent unnecessary evacuations for suspected fractures requiring radiographic verification." An observational study by Marshburn et al[45] of 58 patients with suspected long-bone fracture involving physicians with minimal ultrasound training corroborates this finding, albeit with a caveat. "Ultrasound scans by minimally trained clinicians may be used to rule out a long-bone fracture in patients with a medium to low probability of fracture." They found ultrasound to have a sensitivity of 92% and a specificity of 83% in their study population. The study of mountainside ultrasound by Nowak et al[10] demonstrates a case report of metacarpal fracture in a snowboarder easily identified by ultrasound, as well as the feasibility of an on-mountain knee assessment, literally on the side of a ski run. A recent prospective study of 110 patients combining ultrasound with the Ottawa ankle rule criteria for suspected ankle fractures showed an increased specificity from 22% for the Ottawa criteria alone to 90% when combined with ultrasound, while keeping the sensitivity greater than 90%. The single fracture missed in the study resulted from not scanning proximally enough along the fibula.[46] Fractures of the lateral process of the talus, mentioned previously, have been diagnosed with ultrasound as well.[47] Plain radiography for this diagnosis has a sensitivity of approximately 50%. The sensitivity for ultrasound in detecting a fracture in the lateral process is unknown, but it can be done and may be helpful for determining management in the resort clinic setting.

Ultrasound has also been shown to be effective in joint, ligament, and tendon evaluation, including the ankle, knee, and shoulder.[10,15,48] Confirmation of successful reduction of glenohumeral dislocation with both posterior and anterior views have been reported in the literature numerous times, although it has not been a prospectively validated tool. Ultrasound is generally agreed to be accurate, and even quicker, than plain films for this purpose.[49–51] Regarding possible concomitant fracture of the humerus accompanying glenohumeral dislocation, there are significant data to suggest that plain films may be avoided if there is low suspicion for fracture and a normal postreduction physical examination. This holds especially true when the patient has a history of recurrent shoulder dislocations.[52,53]

Vascular assessment in both the traumatic and atraumatic extremity is also performed adequately with ultrasound.[54,55] A study of 356 patients presenting with penetrating trauma to the extremity showed that Doppler pressure indices in conjunction with a good physical examination were 100% sensitive for detecting clinically significant vascular injuries.[56] The role of ultrasound in the detection of deep venous thrombosis (DVT) is well established, which may be important if distinguishing between DVT from travel and immobilization versus questionable mountainside trauma.[57] In addition, studies suggest that a normal ultrasound of the acute scrotum, when taken in conjunction with a normal physical examination, practically rules out testicular disease, even in a trauma scenario.[58,59] A retrospective observational study of a convenience sample of 36 patients presenting with testicular disease who had bedside ultrasounds performed in the emergency department showed an overall sensitivity of 95%, including diagnoses of testicular fracture and torsion. Although no prospective studies have been performed to validate this use, the existing literature is encouraging.

As a side note, ultrasound-guided nerve blocks are being increasingly used at the bedside and can negate the

need for procedural sedation during painful procedures such as shoulder reduction, as well as lessen the need for systemic analgesia (and its accompanying untoward effects on mental and respiratory status) with other injuries. Ultrasound-guided interscalene blocks, for example, can be used for shoulder reduction and are becoming more common. A recent prospective, randomized study of 42 patients receiving either an interscalene block or undergoing procedural sedation for shoulder reduction showed equal efficacy and patient satisfaction in both groups.[60] Femoral, popliteal, ulnar, and radial nerve blocks, among others, are also being increasingly used.

High altitude illness

Acute mountain sickness (and the accompanying, less common complications of HAPE and high altitude cerebral edema) is a common complication of traveling to high elevation.[61] A cross-sectional study by Honigman et al[62] of 3158 adult travelers to elevations of 6300 to 9700 feet found that "acute mountain sickness occurs in 25%" of visitors. Another study conducted at 9600 feet of elevation in Colorado recorded 150 patients presenting with HAPE to a resort clinic during a 39-month period.[63] It should be noted that although high altitude illness is more common in the Rocky Mountains, it is seen regularly at elevations less than 10 000 feet, lower than several resorts in the popular Lake Tahoe area of California. In a 2003 adventure race in the Lake Tahoe area, more than 11% of participants were documented as having sought treatment for an ultimate diagnosis of "high altitude illness."[64] A retrospective study of emergency medical services from Kings Canyon and Sequoia National Parks showed 23 cases of high altitude illness, including 5 cases of HAPE (one being fatal), during a 38-month period.[65]

As discussed in the prior section on head injury, ONUS is useful in detecting EICP, and even at high altitude, ONSD correlates with degree of high altitude illness severity.[18] Further research is needed, however, to define exact parameters of ONSD at altitude and to determine whether a single measurement in time is useful in this setting. Changes in ONSD with time may prove to be more helpful. Ultrasound can be used as a sensitive indicator and for grading of pulmonary edema.[32,66] As in the assay for pneumothorax, it uses B-lines as the primary detection method. In direct contrast to their absence in pneumothorax, they are abundant in pulmonary edema. A study of 66 consecutive dyspneic patients in a medical intensive care unit by Lichtenstein et al[66] illustrated this well, finding a sensitivity of 100% and a specificity of 92% by detecting 3 or more comet-tails in 2 separate lung fields. By calculating a "comet-tail score," the degree of pulmonary edema can be estimated accurately. A study of 11 consecutive HAPE patients by Fagenholz et al[32] performed in the Himalayas looked specifically at pulmonary edema secondary to high altitude illness. They found that the comet-tail score was predictive of hemoglobin oxygen saturation as well as clinical status, and concluded that "the comet-tail technique effectively recognizes and monitors the degree of pulmonary edema" in these patients. At this point in time, routine use of ultrasonography may not have a well-defined role in evaluating high altitude illness, but this may change as research elucidates specific ultrasonographic parameters and as management algorithms are studied.

Discussion

Many factors undoubtedly exist in the consideration of ultrasound for routine use in mountainside clinics. Cost of machines, feasibility of organizing their implementation, and the general requirement that an ultrasound-trained physician be available for viewing the scans are important issues. The cost of ultrasound machines is decreasing for basic models as technology is progressing (and trickling down) for more advanced ones. At the time this study was written, $10 000 buys an ultrasound machine that is more than capable of all of the techniques and applications previously discussed. During the past decade, ultrasound has evolved into remarkably portable units, and now handheld, pocket-sized units are making their appearance in the market. The aforementioned study by Nowak et al[10] begins to explore the diagnostic potential in unconventional settings by demonstrating its utility as a mountainside tool for specific musculoskeletal snowboard injuries. Although this study illustrates just a few applications, it demonstrates the potential for real application outside of the office setting. Because of the relatively inexpensive cost and small size of both handheld models and more conventional units, implementation within clinics could be relatively straightforward.

Staffing of clinics with clinicians trained in the use of bedside ultrasound is another important consideration. Studies have begun to emerge that look specifically at the resources required to train clinicians in ultrasound. Noble et al[67] performed a study of 27 prehospital physician providers in France with varying degrees of ultrasound experience, teaching them to identify pneumothorax and pulmonary edema, and had encouraging results, finding that a brief training module substantially improved image recognition and suggesting that specific, goal-directed ultrasound application utilization is readily taught. Additionally, the number of emergency and critical care physicians who are trained and proficient in ultrasound is increasing. It is now a required part of every new emergency medicine residency graduate's training, and it is

almost unheard of in this day and age to find an academic emergency department or intensive care unit that does not have a portable ultrasound machine available.

As an alternative to having an ultrasound-trained physician on site, one can also look at the significant amount of research performed using telemedical ultrasound. A study of 146 patients performed in a small, rural hospital showed that remote ultrasound guidance was satisfactory and made interhospital transfer unnecessary in 42% of patients who would have otherwise undergone transfer, and the results influenced other management decisions 59% of the time.[68] Research on remote guidance in austere settings appears promising as well.[12,69] This is demonstrated in a study by Otto et al[12] that used a group of climbers at Everest Base Camp, who were in no way trained in ultrasound beforehand, to use ultrasound to go through the assay for pulmonary edema. They were given a 2-minute orientation over a satellite phone and proceeded through the examination under remote guidance with real-time feedback and remote image viewing through video streaming output. This is certainly much more austere than what might normally be encountered at a ski resort clinic but demonstrates its utility nonetheless. The setup used was remarkably simple, essentially boiling down to a commercial ultrasound unit and a two-way communication system. A similar setup could be useful when used at ski resort clinics to obtain expert guidance to assist with management decisions.[70] Midlevel providers are also increasingly being trained in specific ultrasound applications. As technical proficiency, interpretation ability, and telemedical setups become more advanced and ubiquitous, ultrasound may also be used in clinics staffed primarily by these providers.

Importantly, the overall number and percentage of evacuations and transfers from resort clinics has not been studied (to our knowledge). Obtaining these data would help further define specific ultrasound applications with the greatest potential for resort clinics. The argument could be made that there is not a real need for ultrasound in resort clinics and that it is not cost-effective. Without the data and numbers on clinic-to-hospital transfers, however, this is a difficult position to uphold. One can picture many scenarios where if unnecessary transfers could be prevented, ultrasound implementation could be highly cost-effective, not to mention more convenient for both patients and physicians. The opposite is also true, when the decision to transfer based on ultrasound findings in the face of a relatively benign physical examination could be lifesaving. There is current research being conducted on algorithms to determine when transfer from ski area clinics to trauma centers is necessary and by what means.[71] It is possible that certain ultrasound examinations and findings may be beneficially incorporated into this decision-making process. The above scenarios suggest that there may be potential roles for ultrasound that are worthy of future study. The vast array of rider injuries, pathologic processes, and differential diagnoses supports this as well.

Ultrasound is gaining popularity and being used in more and more diverse settings, ranging from Everest Base Camp to natural disasters to military operations. In the prehospital setting, however, it has been difficult to quantify its success overall. In a review published in early 2010 by Jørgensen et al,[29] it was found that data regarding the use of ultrasound in the prehospital setting for thoracic and abdominal trauma are sparse and often of low quality. They found that previous studies described a broad variety of patients and clinical challenges that made it difficult to make any solid conclusions. This should not be looked at negatively, for it is evident by the abundant literature supporting the utility of ultrasound that the potential is there, not only for evaluation of skiers and snowboarders but also for many medical scenarios in prehospital and remote settings. It suggests that goal-directed techniques that answer specific questions should be evaluated on an individual basis. What remains to be seen is whether ultrasound will begin to play a bigger role in day-to-day practice in some of these novel, at least for the time being, applications.

Conclusions

The medical literature supports ultrasound as a potentially beneficial tool at ski resort clinics. Further studies would be useful to determine whether real improvements in patient management and medical cost savings would be made with its introduction. Additional data on transfers from ski resort clinics to advanced medical facilities would also be useful in elucidating high-yield applications. Of the applications that appear most promising in terms of outcome, cost, and overall efficiency of patient management, musculoskeletal ultrasound (including ligament and fracture evaluation), introduction of FAST (and EFAST) examinations, and use as a screening tool to rule out EICP are all attractive and should be considered for further research.

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