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EDITOR'S NOTE

The Roles, Responsibilities, and Realities of Science Journal Editors

The job of the journal editor, or editor-in-chief depending on the nomenclature favored by the publication, is to serve as the highest authority to guide the delivered product. Similar to the function of research ethics boards, the position should be authorized and supported by the highest level of the parent organization and then allowed to operate without political pressure. Journals must deliver credible and meaningful content to sustain an intelligent readership, and they should not be burdened by political or financial metrics that can compromise scientific integrity.

Journal content will vary widely from issue to issue, reflecting the freeform nature of scholarship. Science tends to progress in fits and starts, with individuals working on a dizzying array of topics and delivering a wide range of quality, applicability, and construct. Some manuscripts may be expected to draw a good audience, but many defy expectations. It is difficult to know which will capture interest now, in the future as community focus evolves, or not at all. Topic diversity can be useful in stimulating critical thought and new research directions.

Some journals promote specific content through invited pieces, but many will rely on unsolicited submissions. The best approach in any case is to assess each submission objectively. There should be no preconception of outcome prior to evaluation. Some pieces may be rejected after a "first look" if essential criteria are not met. Issues may involve subject matter and/or construct elements. Construct standards will typically evolve with the publication record. New journals will often have to be more flexible, but as the perceived value and submission quality increase, the tolerance for construct errors and perceived ill fit will usually decrease.

Editors set the bar for submission standards, and monitor and revise them to balance the trajectory of the journal with community expectations and tolerance. Attention to detail in meeting submission guidelines should not be the most challenging part of manuscript preparation, but it can be a substantial barrier for some authors. Egregious violations might prompt immediate disqualification from peer review, but there should be some flexibility for manuscripts worthy of nurturing. Editors have to be mindful of the time reviewers will spend, and the frustrations they may feel in working with poorly crafted manuscripts, so decisions on what should or should not go out for review deserves careful consideration.

Editors must also strike a balance between encouraging and discouraging authors. Summary dismissal is appropriate for truly inappropriate submissions, but if there is hope for the current offering or future efforts, authors need to know what to expect and where their efforts are going wrong. Time must be protected when the submission tempo is high, but thoughtful insights can have positive effects on career development.

Reviewers need to feel respected if they are to support a journal. Some will accept invitations to review only for manuscripts closely aligned with their expertise. Others will be more flexible, accepting invitations and applying their best efforts on a wider array of submissions. Reviewers should be able to focus on the scientific content as much as possible, and their recommendations heard even if not accepted. Editors should not be obligated to agree with the recommendations of any reviewer, but resentment can be minimized and consistency of vision enhanced if the reasons for disagreement are made clear. The minimum standard in this should be sharing all reviews and editorial comments with all reviewers. Clear language justifications for editorial decisions can help both authors and reviewers.

Editors also need to be prepared for reviewers who make statements viewed as wholly inappropriate. These may result from not understanding journal standards, misreading manuscripts, or simple errors. Leaving conflicting comments in place can frustrate and confuse authors. Editors can add explanatory remarks to counter inappropriate comments, but this might make reviewers feel targeted. The alternative is for editors to edit or remove inappropriate content in the comments to author fields. If this is done, editors should document all changes in separate notes to reviewers to avoid concerns of inappropriate manipulation. The best approach is to provide the exact text changes with a written justification

for the action. Reviewers may be unhappy if they feel their point remained valid, but they are less likely to feel disrespected. In some cases, they may even be appreciative if the revision eliminates something that could adversely affect their credibility.

The variety of submissions to a journal can lead to the need for many hundreds of reviewers. A major task for editors is to ensure recruitment of reviewers with both solid subject matter expertise and a willingness to deliver high-quality review efforts, typically on a reasonably demanding schedule with no direct compensation. Building a network of strong reviewers and releasing weak reviewers is important for the long-term success of a journal.

Editors need to look for the most effective reviewers to advance through engagement. Invitations to join editorial boards should go to the most promising. This stepping stone can lead to invitations to take on section editor or even associate editor roles. It is very possible that those who begin as authors or reviewers can end up having career-long commitments to journals they value.

The need for specific section editors will usually evolve as journals develop. Posts may be created to draw attention to new areas of interest, but they will often be established simply to reflect submission patterns. Recruiting the best subject matter expert section or associate editors will expand an editor's ability to identify and recruit the best reviewers, and can increase the interest of subject matter authors.

Section or associate editors should review manuscripts and look for material gaps in the work of reviewers. They can add comments to the authors, secure additional reviews, and make disposition recommendations. Editors should look for and address material gaps in the work of all others before rendering their decisions.

Identifying as many issues as possible in the first review cycle will help authors deliver revisions more likely to advance quickly. It must be clear to all, though, that invitation for revision does not guarantee acceptance of a manuscript. Anyone involved in the review process can uncover flaws at any point that provide cause to remove a manuscript from consideration. The editor is responsible for ensuring that the evaluation in every cycle is sufficient to render the appropriate decision.

Ongoing debates consider whether single-blinding, double-blinding, or no-blinding is the best approach for fair reviews. It is possible that knowing author names can produce bias for or against a manuscript, or that being identified as a reviewer may hinder honest evaluation, but there is no simple solution. True blinding is often difficult to achieve in specialized fields, and speculation can be as disruptive as knowledge. In reality, author names should not matter in objective evaluations. Each submission should be evaluated on its intrinsic strengths and weaknesses. The best authors can write great papers, but they can also have their names attached to poor ones. Similarly, unknown authors can produce manuscripts of any level of quality. Editors must be secure enough in their professional and personal positions to be unfettered in making honest evaluations and rendering any appropriate decision.

Editors, like any good manager, should take a little less than the credit deserved for good work, and a little more of the blame deserved for missteps. They need to be diligent to keep the balance on the positive side. It is a practical reality that standard peer review does not include evaluation of the original data used by authors. Reviewers may have different levels of trust in the skill, diligence, and integrity of authors, but editors should always be a bit more skeptical regarding the work of both authors and reviewers. The best outcome is to avoid errors, but they must also be managed directly if they do occur. Honest errors of material consequence can simply be handled through errata, with the corrections published quickly with no assignment of blame. Discovery of fraudulent practice is much more serious, but quick action with clear explanations is the best course. Authors may be invited to voluntarily retract offending works, but editors should move forward with dispatch in any event. The negative impact on the journal and leadership is likely to be lessened by timely and open action.

Letters to the editor are an important avenue through which the community can flag emerging issues or perceived problems in recent publications. Editors should embrace letters without defensiveness. The bar for acceptance of letters should be meaningful, but generally lower than for primary submissions to protect the voice of letter writers. The authors of any work being questioned should be invited to respond in written form, but letters can proceed even if they do not contribute. Ultimately, editors should view engagement in letters as a positive factor.

Editors working for credible, peer-reviewed scientific journals should not prioritize publishing content, but prioritize publishing sound content. Editors do not have to be interested in or even agree with everything published in the journals they shepherd, but they must ensure that every piece meets all reasonable standards for publication as valid and appropriate content. There should be no concern over the direction of findings for valid and meaningful research.

Editors should not expect to win popularity contests. They enforce standards for authors and reviewers, and they provide candid feedback and decisions that will sometimes sting. Their methods may not always be appreciated and their decisions will not always be welcomed. They should be open to compromise when

warranted since peer review is a negotiation, but they are also expected to stand by sound decisions. Errors will be made in the review process, but a solid foundation of well thought out process, objective evaluation, and documentation can ensure a robust system. Sustained efforts can help journals grow in a positive direction. Editors have to navigate confidently but also cautiously. Increasing the rigor of a journal requires some shared pain, and editors have to apply enough pressure for progress to occur, but not so much as to promote insurrection. Evolution is slow, but strong leadership and collective effort can make it happen.

Wilderness & Environmental Medicine has advanced in recent years, seeing substantial increases in submission numbers and impact factor, and good numbers in handling time. The manuscripts least likely to advance are identified as rapidly as possible to allow more time for those with greater promise. The demands put on authors is substantial, with a goal of helping to ensure the best product possible reaching the readership and as an investment to build skills in the community. Continued success relies on the skilled and committed effort of many researchers, authors, reviewers, and editors. Seminars have been delivered regularly at Wilderness Medical Society meetings to help authors and reviewers to refine their skills. The reviewer-in-training program was developed to enhance the pipeline of reviewers, with the expectation that it would also help to build writing skills. Reviewer scores are used to issue reviewer awards and to identify candidates for editorial board membership. Strengthening research and science communication skills can pay dividends in many ways.

Supporting the efforts of a credible, medical society-based, peer-reviewed journal ensures a high-quality literature record, provides a training ground for interested professionals, and serves as an anchor for many shared passions. Please stand and be counted.

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ORIGINAL RESEARCH

Poor Knowledge of Acute Mountain Sickness in Latin American Medical Students

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Introduction—Acute altitude exposure is a common event in Latin America that can result in mild to severe altitude illness. Medical students from some Latin American countries receive little information on this topic. Our aim was to determine the knowledge and incidence of acute mountain sickness (AMS), as well as the methods used to prevent AMS among medical students attending the Pan-American Student Meeting in Cusco, Peru, a city at high altitude (3400 m).

Methods—We conducted a cross-sectional study on medical students attending a conference. Participants completed a questionnaire on the day of registration that collected demographic data and investigated students' knowledge of AMS, its prophylaxis, and their personal experience of symptoms.

Results—A total of 840 students attended the meeting. Two hundred eighty-eight returned surveys, 51 from high altitude locations. Respondent age was 23±3 y (mean±SD), and 72% were female. Thirty-two percent had basic knowledge about symptoms of AMS. Headache was recognized as a symptom by 79%. Knowledge of AMS prophylaxis was reported by 70%. Coca leaf products and dimenhydrinate were mentioned by 30 and 16%, respectively, whereas acetazolamide was recognized by only 10% of participants. AMS incidence was 42%. Prophylactic measures were adopted by 47% of the participants in our study. Thirty-six percent used dimenhydrinate and 27% used coca tea. Less than 1% used acetazolamide as recommended.

Conclusions—We found poor knowledge of AMS and effective prophylaxis among medical students from several South American countries traveling to 3400 m.

Keywords: altitude illness/prevention, educational measurements, medical education, Peru

Introduction

In Latin America, nearly a quarter of the population lives at altitudes above 2500 m.[1] Each year, millions of people travel to high altitude regions for purposes such as mountaineering, tourism, business, and religious pilgrimages.[2,3] Latin American physicians should be familiar with acute mountain sickness (AMS). Cities such as La Paz, Bolivia (3650 m); Quito, Ecuador (2850 m); Bogota, Colombia (2640 m); and Cusco, Peru (3400 m) regularly host medical student conferences at which participants are exposed to high altitude. AMS can interfere with social, recreational, and scientific activities.[4,5]

AMS is a set of nonspecific symptoms, found in nonacclimatized individuals after rapid ascent to altitudes over 2500 m.[6-8] The diagnosis of AMS is based on clinical features. The presence of headache is required for the diagnosis of AMS. Other symptoms may include nausea, vomiting, loss of appetite, fatigue, lightheadedness, and weakness.[9-13] AMS occurs in up to 25% of nonacclimatized people who ascend rapidly to 3500 m.[14] Symptoms most commonly begin within 6 to 12 h of arriving at high altitude.[12,15]

There are ways of reducing the risk of AMS, such as gradual ascent and use of prophylactic medication (acetazolamide and dexamethasone).[6,16,17] The aim of this study was to determine the incidence of AMS and the

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methods used to prevent it among medical students attending the Pan-American Medical Student Scientific Meeting in Cusco, Peru.

The organizers of the conference provided no information to participants regarding the symptoms or prevention of AMS before the event or on arrival in Cusco.

Methods

Our study was approved by the organizing committee of the Pan-American Medical Student Scientific Meeting.

We conducted a cross-sectional descriptive study, with data collected using a questionnaire (Table 1). We invited all students attending the meeting in Cusco, Peru, in 2018 to participate voluntarily and anonymously. We conducted the survey on the day of registration and handed the questionnaires to respondents. They were given time to fill in their answers and hand back the completed questionnaires. We developed the 14-item questionnaire after a literature review and discussion among the authors, in consultation with an expert in high altitude medicine.[18,19] No incentives were offered for participation.

The questionnaire (Table 1) consisted of 2 parts. The first part included demographic data, age, sex, place of residence, and information about university of origin and year of medical school. The second part evaluated knowledge of symptoms and prevention of AMS and personal experience of symptoms. For analysis of AMS prophylaxis, we grouped responses into 2 categories: pharmacologic and nonpharmacologic. Regarding acetazolamide, we classified use as appropriate if it was started at least 24 h before ascent at a dose of 125 mg every 12 h. Respondents were described as demonstrating at least a basic knowledge of AMS if they identified symptoms of AMS as headache and at least 2 of the following: fatigue, dizziness, and nausea.[19]

We diagnosed AMS in participants living below 2500 m based on the Lake Louise AMS scoring system of 2018 as headache plus at least 1 of the following symptoms: gastrointestinal (loss of appetite, nausea, or vomiting), weakness and/or fatigue, and lightheadedness and/or dizziness.[13,20,21] Some items in the questionnaire allowed more than 1 answer (eg, symptoms that respondents identified with AMS could be headache or headache and dizziness).

For the analysis, demographic data and knowledge of AMS symptoms included all participants. For the analysis of symptoms and prophylaxis of AMS and the remainder of questions, only respondents traveling from locations below 2500 m were included. Data were analyzed using Microsoft Excel spreadsheets. Data are depicted as mean±SD, proportions, and percentages.

Results

There were 840 students who attended the meeting. Two hundred eighty-eight (34%) returned the questionnaire. Respondent age was 23±3 years, and 72% were female. Of respondents, 237 (82%) were students traveling from locations below 2500 m, and 51 (18%) lived above 2500 m.

Peru, Paraguay, Brazil, Bolivia, Colombia, Panama, Mexico, and Honduras were represented. Peru was the country with the largest number of respondents (74%), followed by Paraguay (11%) and Brazil (4%). A total of 48 universities were included. Twenty-nine percent of students were in their fourth year and 25% were in their fifth.

Among respondents, 208 (88%) had previously been to high altitude, 24 (10%) had never been to high altitude, and 5 (3%) did not answer. A total of 106 (62%) reported having had AMS previously, 86 (36%) denied previous AMS, and 5 did not answer.

Most students (257 of 288) claimed to have knowledge of AMS symptoms. Headache was the most frequently identified symptom of AMS, followed by nausea, lightheadedness, and vomiting (Table 1). We found that 24% of respondents living above 2500 m and 28% of those living below 2500 m had at least basic knowledge of AMS.

Students were asked about the possible impact of AMS on general well-being. One hundred sixty-seven respondents (70%) answered that AMS could seriously affect health (ie, could lead to serious complications, hospitalization, or death), 33 (14%) students denied such health impact, and 37 (16%) interviewees did not know.

Fifty-eight (25%) students reported having no symptoms, 74 (31%) reported having symptoms that did not meet our criteria for AMS, and 99 (42%) had symptoms that met our criteria for AMS (Table 1).

One hundred sixty-six respondents (70%) said that they had knowledge about prophylactic measures against AMS. We grouped responses into 2 categories: nonpharmacologic and pharmacologic (Table 1). Among the nonpharmacologic measures, acclimatization was the most frequently reported, mentioned by 16 respondents (10%). Seven respondents (4%) mentioned “modifying diet.” The most commonly mentioned pharmacologic intervention was coca leaf products (n=27 [16%]). Seventeen respondents (10%) identified acetazolamide as a prophylactic medication.

Table 1. Survey questions about acute mountain sickness using respondents per questions as denominator

Demographic data and survey questions	*Absolute count* (*n*)	*Relative frequency* (%)
Age (n=288) (mean±SD), y	23±3	
Sex (n=288)		
Female	207	72
Male	81	28
Place of residence (n=288)		
Lima	74	26
Asunción	20	7
Arequipa	19	7
Cusco	18	6
Piura	17	6
Others	140	49
Year of medical school (n=288)		
Fourth year	82	28
Fifth year	81	28
Third year	48	17
Sixth year	23	8
Second year	22	8
Other	32	11
University (n=288)		
Universidad Ricardo Palma	31	11
Universidad Nacional de San Antonio Abad del Cusco	16	6
Universidad Católica de Santa María	15	5
Universidad Nacional Mayor de San Marcos	14	5
Universidad Nacional de Asunción	13	5
Other	199	69
Have you ever been above 2500 m? (n=237)		
Yes	208	88
No	24	10
Unsure	5	2
Do you know the acute mountain sickness symptoms? (n=288)		
Yes	257	89
If your answer is yes, which ones?[a]		
Headache	203	79
Nausea	141	55
Lightheadedness	109	42
Vomiting	103	40
Dyspnea	71	28
Tiredness/Fatigue/Weakness	31	12
Dizziness	16	6
General discomfort/Malaise	14	5
Tachycardia	12	5
Other	109	42
Can your health get seriously compromised by acute mountain sickness complications? (n=237)		
Yes	167	70
No	33	14
Unsure	37	16
Have you ever experienced acute mountain sickness? (n=237)		
Yes	146	62
No	86	36
Unsure	5	2

(continued on next page)

Table 1 *(continued)*

Demographic data and survey questions	*Absolute count* (*n*)	*Relative frequency* (%)
Have you felt any of the symptoms below upon your arrival to Cusco?[a] (n=237)		
Headache	126	53
Weakness/Fatigue	91	38
Nausea/Vomiting/Loss of appetite	70	30
Dizziness/Lightheadedness	53	22
Difficulty sleeping	43	18
Loss of balance	25	11
Mental confusion	13	6
None	58	25
Can acute mountain sickness be prevented? (n=237)		
Yes	184	78
No	18	7
Unsure	35	15
Do you know any preventive measures for acute mountain sickness? (n=237)		
Yes	166	70
If your answer is yes, which ones?[a]		
Nonpharmacological measures		
Acclimatization	16	10
Modifying diet	7	4
Adequate hydration	6	4
Others	15	9
Pharmacological measures		
Coca leaf products	49	30
Dimenhydrinate	27	16
Acetazolamide	17	10
Other	114	69
Have you used any measure (eg, action, medication) to prevent acute mountain sickness? (n=237)		
Yes	111	47
If your answer is yes, which one?[a]		
Dimenhydrinate	40	36
Coca tea	30	27
Sorojchi pills[b]	24	22
Acetazolamide	6	5
Other	28	25
When did you start the preventive measure? (n=111)		
1 h before the trip	12	11
2 h before the trip	8	7
3 h before the trip	6	5
24 h before the trip	2	2
Other	15	14
During the trip	34	31
Upon arrival	34	31

[a]There could be more than 1 answer.
[b]Combination of acetylsalicylic acid, acetaminophen, and caffeine.

Use of prophylactic measures was reported by 111 respondents who traveled from locations below 2500 m (Table 1). Adequate hydration was reported by 2 (2%) students among the nonpharmacologic category. The most commonly used drug was dimenhydrinate, reported by 40 respondents (36%), whereas only 6 (5%) were taking acetazolamide. Of the 6 students who were using acetazolamide, only 2 of them started using it before the trip.

Discussion

In our study, the level of knowledge of AMS was low. This is surprising because respondents were medical students. We expected students living above 2500 m to be more aware of AMS; however, we found that only a quarter had basic knowledge of AMS. A similarly low level of knowledge was reported in a survey of experienced climbers.[18] Our finding that headache was the most recognized symptom was consistent with previous surveys of trekkers and tourists.[18,19,22] The incidence of AMS in our survey was 42%, consistent with the 38 to 45% reported in other studies in which participants ascended above 3500 m.[23,24]

The Wilderness Medical Society guidelines[25] and a recent Cochrane review[26] recommend that acetazolamide, taken prophylactically, should be started 24 h before ascending. Eighty percent of the respondents claimed to know how to prevent AMS, but the measures they mentioned, such as adequate hydration, coca leaf products, and dimenhydrinate, were not in accordance with current recommendations.

Nonpharmacologic measures can be used to prevent AMS. The most effective nonpharmacologic method to prevent AMS is gradual ascent to allow time for acclimatization. Few of our respondents mentioned "acclimatization." Respondents also mentioned "modifying diet," such as smaller meals, low-fat and lactose-free diets, and "adequate hydration."

Although acetazolamide is the most commonly used preventive medication,[25-28] only a small fraction (5%) of the medical students identified acetazolamide as such, and only 2 respondents reported using it properly. A previous study reported that only 9% of tourists knew about acetazolamide as a preventive measure.[22] These studies highlight the lack of knowledge of this medication. In contrast, a study of experienced high altitude marathon runners participating in the Everest marathon found that 88% knew that symptoms could be prevented with medication, and 73% were aware of acetazolamide.[18]

LIMITATIONS

Our small sample does not necessarily represent the general population of Latin America and did not reflect the relative populations of countries. We had a low response rate; as such, caution must be taken in generalizing these results to a broader sample. Also, students were not randomly selected for the study. The place of residence was determined according to the place where respondents studied, but this may not necessarily reflect their home residence. In our study, two-thirds of respondents were female. Although there has been an increase in female students attending medical schools in Latin America in recent years, this does not represent the current equal sex ratio of the general population. Our questionnaire contained multiple choice questions, limiting the ability of respondents to explain their answers. The respondents may not be representative of all Latin American medical students who potentially have even less knowledge of AMS.

Conclusions

Most medical students from South America attending a conference at 3400 m above sea level lacked basic knowledge of symptoms, treatment, and prevention of AMS. Forty-two percent of students met the criteria for AMS. It is important for physicians to know how to prevent, diagnose, and treat AMS. We recommend that Latin American medical schools incorporate high altitude medicine into their curricula.

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References

1. Huddleston B, Ataman E, de Salvo P, Zanetti M, Bloise M, Bel J, et al. Towards a GIS-based analysis of mountain environments and populations. *FAO*. 2003;1(10):2–4.
2. Netzer N, Strohl K, Faulhaber M, Gatterer H, Burtscher M. Hypoxia-related altitude illnesses. *J Travel Med*. 2013;20(4):247–55.
3. Basnyat B, Hofmeyr R, Tölken G, De Decker R. Acute high-altitude illness. *S Afr Med J*. 2017;107(12):1047–8.
4. Kim SB, Kim JS, Kim SJ, Cho SH, Suh DC. Altitude stress during participation of medical congress. *Neurointervention*. 2016;11(2):73–7.
5. Park D, Kim M, Lee GY, Yang KH, Park HS, Suh DC. Medical problems during participation of medical congress—a long trip to Val d'Isere from Korea. *Neurointervention*. 2016;11(1):1–4.
6. MacInnis MJ, Carter EA, Freeman MG, Pandit BP, Siwakoti A, Subedi A, et al. A prospective epidemiological study of acute mountain sickness in Nepalese pilgrims ascending to high altitude (4380 m). *PLoS One*. 2013;8(10):e75644.
7. Luks AM, Swenson ER, Bärtsch P. Acute high-altitude sickness. *Eur Respir Rev*. 2017;26(143):160096.
8. González P, Alejandro M, Fonseca Z, Fernanda L, Rubio C, Gigiola S. Erythropoietin and reticulocyte levels in lowland residents migrating to middle altitudes. *Rev Univ Ind Santander Salud*. 2017;49(4):535–9.
9. Bärtsch P, Swenson ER. Acute high-altitude illnesses. *N Engl J Med*. 2013;368(24):2294–302.
10. Marmura MJ, Hernandez PB. High-altitude headache. *Curr Pain Headache Rep*. 2015;19(5):483.

11. Heo K, Kang JK, Choi CM, Lee MS, Noh KW, Kim SB. Prophylactic effect of erythropoietin injection to prevent acute mountain sickness: an open-label randomized controlled trial. *J Korean Med Sci*. 2014;29(3):416–22.
12. Meier D, Collet T-H, Locatelli I, Cornuz J, Kayser B, Simel DL, et al. Does this patient have acute mountain sickness?: The rational clinical examination systematic review. *JAMA*. 2017;318(18):1810–9.
13. Roach RC, Hackett PH, Oelz O, Bärtsch P, Luks AM, MacInnis MJ, et al. The 2018 Lake Louise acute mountain sickness score. *High Alt Med Biol*. 2018;19(1):4–6.
14. Lawrence JS, Reid SA. Risk determinants of acute mountain sickness and summit success on a 6-day ascent of Mount Kilimanjaro (5895 m). *Wilderness Environ Med*. 2016;27(1):78–84.
15. Williamson J, Oakeshott P, Dallimore J. Altitude sickness and acetazolamide. *BMJ*. 2018;361:k2153.
16. Burtscher M, Gatterer H, Faulhaber M, Burtscher J. Acetazolamide pre-treatment before ascending to high altitudes: when to start? *Int J Clin Exp Med*. 2014;7(11):4378–83.
17. Davis C, Hackett P. Advances in the prevention and treatment of high altitude illness. *Emerg Med Clin North Am*. 2017;35(2):241–60.
18. Letchford A, Paudel R, Thomas OD, Booth AS, Imray CHE. Acute mountain sickness (AMS) knowledge among high altitude marathon runners competing in the Everest marathon. *Wilderness Environ Med*. 2016;27(1):111–6.
19. Paz A, Steinfeld I, Potasman I. Are we doing our best to educate travelers about the risks of acute mountain sickness? An on-site prospective study in the Himalayas. *J Travel Med*. 2007;14(3):168–72.
20. Maggiorini M, Muller A, Hofstetter D, Bartsch P, Oelz O. Assessment of acute mountain sickness by different score protocols in the Swiss Alps. *Aviat Space Environ Med*. 1998;69(12):1186–92.
21. Hackett PH, Roach RC. High-altitude illness. *N Engl J Med*. 2001;345(2):107–14.
22. Merritt AL, Camerlengo A, Meyer C, Mull JD. Mountain sickness knowledge among foreign travelers in Cuzco, Peru. *Wilderness Environ Med*. 2007;18(1):26–9.
23. Mairer K, Wille M, Bucher T, Burtscher M. Prevalence of acute mountain sickness in the Eastern Alps. *High Alt Med Biol*. 2009;10(3):239–45.
24. Kriemler S, Bürgi F, Wick C, Wick B, Keller M, Wiget U, et al. Prevalence of acute mountain sickness at 3500 m within and between families: a prospective cohort study. *High Alt Med Biol*. 2014;15(1):28–38.
25. Luks AM, Auerbach PS, Freer L, Grissom CK, Keyes LE, McIntosh SE, et al. Wilderness Medical Society clinical practice guidelines for the prevention and treatment of acute altitude illness: 2019 update. *Wilderness Environ Med*. 2019;30(4S):S3–18.
26. Nieto Estrada VH, Molano Franco D, Medina RD, Gonzalez Garay AG, Martí-Carvajal AJ, Arevalo-Rodriguez I. Interventions for preventing high altitude illness: Part 1. Commonly used classes of drugs. *Cochrane Database Syst Rev*. 2017;6(6):CD009761.
27. Salinas-Piélago J. Review on the use of coca tea in prevention of acute mountain sickness. *Rev Neuropsiquiatr*. 2016;79(3):166–8.
28. Parise I. Travelling safely to places at high altitude—understanding and preventing altitude illness. *Aust Fam Physician*. 2017;46(6):380–4.

WILDERNESS & ENVIRONMENTAL MEDICINE 2022; 33(2): 154–61

ORIGINAL RESEARCH

Professional Outcomes and Satisfaction Among Graduate Medical Education Wilderness Medicine Fellowship Alumni in the United States

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Introduction—Wilderness medicine (WM) graduate medical education (GME) fellowships were established in 2003. Outcomes and satisfaction of US WM GME fellowship alumni can inform prospective applicants and program directors of the strengths of fellowships and professional gaps in them.

Methods—A 34-question Qualtrics survey was emailed to 111 alumni from 17 institutions listed in the Wilderness Medical Society's GME database in May 2019. Professional service, scholarship, and satisfaction were queried. Results are represented as percent response (n=answered affirmative) based on the number of respondents per question.

Results—The survey response rate was 41% (n=46); 67% reported (n=31) Fellowship of the Academy of Wilderness Medicine recognition. Within the last 5 y, 71% (n=32) reported publications in WM. Free text entry questions had 78% (n=28) describe improved clinical skills, and 68% (n=26) were exposed to new career choices in fellowship. Those who rated exposure to a variety of WM knowledge and skills highly rated the overall fellowship experience higher ($P<0.001$), as did those reporting a higher number of WM publications ($P=0.023$). Nearly half, 48% (n=21), felt they could hold their current position without fellowship training. In hindsight, 76% (n=34) would follow the same professional path.

Conclusions—WM GME fellowship alumni reported high rates of professional engagement and scholarly productivity in the subspecialty. Responding alumni overwhelmingly rated the fellowship experience positively. Fellowships that ensure a wide exposure to experiences and foster scholarly productivity are more likely to yield professionally satisfied graduates.

Keywords: career choice, academic productivity, educational leadership, engagement, professional success, scholarly work

Introduction

University-based graduate medical education (GME) programs offer physicians and other healthcare providers an opportunity to train within a subspecialty and obtain a unique body of knowledge. There is a paucity of studies on wilderness medicine (WM) GME fellowships, and completion of these programs does not generally earn graduates higher pay but instead offers unique knowledge and skills, academic leadership, and scholarship within a subspecialty field. WM GME fellowships are often emergency medicine based, accepting emergency medicine trained physicians and in some cases family medicine trained physicians; few programs accept self-supported physicians from other training backgrounds, nurse practitioners, and physician assistants. Currently all WM GME fellowships, as described above, are US-based programs. The first WM GME fellowship program was established in 2003, and at the time of the survey, there were 15 active WM GME fellowship programs (Table 1). Between the time the study was performed (2019) and time of manuscript publication, the number of active programs has increased 25%, with 5 institutions adding new WM GME fellowships (Table 1 footnote). To date,

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Table 1. Wilderness medicine fellowship programs and alumni in the United States in 2019

Fellowship program institution	*Year started*	*No. of survey respondents (% total responses)*	*No. of alumni in the database (% survey response in 2019)*
Stanford University School of Medicine	2003	9 (20)	18 (50)
Harvard Medical School	2005	5 (11)	13 (38)
The University of Utah School of Medicine	2007	8 (17)	11 (73)
The University of California San Francisco Fresno Medical Education Program	2008	3 (7)	13 (23)
Madigan Army Medical Center	2010	3 (7)	12 (25)
The University of Colorado School of Medicine	2011	3 (7)	10 (30)
Medical College of Georgia at Augusta University	2011	2 (4)	4 (50)
The State University of New York Upstate Medical University[a]	2011	1 (2)	5 (20)
The University of Massachusetts Chan School of Medicine, Baystate	2012	5 (11)	15 (33)
George Washington University School of Medicine	2012	1 (2)	2 (50)
The University of California San Diego School of Medicine	2013	2 (4)	5 (40)
Eastern Virginia Medical School[a]	2013-16	0 (0)	0 (0)
The University of New Mexico School of Medicine	2014	2 (4)	5 (40)
Yale University School of Medicine	2016	1 (2)	3 (33)
Virginia Tech Carilion School of Medicine	2016	0 (0)	9 (0)
The David Geffen School of Medicine at University of California Los Angeles	2018	1 (2)	1 (100)
Wake Forest School of Medicine	2018	0 (0)	1 (0)
Totals		n=46	n=111 (in 2019)

Note: Between the time the survey was sent out and publication, the number of active programs had increased to 20, with the State University of New York Upstate Medical University reinstating its program and Madigan Army Medical Center not currently recruiting. The 5 new institutions include The University of California Irvine School of Medicine; The Geisel School of Medicine at Dartmouth; The University of Nevada, Reno School of Medicine; The Oregon Health and Science University School of Medicine; and The Joe R. and Teresa Lozano Long School of Medicine at The University of Texas Health Science Center at San Antonio.

[a]Retired program as of 2019.

the accreditation council for GME does not accredit WM fellowship programs since WM is not one of the specialties represented by the American Board of Medical Specialties member boards.

The WM fellowship curriculum is designed to shape fellows into academic leaders, educators, and researchers within the field of WM.[1,2] An evaluation of professional outcomes and satisfaction of WM GME fellowship alumni in the United States may guide current and future programs. The objective of this research was to understand how fellows apply their training to advance the WM subspecialty and their careers and to learn about the perceived value of and program satisfaction with a WM fellowship from the perspective of fellowship graduates.

Methods

An online Qualtrics survey was emailed to 111 GME WM fellowship graduates from 17 different institutions in May through June 2019 (Table 2). Emails were obtained through the Wilderness Medical Society (WMS) GME fellowship alumni database. This database is updated annually to include contact information for graduates of GME WM fellowship training programs and is maintained by WM fellowship program directors.

The survey consisted of 34 multiple choice, fill in the blank, and preference rank questions written by the researchers (Table 2). Commonly used terms, such as "publication," "leadership," and "professor" were not strictly defined in the survey, and respondents independently interpreted each question.

All participants were initially contacted via email and invited to participate in an anonymous and voluntary survey. The survey was active for 8 wk after the first email. An email reminder was sent out to all contacts 1 wk after the initial survey was sent, and a second reminder after 3 wk. Each email contained the same link to the confidential survey. To control for duplicate submissions, only 1 survey response per email address was accepted. Respondents were not offered monetary compensation for their participation.

Table 2. Study survey and response rate

Survey question (no. of respondents)	*Answer: no. (% of responses)*		
1.Which have you completed? (46)	FAWM only: 0	GME only: 16 (35)	Both: 30 (65)
2. What year did you complete your FAWM (if applicable)? (21)	Prior to 2005: 0	2006–2012: 7 (33)	2013–2019: 14 (67)
3. Where did you complete your fellowship? (46)	See Table 1: 46 (100)		
4. Fellowship completion year (46)	2003–2008: 3 (7)	2009–2014: 6 (13)	2015–2019: 37 (80)
5. Sex (46)	Male: 27 (59)	Female: 17 (37)	Decline: 2 (4)
6. Did you take courses in Wilderness Medicine prior to fellowship? (30)	Student elective: 15 (50) Leadership school: 11 (37)	Residency rotation: 17 (57) Other: 4 (13); DiMM, WEMT, military	Conference CME: 23 (77) None: 2 (7)
7. When did you decide on a WM fellowship? (45)	Undergrad: 3 (7) Attending: 4 (9)	Medical School: 5 (11)	Residency: 33 (73)
8. Are you a current member of any wilderness medicine societies or focused groups? (46)	Yes: 46 (100)	No: 0	
9. In the past 5 y have you mentored WM fellows in an academic institution or through the WMS? (45)	Yes: 25 (56)	No: 20 (44)	
10. In the past 5 y have you conducted and published research within the field of WM? (45)	Yes: 32 (71)	No:13 (29)	
11. In the past 5 y, how many publications in the field of WM have you authored? (45)	None: 11 (24) ≥10: 1 (2)	1–5: 28 (62)	≥5: 4 (9)
12. In the past 5 y have you conducted and published research *outside* the field of WM? (45)	Yes: 21 (47)	No: 24 (53)	
13. In the past 5 y, how many publications *outside* the field of WM have you authored? (45)	None: 24 (53) ≥10: 0	1–5: 18 (40)	≥5: 3 (7)
14. In the past 5 y have you held broader scientific or health community leadership positions? (45)	Yes, WM: 6 (13) No: 30 (67)	Yes, another field: 4 (9)	Yes, both: 5 (11)
15. In the past 5 y have you held a leadership role within a professional society or scientific conference? (45)	Yes, WM: 13 (29) No: 27 (60)	Yes, another field: 0	Yes, both: 5 (11)

(continued on next page)

Table 2 *(continued)*

Survey question (no. of respondents)	*Answer: no. (% of responses)*		
16. Do you currently feel proficient in the knowledge and skills taught in a WM fellowship? (45)	Yes: 43 (96)	Not sure: 2 (4)	
17. Do you currently practice medicine? (45)	Yes 45 (100)	No 0	
18. Which best describes your workplace? (Choose all that apply.) (45)	Academics: 18 (40)	Private practice: 9 (20)	Both: 18 (40)
	Clinic: 2 (4)	Hospital: 43 (96)	
	Teaching: 15 (33)	Administration: 5 (11)	Research: 5(11)
	Consultant: 4 (9)	Expedition: 10 (22)	
Please rate how much you agree with the following statements (Q19–Q24):	Extremely disagree; Disagree; Slightly disagree; Neither agree nor disagree; Slightly agree; Agree; Extremely agree (See Table 3)		
Survey question (No. of respondents)			
19. My fellowship director was responsive to questions and concerns regarding career opportunities. (45)			
20. My fellowship offered exposure to an adequate variety of WM knowledge and skill sets. (45)			
21. My fellowship offered sufficient exposure to research opportunities in WM. (44)			
22. My fellowship adequately prepared me for a career in academic medicine. (43)			
23. My fellowship experience helped me build a relationship with a network of WM colleagues. (43)			
24. My fellowship experience helped me advance in my scholarly work. (45)			
25. How would you rate your fellowship experience? (Same scale; substitute agreement with satisfied) (45)			
Free text response entry (Q26–34)			
26. What is your current occupation and title(s)? (40)			
27. What percent of your time is allocated to each position(s)? (34)			
28. If the WM fellowship influence your choice in position(s), please state how: (25)			
29. Did the WM fellowship expose you to career choices previously unknown? (38)			
30. Do you think you would hold your current position(s) without the WM fellowship training? (44)			
31. How would you describe the effect the WM fellowship had on your clinical skills? (40)			
32. How did the WM fellowship influence your personal identity and world view? (32)			
33. In hindsight, would you follow the same professional path and attain a WM fellowship? (45)			
34. Do you have any general comments or reflections on the value of your WM fellowship? (31)			

CME, continuing medical education; DiMM, Diploma in Mountain Medicine; FAWM, Fellow of the Academy of Wilderness Medicine; WEMT, wilderness emergency medical technician; WM, wilderness medicine; WMS, Wilderness Medical Society.

Table 3. Satisfaction-related questions

Question	*Abbreviated*	*Question text*	*Mean*	*SD*	*N*
Q19	Satisfied director	My fellowship director and mentors were responsive to my questions and concerns regarding career opportunities.	5.7	1.4	45
Q20	Satisfied knowledge	My fellowship offered exposure to an adequate variety of wilderness medicine knowledge and skill sets.	6.1	1.3	45
Q21	Satisfied exposure	My fellowship offered sufficient exposure to research opportunities in Wilderness Medicine.	6.0	1.1	44
Q22	Satisfied career	My fellowship adequately prepared me for a career in academic medicine.	5.9	1.2	43
Q23	Satisfied network	My fellowship experience helped me build a relationship with a mentor and a network of colleagues in Wilderness Medicine.	6.1	1.3	43
Q24	Satisfied scholar	My fellowship experience helped me advance in my scholarly work.	5.9	0.9	45
Q25	Satisfied overall	How would you rate your overall fellowship experience?	6.0	1.3	45

Note: Numeric coding: extremely dissatisfied=1, very dissatisfied=2, slightly dissatisfied=3, neutral=4, slightly satisfied=5, very satisfied=6, extremely satisfied=7. A 1-way within-subjects analysis of variance was conducted to compare differences in satisfaction between questions. The results were not statistically significant (P=0.34).

Inclusion criteria from the database included alumni of any US GME WM fellowship program, with documentation that they graduated on or before June 2019. Alumni of WM fellowship programs from Eastern Virginia Medical School and The State University of New York Upstate Medical University were included as they are part of the alumni database, even though at the time both programs were inactive. For each question on the survey, individuals who provided an answer were included in the data analysis, and not answering a question was permitted.

Exclusion criteria included individuals who hold a Fellow of the Academy of Wilderness Medicine (FAWM) distinction from the WMS but did not complete a GME fellowship. Respondents who did not enter a fellowship institution or graduation year were excluded, and any individual entry with all questions left blank except fellowship institution and/or graduation year was excluded. Any individual who did not answer a question (ie, left blank) but completed the survey was excluded only from the data analysis of the single question.

Data were exported from Qualtrics survey software into an Excel spreadsheet. Descriptive statistics are represented as percent response (n=answered affirmative). Respondents were asked to rate their level of satisfaction across 6 areas of the fellowship program as well as the program overall (Table 3). To determine if satisfaction were equal across satisfaction domains, we conducted a 1-way within-subjects analysis of variance. To determine the factors that impacted the overall satisfaction rating (satisfied overall), we conducted a multiple regression. Analyses were conducted using the R statistical program; missing data were treated using listwise deletion. Regression analysis is presented as (R^2 value, P-value) and (β coefficient value, P-value). A P-value of <0.05 was considered statistically significant. Institutional review board approval was obtained through the University of California San Francisco Fresno medical education program.

Results

The survey response rate was 41% (n=46/111). Each survey question and its response rate are outlined in Table 2. In total, respondents collectively reported publication of 190 articles, 114 of these articles within WM and 76 within another field. Satisfaction with different aspects of a structured fellowship training program were all rated highly (Table 3). The survey responses relating to satisfaction were not statistically significantly different depending upon section (P=0.34).

In terms of the overall experience (satisfied overall) we analyzed various covariates to determine which

Table 4. Factors impacting overall WM fellowship program satisfaction

	Coefficients	*Standard error*	*t-value*	*P-value*
Constant	−1.10	0.78	1.41	0.167
Satisfied director	0.00	0.13	0.03	0.973
Satisfied knowledge	0.79	0.13	6.18	<0.001[a]
Satisfied exposure	−0.08	0.14	0.54	0.594
Satisfied career	0.25	0.16	1.54	0.133
Satisfied network	0.21	0.11	1.90	0.067
Satisfied scholar	−0.05	0.17	0.27	0.791
Publications within WM	0.10	0.04	2.39	0.023[b]
Publications outside WM	0.03	0.07	0.37	0.716
Have mentored WM fellows	−0.01	0.22	0.04	0.969

Note. N=43, r^2=0.80, P<0.001. Missing data were treated using listwise deletion.
WM, wilderness medicine.
[a] P<0.001.
[b] P<0.05.

factors of the experience related to overall higher satisfaction ratings. A multiple regression that included satisfaction ratings (Table 3), number of publications, and participation as a mentor in WM was statistically significant (R^2=0.80, P<0.001). The results (Table 4) showed that participants who rated exposure to a variety of wilderness medicine knowledge and skills tended to rate the overall experience higher (β=0.79, P<0.001). Additionally, those who had a higher number of publications in wilderness medicine also rated the overall experience higher (β=0.10, P=0.023).

Overall, 48% (n=21) of respondents felt they would be able to hold their current occupation and/or job title without the WM fellowship training, with 39% (n=17) feeling it would not be likely and 14% (n=6) unsure or unclear. Professional titles endorsed by respondents in free text responses included emergency medicine physicians, medical directors, assistant professors, clinical instructors, WM fellowship directors, and nurse practitioner. Medical directors reported overseeing emergency medical services, search and rescue, and endurance racing events. Sixty-eight percent (n=26) of respondents felt their WM fellowship exposed them to career choices previously unknown, and named an introduction to academics, fellowship direction, race medicine, and expedition medicine as specific examples. Fifty-six percent (n=14) of respondents stated the WM fellowship influenced their choice in professional position(s), 36% (n=9) of respondents did not think it was influential, and 8% (n=2) were unsure. In hindsight, 76% (n=34) of respondents confirmed they would follow the same professional path, and 7% (n=3) asserted they would have chosen a different institution for their fellowship or criticized their own institution.

Seventy-eight percent (n=28) of respondents described improved clinical skills because of their WM fellowship training, and 22% (n=8) reported minimal/no significant impact on clinical skills. In free text comments, several themes emerged: developed and/or improved outside hospital clinical skills (17%, n=6), developed and/or improved improvisational thinking/leadership and resource management/decision-making skills (17%, n=6), and broadened and/or improved a unique body of WM knowledge and skills (17%, n=6). Ninety-four percent (n=32) felt their personal identity and/or world views were influenced by their fellowship experience.

Discussion

A consensus wilderness medicine curriculum document stated that WM fellowship alumni should be able to demonstrate an understanding of WM knowledge and skills in different environments, possess the skill set necessary for an academic career in WM, and contribute to WM literature.[1,2] WM fellowship programs are graduating fellows who report feeling comfortable with the unique skills and knowledge taught during fellowship. High rates of reported publications in WM within the last 5 y suggest the cohort is advancing WM knowledge, regardless of whether these publications were done during or after a fellowship program.

It would have been ideal to compare results of alumni from other nonaccredited GME fellowship pathways predominately populated by the specialty of emergency medicine. A search for similar work was done using the Emergency Medicine Resident Association fellowship guide as reference.[3] A limited number of articles was available; peer-reviewed articles from non-EM specialties are included because they still serve as a point of comparison as the methodology is similar. Fellows illustrate a

high degree of professional involvement in a WM professional society or focused group, compared to 78% (n=18/23) participation in informatics professional societies among pathology informatics fellowship alumni.[4] WM fellows are participating in and contributing to the development of WM professional groups. WM societies and focused groups include but are not limited to the WMS, the Undersea and Hyperbaric Medical Society, the Society for Academic Emergency Medicine wilderness medicine interest group, and the American College of Emergency Physicians wilderness medicine section.

A large proportion of WM fellows work in academic medicine, with rates similar to those who complete a medical education fellowship in emergency medicine.[5] Respondents are contributing to the WM profession through high levels of medical society participation, but compared with pediatric emergency medicine fellows, WM fellows hold fewer leadership roles. The number of leadership positions held in the broader scientific community was 10% lower than among graduates of pediatric emergency medicine fellowships.[6] Similarly, the number of minimally invasive surgery fellows who occupy hospital or community leadership roles was 40% higher than among WM fellows.[7] Further research is needed to understand why few fellows hold WM leadership roles within community and hospital settings.

Eighty-eight percent of geriatric emergency medicine fellows and 89% of emergency ultrasound fellows believe completion of their respective fellowships helped them obtain their current career positions, compared to 40% of WM fellowship graduates.[8,9] This is significant as it raises questions about the benefits of pursuing a WM fellowship. However, fellowship satisfaction in WM is still high among respondents, and our research shows that fellows are benefiting from their experience not only professionally but also personally. Common themes from free text entries included influence on career choice, a broadened awareness of the global medical community, and confidence and personal identity within the subspecialty. These multidimensional influences are similar to influences among those who complete a fellowship in medical education, without a focus on emergency medicine.[10] Fellows from medical education and WM fellows expressed confidence as educators, a sense of self-reliance, enhanced professional credibility, and an identity within a subspecialty community.[10] Future data collections may attempt to understand the relationship between high fellowship satisfaction and changes in professional and personal outlooks.

This paper focused on US GME fellowships. International medical educational opportunities are not included. There are international certification programs that do not require medical residency training for completion. Examples include the University of Exeter in England, which offers a clinical fellowship in extreme medicine for medical students. The Royal College of Physicians and Surgeons of Glasgow offers a nonclinical, postgraduate international diploma in expedition and wilderness medicine. Many organizations offer a Diploma in Mountain Medicine (DiMM), which is an internationally recognized certification. Although providing a complementary pathway to enhancing personal and professional satisfaction with incorporation of wilderness medicine into a career, fee-based certification programs are not analogous to postgraduate university-based GME training opportunities; direct comparison is not appropriate within the scope of this paper.

A minority of respondents expressed career-changing frustration with the culture of the academic environment. Some did not feel respected, others wished they had chosen different institutions for fellowship, and 2 individuals ultimately did not choose an academic career because of their fellowship experience. This noticeable dissatisfaction could be due to a mismatch in a fellow's expectations and the reality of their fellowship. Another explanation could be that some programs are new and there is a natural flow of trial and error. There may be a role for a GME committee at professional societies to fill this identified gap both confidentially and systematically.

Further research could explore the program satisfaction and academic productivity of individuals who attain the distinction of being an FAWM through the WMS. A comparison between GME WM fellowships and an FAWM distinction could lead to greater insight into enhanced training and professional satisfaction among professionals who are looking to advance the subspecialty. Fellows who have completed an honorary fellowship in psychiatry, for example, feel the associated mentorship program within the professional society had the greatest potential for future development and was an area of high value to early professionals.[11] The personal satisfaction from mentorship relationships may increase long-term involvement in the subspecialty and should be examined in the context of the distinction of FAWM.

LIMITATIONS

The sample and sample size are significant limitations to our study. The WMS GME fellowship database used to collect alumni email addresses was likely not a comprehensive list. Some fellowship directors are not active in the WMS and may not regularly update the database with their graduates. Researchers did not validate email addresses, which may contribute to the small sample size. The population size of WM fellowship alumni, at 111 persons in the database (in 2019), requires a

proportionally large ideal sample size of 87 responses to keep the margin of error at 5% if maintaining a confidence level of 95%. Our sample size was only 48 respondents.

In order to make the survey user friendly, and to maximize the number of responses available to interpret, completion of all questions on the survey was not required. The shifting denominator and various sample sizes, by survey question, weakens the generalizability of our conclusions. Future studies would benefit from requiring answers to all questions prior to survey submission.

The study was based on a voluntary response survey and relies on retrospective self-reports, which introduce issues of selection and reporting bias. Due to the anonymity of the survey and the lack of required documentation, overinflated self-reports of research and publication activity are possible. Respondents may have included non-peer-reviewed publications, and it is likely that a single peer-reviewed publication shares multiple co-authors who responded to the survey, inflating the estimation of the total number of publications produced by fellowship alumni. Research publications were not objectively measured by a survey query for personal citations or PubMed IDs due to the time-consuming nature of such an inquiry, and such documentation would eliminate any sort of respondent anonymity. While the majority of respondents are involved in one or more fields of academia, the survey did not query a specify skill set for an academic career, and further research is required to understand if WM fellowship alumni are meeting academic standards.[1,2] Honorary titles without administrative responsibilities could have been reported as leadership roles. The lack of verifying self-reports must be considered when reviewing any conclusions from this data. The survey outcomes were limited to US-based publications and leadership opportunities and did not include international programs or degrees.

Conclusions

WM GME fellowship alumni report contributing to the subspecialty through high rates of professional engagement and scholarly productivity. Reported peer-reviewed publication rate was strongly associated with satisfaction responses. Despite overall high satisfaction with their postgraduate programs, many respondents still felt they would be able to hold their current professional position(s) without the training. WM GME fellowship programs providing a wide exposure to wilderness knowledge and skills are more likely to yield professionally satisfied graduates, thereby increasing the perceived value of the training beyond future job titles.

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References

1. Lipman GS, Weichenthal L, Harris NS, McIntosh SE, Cushing T, Caudell MJ, et al. Core contents for wilderness medicine fellowship training of emergency medicine graduates. *Acad Emerg Med*. 2014;21(2):204–7.
2. Sward DG, Bennett BL. Wilderness medicine. *World J Emerg Med*. 2014;5(1):5–15.
3. Shafer K, ed. *Wilderness Medicine. EMRA fellowship guide: Opportunities for Emergency Physicians*. 2nd ed. Irving, TX: Emergency Medicine Residents' Association, 2018.
4. Rudolf JW, Garcia CA, Hanna MG, Williams CL, Balis UG, Pantanowitz L, et al. Career paths of pathology informatics fellowship alumni. *J Pathol Inform*. 2018;9:14.
5. Jordan J, Ahn J, Diller D, Riddell J, Pedigo R, Tolles J, et al. Outcome assessment of medical education fellowships in emergency medicine. *AEM Educ Train*. 2021;5(4):e10650.
6. Gorelick MH, Schremmer R, Ruch-Ross H, Radabaugh C, Selbst S. Current workforce characteristics and burnout in pediatric emergency medicine. *Acad Emerg Med*. 2016;23(1):48–54.
7. Park AE, Sutton ER, Heniford BT. Minimally invasive surgery fellowship graduates: their demographics, practice patterns, and contributions. *Surgery*. 2015;158(6):1462–7.
8. Goldflam K, Papanagnou D, Lewiss RE. Emergency ultrasound: a survey study of fellowship graduate characteristics and career paths. *J Ultrasound Med*. 2018;37(2):487–92.
9. Thatphet P, Rosen T, Kayarian F, Southerland L, McQuown CM, Dresden S, et al. Impact of geriatric emergency fellowship training on the careers of emergency physicians. *Cureus*. 2021;13(9):e17903.
10. Lown BA, Newman LR, Hatem CJ. The personal and professional impact of a fellowship in medical education. *Acad Med*. 2009;84(8):1089–97.
11. Roberts LW, Kim JP, Samuels C, Winstead D. Perceptions of the professional development value of honorary fellowship award experiences. *Acad Psychiatry*. 2016;40(5):761–7.

WILDERNESS & ENVIRONMENTAL MEDICINE 2022; 33(2): 162–8

ORIGINAL RESEARCH

Static Rope Rescue Operations in Western Norway: A Retrospective Analysis of 141 Missions

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Introduction—The Norwegian national standard for rescuers describes medical and rescue requirements for helicopter emergency medical services (HEMS) technical crew members, but there is a lack of scientific data supporting these requirements and their safety relevance. The study aims to analyze the rescue profile of Norwegian HEMS static rope human external cargo operations, emphasizing terrain challenges and additional safety measures utilized on-site.

Methods—We conducted a retrospective descriptive analysis of static rope missions performed in daylight by 3 HEMS bases in Western Norway in the period 2015 to 2019. The analysis measures evacuation methods, terrain, on-site safety measures, and medical treatment.

Results—Out of 8352 primary HEMS and search and rescue missions, a total of 141 (2%) static rope missions were performed by the 3 HEMS bases in Western Norway. The most commonly used evacuation method was triangle harness (62%) and a static rope length of 30 m (81%). Ninety-two (65%) missions were completed in simple terrain, 38 (27%) in challenging terrain, and 11 (8%) in complex terrain. There were no reported accidents, but a small number of adverse events were registered. The most frequent medical intervention administered on-site was pain management, followed by spinal immobilization.

Conclusions—Thirty-five percent of the static rope missions performed by HEMS in Western Norway were completed in challenging or complex terrain, requiring additional safety measures on-site. The most common safety measure needed was the ability to operate in a mountain or alpine environment. Our findings support the safety relevance of a national standard for rescuers.

Keywords: air ambulance, rescue work, safety management, wilderness medicine

Introduction

Previous studies on human external cargo (HEC) rescue have indicated that HEC missions can be a useful means to reach and evacuate patients from areas where access is difficult, as compared to ground-based rescues.[1-4] Currently, 2 different HEC methods are applied in the helicopter emergency medical service (HEMS): hoist and static rope. Both are accepted as equivalent HEC rescue methods by the European Union Aviation Safety Agency when landing is not a safe option.[5] A recent study from Norway showed that static rope HEC missions can reduce time to treatment and time to hospital by providing early access to medical treatment and evacuation.[6] Although most patients evacuated in HEC missions have suffered minor injuries, medical treatment is frequently required, and pain management is the most regular treatment given.[6-8] More advanced treatment options such as endotracheal intubation are rare.[6,8-10]

Static rope missions have been a part of the Norwegian HEMS mission profile since the late 1970s. There is a well-established consensus within the HEMS service that static rope missions require rescuers who are physically capable and skilled in rescue techniques like

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mountaineering and swimming, but there is a lack of scientific data supporting this notion. A government-approved national standard for rescuers in the air ambulance service, the rescue helicopter service, and offshore search and rescue gives a good overall outline of the required competences for rescuers in HEMS, but it is quite general in its competence descriptions, leaving room for individual interpretation.[11-13]

The main objective of this study was to identify the typical features of static rope missions in Norwegian HEMS, focusing on terrain challenges, rescue methods, and on-site patient care. This knowledge could allow us to postulate on the competence and skills needed for rescuers in Norwegian HEMS to perform HEC missions and on whether additional safety measures are required in these missions.

STATIC ROPE IN NORWEGIAN HEMS

The Norwegian HEMS utilizes only the static rope HEC method, with the HEMS technical crew member as the rescuer. None of the helicopters are equipped with a hoist. The HEMS technical crew members are emergency medical technicians, paramedics, or nurses with additional training and competence in rescue techniques, operational concepts, medicine, and flight operations, as specified in the national standard.[5,12] The pilot maneuvers the helicopter visually during the static rope mission and is supported by the emergency physician, who is positioned on the starboard side of the cabin with the door fully opened. The physician acts as a load observer, indicating directions in all 3 dimensions, based on visual observations, standardized hand signals from the HEMS technical crew member, and standardized communication. National rules and risk analyses stipulate that static rope missions only be performed during daylight. Depending on terrain and operational conditions, static rope missions can be carried out with different rope lengths, from 10 to 60 m. Missions requiring a hoist are often performed by or in cooperation with helicopters from the rescue service, which are equipped with a hoist.

All static rope missions are conducted in accordance with a standard operating procedure, and all missions include standard safety measures (Table 1), both hard defenses (eg, harnesses, helmets, dual hooks, static rope) and soft defenses (eg, human performance, standardized procedures, communication, manual helicopter handling skills).[14] When the HEMS technical crew member operates at the target site, there is frequently a need for additional safety measures, most often soft defenses such as basic mountaineering skills if the crew member disconnects from the static rope, but there is currently no established system for registering this aspect.[12]

There are 2 main static rope methods in the Norwegian service: static rope over land and static rope over water. In static rope over land, the HEMS technical crew member is lifted from a preparation site to and from the target site, hanging from the static rope. In static rope over water, there are 2 procedures. The primary procedure for static rope over water is an adjusted variant of a military helocast technique, called "ihopp."[15] The HEMS technical crew member is attached to the rope, sits on the starboard side of the helicopter, and jumps into the water from approximately a 3.5-m hover; thereafter, he or she is lifted ashore, together with the victim, hanging from the 10-m rope (Figure 1). The secondary static rope over water procedure is a traditional water pickup, where the HEMS technical crew member is lifted to and from the target site hanging from the rope. All crew members are required to do static rope training every 90 d and static rope over water training every 180 d.

Methods

All operational data from the Norwegian HEMS missions are entered in an operational database, the Norwegian air ambulance occurrence logging and administrative system (NOLAS), developed in FileMaker (Filemaker Inc, Santa Clara, CA). For the purpose of this study, we chose to collect data from the 3 HEMS bases in the Western Norway Regional Health Authority: Førde, Bergen, and Stavanger. These HEMS bases carry out approximately 22% of all HEMS missions in Norway, and the region has a slightly higher rate of static rope missions compared to other regions.[16] The Western HEMS bases are all located in urban areas but cover a mixed urban and rural population of approximately 1.2 million with a geography varying from coastline to high mountains. We limited data extraction to the period from January 2015 through December 2019 to obtain data from the most recent missions and incorporate a period after the "ihopp" procedure was reintroduced by the service in 2012. Initially, we identified primary missions and search and rescue missions in which the static rope on the helicopter was used (Figure 2). Quantitative data from the static rope missions concerning rope lengths, evacuation methods, rescue equipment, geographic area, target accessibility, adverse events, and accidents, combined with the mission report written in free text by the HEMS technical crew member, were retrieved from NOLAS by the system administrator.

Different definitions and classifications of terrain exist, but few are specific to HEMS and helicopter rescue. The Union Internationale des Associations d'Alpinisme grading scale for mountaineering and

Table 1. Definitions of central words and concepts used in the study

Safety measure	A hard or soft defense planned to prevent, mitigate, or control an undesired event or accident. A hard defense is a safety measure passively preventing an accident from taking place (eg, attachment to an anchor or rope). Soft defense refers to human performance safety measures actively preventing an accident from taking place (eg, use of mountaineering or swimming skills to operate safely).[14]
Additional safety measure	Additional hard or soft defenses required on-site by the rescuer.
Simple terrain	Terrain with a low risk severity, no injury potential. Safe to operate unaided on-site.
Challenging terrain	Terrain with a medium risk severity, minor injury potential. Active use of soft defenses as additional on-site safety measure is required.
Complex terrain	Terrain with a high risk severity, severe injury potential. Active use of both soft and hard defenses as additional on-site safety measures is required.
Adverse event	Undesirable event without personnel or material damage.
Victim	Unharmed person not admitted to a medical facility.
Patient	Person admitted to a medical facility.
Fatality	Person deceased at target site.
Primary mission	Mission dispatched by an emergency medical communication center to patients located outside of a medical facility.
Secondary mission	Interhospital transfer mission.
SAR mission	Search and rescue (SAR) mission dispatched by the joint rescue coordination centers.
Rescue mission	A primary or SAR mission where a registered rescue technique or method is utilized, such as static rope, light on skid, ground-based rescue, water rescue, or aerial search exceeding 5 min.

descriptions of slope angles or accessibility are used in several studies to specify terrain.[11,17-21] To include the on-site risk severity in rescue missions, a system for classifying simple, challenging, and complex terrain was developed for the intent of this study by the Norwegian air ambulance rescue technical department (Table 2). The main purpose of the system was to incorporate the physical characteristics of the terrain and to identify whether the HEMS technical crew member could operate unaided on-site (low risk severity), actively had to use additional soft defenses (medium risk severity), or actively had to use both additional hard and soft defenses (high risk severity). This system was used to accurately classify the terrain in retrospect. At first, terrain data from the mission reports were categorized according to Table 2. Then, mission data and the terrain classifications were validated by each of the HEMS technical crew members, respectively.

Missions reported as physically demanding were registered to provide insight into the physical requirements of static rope missions. Medical treatment given on-site by the HEMS technical crew member, registered in NOLAS, was also quantified.

Figure 1. Ihopp: the primary static rope over water procedure in Norwegian HEMS (courtesy of Fred Sirevaag).

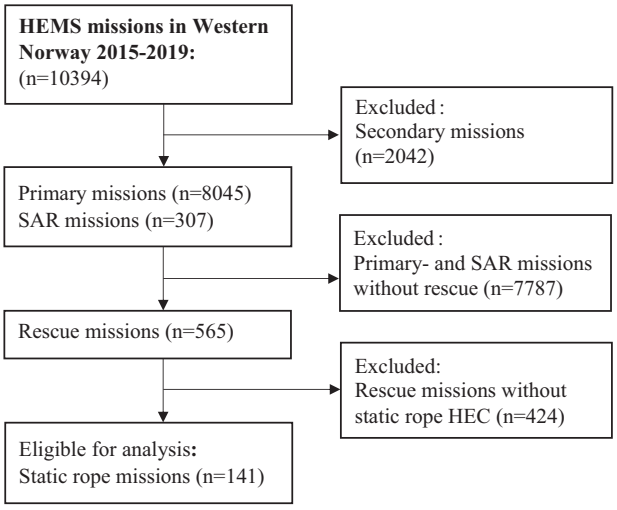

Figure 2. Flowchart showing selection of static rope missions qualified for analysis.

The study was exempted from ethical review by the Norwegian Regional Committee for Medical and Health Research (REK Helse Vest) after a preliminary review, since the study does not collect patient identifiable data or impose experimental treatment (reference number 255231). The study was approved by the Norwegian air ambulance data collection officer in accordance with the rules from the Norwegian Social Science Data Services. Voluntary consent from all HEMS technical crew members was collected before proceeding with data collection from all potentially involved participants in the study.

Results

We identified 8045 primary HEMS and 307 search and rescue missions in the 5-y period for which data were collected. Of these, 565 (7%) were rescue missions, with 141 (2%) fulfilling the criteria of a static rope mission. Twenty-three different HEMS technical crew members with an average of 9 y of experience were involved in the 141 missions. Fifty-six missions were initially identified as performed in challenging or complex terrain after an analysis of the mission reports. Seven of these were downgraded to simple terrain by the involved HEMS technical crew members, as the reported terrain description did not reflect the actual on-site risk severity. This resulted in an accurate classification of 92 (65%) missions in simple terrain, 38 (27%) in challenging terrain, and 11 (8%) in complex terrain. The missions in challenging and complex terrain required additional safety measures on-site (Table 2). The most common safety measure needed was the ability to operate in a mountain or alpine environment (26%), followed by water or swift-water (4%), avalanche (4%), and snow-covered glacier and ice (1%). Four adverse events were reported (3%): 2 minor rotations, 1 with a triangle harness and 1 with a stretcher, and 2 contacts with objects, both with a triangle harness. All these events were in simple terrain with the use of a 30-m rope. There were no accidents reported during the study period.

Sixteen static rope missions (11%) were reported as physically demanding by the individual HEMS technical crew members. The most frequent reason recorded was that the HEMS technical crew member was alone at the target site, either with a victim/patient needing repositioning for a safe evacuation or a patient/fatality that had to be placed in a stretcher.

Most static rope missions were carried out over land (96%). Only 5 static rope missions were reported over

Table 2. Terrain classifications and safety measures during 141 helicopter emergency medical services static rope missions in Western Norway 2015–2019

Terrain classifications and safety measures	*n (%)*	*Total*
Simple[a]		92
Mountain/Alpine terrain with a steepness <30°	90 (64)	
ATES 1	2 (1)	
Challenging[b]		38
Solo movement in mountain/alpine terrain equivalent UIAA 3–4 or a steepness >30°	26 (18)	
Solo movement on snow-covered glacier and ice with a steepness >30°	2 (1)	
Solo movement in terrain equivalent ATES 2	5 (4)	
Rescue swimming in open water with waves <1 m	4 (3)	
Swift-water rescue equivalent IRGS 1–3	1 (1)	
Complex[c]		11
Solo movement in mountain/alpine terrain equivalent >UIAA 4 or a steepness >40° and		
Use of the helicopter static rope as a fall protection	5 (4)	
Attachment to an anchor	6 (4)	

ATES, avalanche terrain exposure scale[21]; UIAA, Union Internationale des Associations d'Alpinisme[19]; IRGS, international river grading scale.[22]

[a]Risk severity low and safe to operate unaided on-site.

[b]Risk severity medium and active use of soft defenses was required as additional on-site safety measure.

[c]Risk severity high and active use of both soft and hard defenses was required as additional on-site safety measures.

water or swift-water, and one of these was completed with the secondary static rope over water procedure in swift-water. Four "ihopp" (3%) were registered, but 2 were cancelled before patient contact. The most frequently used evacuation method was triangle harness (62%), followed by stretcher evacuation (32%). A pickup sling was used in 5 (4%) missions, and the victim's own harness was used in 3 (2%) evacuations. In 81% of all missions, a rope length of 30 m was used. The second most regularly used rope length was 20 m (11%), and 10-m rope was used in 5 missions (4%), all in static rope over water procedures. A rope length of 40 m was used in 4 (3%) missions, and 50 m was used in 2 (1%) missions. The longest rope length, 60 m, was not reported as used in the study period.

Two missions used a double attachment procedure; this is a standardized method where at least 1 attachment point is active at all times, ensuring that the rescuer and patient are secured through all phases of the operation. In 4 missions, the HEMS technical crew member established an anchor at the target site independently. All were in complex terrain, and 1 of the anchors was used in combination with the double attachment procedure. Two anchors involved the use of slings around trees, 1 used slings around rocks, and 1 involved the use of a snow anchor. Five missions reported active use of the helicopter static rope as a fall protection due to a high-risk severity when operating on-site (Table 2).

A total of 117 patients, 12 victims, and 12 fatalities were registered. Thirty-six (41%) of the patients in simple terrain were treated on-site before evacuation. In challenging terrain, 12 (57%) of the patients received medical treatment on-site. Only 4 patients were located in complex terrain, 2 of whom received medical treatment before evacuation. Of those who required medical interventions on-site by the HEMS technical crew member, pain management (58%) was the most frequently administered treatment, most commonly intravenous (33%) and intranasal (25%). The second most common intervention was spinal immobilization (46%), followed by splinting (23%) and fracture realignment (12%).

Discussion

In this retrospective observational study of static rope missions in Western Norway, we found that 35% of the static rope missions were carried out in challenging or complex terrain requiring additional safety measures due to an increased risk severity on-site. Most static rope missions were over land, and the most common medical intervention provided was pain management. No serious incidents were reported in the study period.

Regular safety measures needed seem to be the expertise to assess different operational environments and to be a generalist in mountaineering and rescue swimming (Table 2). These findings have some similarities with results from previous studies. A study from northern Norway classified terrain into simple, demanding, or alpine terrain and focused on whether belaying was required.[18] This study found that 25% of the rescue missions were carried out in demanding terrain and 6% in alpine terrain. However, it did not mention details regarding safety measures or the physical terrain characteristics.[18] A study from the Alpine region of central Europe analyzed terrain difficulties and showed that in 31% of all rescue operations, personal advanced climbing skills were necessary.[17] The consensus recommendations from the International Commission for Mountain Emergency Medicine, regarding HEMS in mountain rescue, also suggests that rescuers should have a high level of experience in mountaineering and rescue techniques.[11] Our findings, especially regarding mountaineering, correlate well with the results from these previous studies, but more data are necessary to postulate detailed requirements in a Norwegian context. Related to the Norwegian national standard, which states that the rescuer should be able to operate in all environments and provide rescue while maintaining the safety of both the patient and the crew,[12] our findings support that the standard has safety relevance when conducting static rope missions.

Most static rope missions were performed with a 30-m rope. This is a practical rope length for most situations and provides a reasonable trade-off in maintaining enough distance between the HEMS technical crew member and the helicopter, allowing access in difficult terrain, and precisely maneuvering the HEMS technical crew member to the scene. From that perspective, it might seem like an efficient solution to stick with this 1 rope length for all missions. When analyzing the rope lengths considering the terrain classifications, 58% of the missions using rope lengths of 10, 20, 40, or 50 m were completed in challenging or complex terrain, compared to 30% of the missions with 30-m rope. This might indicate that more demanding terrain sharpens the need for precision and better visual references for the pilot.

Static rope missions are a very small portion of the HEMS repertoire. Several studies have shown that patients requiring evacuation in remote areas and HEC in Norway suffer from minor injuries.[6-8] The Norwegian model, where the rescue specialist, the HEMS technical crew member, is at the "sharp end" of the rope to provide both a safe rescue and adequate medical care for patients therefore seems like a safe and cost-beneficial model. Regular and increasing dispatches to

rescue missions also necessitate that the service has preparedness and training in rescue techniques.[16]

In common with our research, several studies have shown pain management to be the most common medical intervention provided during HEC missions.[7,9,23] In most services, high-dose pain medication is a physician-only intervention. In Norway, however, the HEMS technical crew member can administer analgesics independently, on delegation from the emergency physician. Recently, intranasal administration has also emerged as an alternative that may be a safe route of administration with a similar analgesic effect.[24] Most missions requiring medical interventions prior to static rope evacuation were performed in simple terrain. However, several patients in challenging and complex terrain required medical treatment before evacuation. This illustrates that the HEMS technical crew member must be able to operate safely to evacuate the patient and be able to provide medical care even in complex and challenging terrain.

To our knowledge, Norwegian HEMS is the only service to have developed and implemented a static rope method for over water rescue such as the "ihopp" procedure. Although the number of static rope over water missions was small in our data, we know from a recent report to the Norwegian Labour Inspection Authority (April 2020) that HEMS is dispatched to incidents involving water rescue on a regular basis, but in most cases the patient is evacuated to land before the arrival of HEMS. Water rescue can be very time-critical, and to minimize preparation time for the "ihopp" procedure, the method allows for the HEMS technical crew member to be fully prepared for "ihopp" when the helicopter takes off from the HEMS base. No studies have so far investigated the relevance and time effectiveness of this method. Further research regarding HEMS HEC water rescue would be beneficial.

In the static rope missions analyzed in our study, missions in complex terrain were rare: approximately 0.1% of all the HEMS missions. Complex terrain involves a higher risk for both patients and rescuers, and although Norwegian HEMS has methods such as the double attachment procedure that can mitigate some of the risks, we do not know for certain how often missions are completed in either challenging or complex terrain on a national level. There are no known quality indicators specific to the skills required by the HEMS technical crew member in a Norwegian context, but the national standard lists several formal rescue requirements.[12,25] Even though the NOLAS database has extensive data regarding HEMS missions in general, the method used in this study for validating terrain classifications has detected that the database lacks details regarding difficulties and challenges encountered on-site in rescue missions. Indexing data as an alternative to free text registering of safety measures and terrain might improve these identified database discrepancies. We hope that the system used in this study to quantify terrain challenges (Table 2) could contribute to a more comprehensive understanding and analysis of rescue missions in the future.

LIMITATIONS

The study has some limitations. First, as it was based on data registered by several HEMS technical crew members over a time span of 5 y, it may be prone to observational bias and reporting bias on behalf of the HEMS technical crew members entering the data. For example, both experience and current training may have influenced the data registered, leading to over- or underreporting. Second, some of the included data are based on the rescue reports written in free text by the HEMS technical crew members; this constitutes a potential important source of analysis bias. To counteract this, all registered data and terrain classifications were validated by the involved HEMS technical crew members using the criteria in Table 2 to ensure accuracy and supply extra information. Third, the number of static rope missions analyzed in this study was small and involved the 3 HEMS bases operating in the area covered by the Western Norway Regional Health Authority. However, a total of 13 HEMS bases operate in Norway, and we do not know for certain whether our findings are representative for other areas of Norway with somewhat different geographic challenges (eg mountain bases). Future studies should, therefore, include prospective data from all 13 HEMS bases in Norway. Fourth, patient sensitive data, like age, gender, or injury, were not included in this study. We therefore cannot exclude the possibility that a patient's condition influenced the choice of rescue technique. Future studies should therefore also include patient data, to improve our understanding of how this may impact the static rope mission profile.

Conclusions

Over a 5-y period at 3 HEMS bases in Western Norway, 49 (35%) out of 141 static rope missions were completed in challenging or complex terrain, requiring additional safety measures on-site. The most common safety measure needed was the ability to operate in a mountain or alpine environment. Of the patients rescued in challenging or complex terrain, 56% received medical treatment before evacuation. Our findings support the safety relevance of the Norwegian national standard for rescuers.

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References

1. Hotvedt R, Kristiansen IS, Forde OH, Thoner J, Almdahl SM, Bjørsvik G, et al. Which groups of patients benefit from helicopter evacuation? *Lancet*. 1996;347(9012):1362–6.
2. Frankema SP, Ringburg AN, Steyerberg EW, Edwards MJ, Schipper IB, van Vugt AB. Beneficial effect of helicopter emergency medical services on survival of severely injured patients. *Br J Surg*. 2004;91(11):1520–6.
3. McVey J, Petrie DA, Tallon JM. Air versus ground transport of the major trauma patient: a natural experiment. *Prehosp Emerg Care*. 2010;14(1):45–50.
4. Carpenter J, Thomas F. A 10-year analysis of 214 HEMS backcountry hoist rescues. *Air Med J*. 2013;32(2):98–101.
5. European Union Aviation Safety Agency. Notice of proposed amendment 2018–04. Available at: https://www.easa.europa.eu/sites/default/files/dfu/NPA%202018-04.pdf. Accessed May 10, 2021.
6. Samdal M, Haugland HH, Fjeldet C, Rehn M, Sandberg M. Static rope evacuation by helicopter emergency medical services in rescue operations in Southeast Norway. *Wilderness Environ Med*. 2018;29(3):315–24.
7. Samdal M, Eiding H, Markengbakken L, Roislien J, Rehn M, Sandberg M. Time course of hoist operations by the search and rescue helicopter service in Southeast Norway. *Wilderness Environ Med*. 2019;30(4):351–61.
8. Reid BO, Haugland H, Rehn M, Uleberg O, Kruger AJ. Search and rescue and remote medical evacuation in a Norwegian setting: comparison of two systems. *Wilderness Environ Med*. 2019;30(2):155–62.
9. Pietsch U, Strapazzon G, Ambuhl D, Lischke V, Rauch S, Knapp J. Challenges of helicopter mountain rescue missions by human external cargo: need for physicians onsite and comprehensive training. *Scand J Trauma Resusc Emerg Med*. 2019;27(1):17.
10. Pietsch U, Knapp J, Kreuzer O, Ney L, Strapazzon G, Lischke V, et al. Advanced airway management in hoist and longline operations in mountain HEMS - considerations in austere environments: a narrative review. This review is endorsed by the International Commission for Mountain Emergency Medicine (ICAR MEDCOM). *Scand J Trauma Resusc Emerg Med*. 2018;26(1):23.
11. Tomazin I, Ellerton J, Reisten O, Soteras I, Avbelj M. Medical standards for mountain rescue operations using helicopters: official consensus recommendations of the International Commission for Mountain Emergency Medicine (ICAR MEDCOM). *High Alt Med Biol*. 2011;12(4):335–41.
12. Norwegian Ministry of Justice and Public Security, Norwegian Ministry of Health and Care Services. Nasjonal standard for redningsmenn i luftambulansetjenesten, redningshelikoptertjenesten og SAR – offshore, 18.july 2002, revision 2 10.february 2019. Available at: https://www.regjeringen.no/contentassets/5289520970904efcbf54ccb6f807f628/revidert-nsr-2019-final-006.pdf. Accessed December 5, 2020.
13. Callender N, Ellerton J, MacDonald JH. Physiological demands of mountain rescue work. *Emerg Med J*. 2012;29(9):753–7.
14. Reason J. Hazards, defences and losses. In: *Managing the risks of organizational accidents*. Farnham, UK: Ashgate Publishing Limited, 1997:1–20.
15. Department of the Army. Aircrew training manual utility helicopter H-60 series. Available at: http://cdn.asktop.net/wp/download/5/TC1_237.pdf. Accessed December 5, 2020.
16. The National Norwegian Air Ambulance Service. Aktivitet luftambulansetjenesten 2020. Available at: http://www.luftambulanse.no/system/files/internett-vedlegg/aktivitet_luftambulansetjenesten_2020.pdf. Accessed May 10, 2021.
17. Kupper T, Hillebrandt D, Steffgen J, Schoffl V. Safety in alpine helicopter rescue operations–minimal requirements of alpine skills for rescue personnel. *Ann Occup Hyg*. 2013;57(9):1180–8.
18. Glomseth R, Gulbrandsen FI, Fredriksen K. Ambulance helicopter contribution to search and rescue in North Norway. *Scand J Trauma Resusc Emerg Med*. 2016;24(1):109.
19. Linxweiler E, Maude M. Appendix A: Rating systems. In: *Mountaineering, The Freedom of the Hills*. 9th ed. The Mountaineers Books; 2017:563–70.
20. Durrer B. Characteristics of emergency therapy in mountain accidents. *Ther Umsch*. 1993;50(4):228–33.
21. Statham G, McMahon B, Tomm I. The avalanche terrain exposure scale. In: *Proceedings of the International Snow Science Workshop, Telluride, CO*. 2006:491–7.
22. Dudnath K, Gorman J, Graham D, Jones P, McLay M, Onions C, et al. Hydrology. In: *Swiftwater and Flood Rescue Technician*. 5th ed. Rescue 3 International; 2016:24–39.
23. Sherren PB, Hayes-Bradley C, Reid C, Burns B, Habig K. Are physicians required during winch rescue missions in an Australian helicopter emergency medical service? *Emerg Med J*. 2014;31(3):229–32.
24. Corrigan M, Wilson SS, Hampton J. Safety and efficacy of intranasally administered medications in the emergency department and prehospital settings. *Am J Health Syst Pharm*. 2015;72(18):1544–54.
25. Haugland H, Uleberg O, Klepstad P, Kruger A, Rehn M. Quality measurement in physician-staffed emergency medical services: a systematic literature review. *Int J Qual Health Care*. 2019;31(1):2–10.

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ORIGINAL RESEARCH

Travel-Associated Venous Thromboembolism

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Introduction—Long-distance travel is assumed to be a risk factor for venous thromboembolism (VTE). However, the available data have not clearly demonstrated the strength of this relationship, nor have they shown evidence for the role of thromboprophylaxis.

Methods—We performed a systematic review of the literature. We also summarized available guidelines from 5 groups.

Results—We found 18 studies that addressed this question. Based on the data presented in the review, we conclude that there is an association between VTE and length of travel, but this association is mild to moderate in effect size with odds ratios between 1.1 and 4. A dose-response relationship between VTE and travel time was identified, with a 26% higher risk for every 2 h of air travel (P=0.005) starting after 4 h. The quality of evidence for both travel length and thromboprophylaxis was low. However, low-risk prophylactic measures such as graduated compression stockings were shown to be effective in VTE prevention. There is heterogeneity among the different practice guidelines. The guidelines generally concur that no prophylaxis is necessary in travelers without known thrombosis risk factors and advocate for conservative treatment such as compression stockings over pharmacologic prophylaxis.

Conclusions—We conclude air travel is a risk factor for VTE and that there is a dose relationship starting at 4 h. For patients with risk factors, graduated compression stockings are effective prophylaxis.

Keywords: airplane, thrombosis, stockings, embolism, heparin, thrombophlebitis

Introduction

Venous thromboembolism (VTE) is a common and sometimes lethal disease. In the United States, the incidence is as high as 900,000 people per year, with 60,000 to 100,000 deaths per year.[1] Risk stratification and disease prevention are especially critical, as sudden death occurs in nearly 25% of patients with pulmonary embolisms (PE).[1] Known VTE risk factors include immobilization, recent surgery, pregnancy, oral contraceptive use, malignancy, and inherited thrombophilias.[2]

An association between extended travel and VTE was first documented in the 1950s,[3] and this relationship continues to be observed. The link was considered so strong that travel-associated VTE was nicknamed "economy class syndrome" in the 1970s.[4] Further studies expanded this relationship to not just air travel, but to any mode of travel.[5] Pathophysiologic mechanisms have been explored, many centering on the role of immobilization, but none have proven the link between travel and VTE.

Despite the common notion that travel and VTE risk are definitively linked, the data are unclear as to the magnitude of this risk, the association between duration or type of travel and VTE risk, and the role of prophylaxis in mitigating this risk. We performed a systematic review of the literature to provide clarity to practitioners. Finally, we reviewed current major guidelines on travel-associated VTE to supplement these findings.

Methods

A systematic literature search was conducted to locate studies addressing the risk of VTE based on travel length

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and the role of thromboprophylaxis in reducing VTE risk. The specific questions were as follows: In adults traveling by plane, train, or automobile, does the risk of thrombosis increase with the length of travel; and in adults traveling by plane, train, or automobile, does the use of thromboprophylaxis decrease the risk of deep vein thrombosis (DVT)/VTE? The search included comparative studies, controlled clinical trials, evaluation studies, guidelines, meta-analyses, randomized clinical trials, or systematic reviews.

The inclusion criteria were comparative studies, controlled clinical trials, evaluation studies, guidelines, meta-analysis, randomized clinical trials, or systematic reviews in the English language published since 2007. We searched Ovid MEDLINE for relevant studies published in the English language since 1946, which resulted in over 500 articles relating to VTE risk and prophylaxis in travelers, 18 of which met the inclusion criteria that allow comparisons of travel length as a thrombosis risk factors and studies/meta-analysis of prophylaxis. Studies analyzed in systemic reviews are not separately mentioned. Two authors (TK, AH) independently evaluated the studies for relevance and quality. Discussion of analysis of individual studies cites original authors' own conclusions and not reanalysis of data by the authors. External guidelines on VTE management in travelers were also identified.

Results

RISK OF VTE BASED ON TRAVEL LENGTH

Our search yielded 4 systematic reviews and 6 nonrandomized studies. One of the systematic reviews also performed 2 meta-analyses, one of air travel alone and the other of all types of transport.[6] Table 1 summarizes the main characteristics of these studies. The studies show an increase in VTE risk with travel, with odds ratios (OR) ranging from 1.1 to 4.0.[2,6,7] Increasing duration of travel was also found to be significantly associated with VTE in 2 studies.[7,8]

One review, including 14 studies totaling over 4000 cases of VTE, found that the overall pooled relative risk (RR) for VTE in travelers was 2.0 (95% CI, 1.5−2.7).[7] Further analysis of a dose-response relationship between travel and VTE found an 18% higher risk for VTE for each 2-h increase in duration of travel by any mode (P=0.010) and a 26% higher risk for every 2 h of air travel (P=0.005).[7] Another review also examined duration of travel and found that both duration (<6 h compared to 6−8 h: OR 0.011) and clinical risk were significantly related to VTE rate.[8]

A 2007 systemic review examined 55 studies, including case-controlled studies, observational studies, and randomized controlled trials. Analysis of 3 of those case-controlled studies showed a pooled OR for flights over 8 h of 3.9 (95% CI, 1.4−10.7). Two of the observational studies found an absolute risk for symptomatic VTE within 4 wk of flights greater than 4 h as 1/4600 flights. Further, the risk of severe PE occurring immediately after air travel increased with duration of flight, from 0 events in flights <3 h to 4.8 per 1 million persons in flights >12 h.[2]

A review of 8 case-controlled studies found that the OR between long travel time and VTE varied from 1.1 to 4.0, which was significant in only 4 out of the 9 studies.[6] Of the 2 meta-analyses completed in this paper, 1 analysis focused on travel by plane, finding the relationship between long travel time and VTE was not significant (OR=1.21; 95% CI, 0.95−1.55). The second meta-analysis focused on all types of transport and reported a slightly higher clinical significance (OR=1.46; 95% CI, 1.24−1.72). A study limited to pulmonary embolisms noted a 17-fold increase in risk with flight distances over 5000 km (>6 h).[9]

Overall, the available research suggests there is thrombotic risk of travel and this does increase with increasing lengths of travel. However, absolute risks remain low with a low quality of evidence. Odds ratios from the systematic reviews show a mild effect size with high variability among reviews. Some studies show no significantly increased association at all.[6,10] Furthermore, the quality of available evidence is low due to study inconsistency as noted in Table 1. In some studies, the risk with very short travel (<4 h) appears to be lower than in controls. This was believed to be due to the "healthy traveler" effect that assumes that people who are traveling have fewer risk factors for thrombosis than controls.[11] In the systematic reviews, the limitations were primarily due to low or unexamined study quality, or inconsistent methods and results across studies. In the nonrandomized studies, primary limitations were inadequate control of confounding and difference in prognostic indicators at baseline. Individual study limitations are listed in Table 1.

EFFICACY OF THROMBOPROPHYLAXIS

Our search yielded 3 systematic reviews and 3 nonrandomized studies. Table 2 summarizes the main characteristics of these studies. Two of the systematic reviews also addressed length of travel and VTE risk,[2,8] while 1 addressed solely the effect of compression stockings on flights lasting at least 4 h and included 10 studies.[2,8,12] This study found that wearing stockings on both legs during flight significantly reduced the risk of VTE, with an OR of 0.1 (95% CI, 0.04−0.25, P<0.00001).[12] Similarly, it was found that graduated compression stockings (GCS) prevented travel-related

Table 1. Studies assessing risk of venous thromboembolism based on travel length

Author; year published; study type; n	*Patient population or studies analyzed*	*Study intervention/comparator*	*Endpoint results/Outcome*	*Study limitations*
Beam et al (2009); prospective; cohort study; n=7940[10]	Patients with suspected PE	Intervention: Recorded 1 of 6 types of immobility: no immobility, general or whole-body immobility >48 h, limb (orthopedic) immobility, travel >8 h causing immobility within the previous 7 d, neurologic paralysis, or other immobility not listed above.	Risk of VTE was substantially increased by presence of limb, whole-body, or neurologic immobility but not by travel greater than 8 h (travel OR=1.19; 95% CI, 0.85−1.67).	None
Chandra et al (2009); systematic review with meta-analysis; 14 studies with n=4055[7]	Reports investigating association between travel and VTE for persons who used any mode of transportation and if nontraveling persons were included for comparison	Intervention: Patients traveling at least 3 h (11 studies), with 3 studies with no limitation or not reporting travel time. Comparator: Nontravelers	Overall pooled RR for VTE in travelers: 2.0 (95% CI, 1.5−2.7); after exclusion of studies with referred controls: pooled RR: 2.8 (CI, 2.2−3.7), without significant heterogeneity; 18% higher risk for VTE for each 2-h increase in duration of travel by any mode (*P*=0.010) and a 26% higher risk for every 2 h of air travel (*P*=0.005).	Methods and/or results were inconsistent across studies.
Kuipers et al (2007); systematic review; 55 studies[2]	Studies of air travel with VTE	Intervention: *Case-Control studies (n=10)*: travel frequency of cases of symptomatic VTE. *Observational follow-up studies (n=14):* travelers screened for VTE. *RCTs (n=11):* assessed the effect of various prophylactic measures on the risk of VTE after air travel. *Pathophysiological studies (n=14):* Studies looked at what factors and mechanisms increase the risk of VTE after air travel.	*Case-Control studies:* Pooled OR=1.7 (95% CI, 1.4−2.1) Flights >8 h: pooled OR=3.9 (95% CI, 1.4−10.7) *Observational follow-up studies:* absolute risk of a symptomatic event within 4 wk of flights >4 h: 1/4600 flights. Risk of severe PE immediately after travel: 4.8 per million in flights longer than 12 h. *RCTs:* Due to high risk of bias among studies, the results were not discussed in the systematic review. *Pathophysiological studies:* Insufficient data and excessive variability to draw conclusions.	Quality of studies was not appraised or studies were low quality. Methods and/or results were inconsistent across studies.

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Table 1 *(continued)*

Author; year published; study type; n	*Patient population or studies analyzed*	*Study intervention/comparator*	*Endpoint results/Outcome*	*Study limitations*
Kuipers et al (2014); prospective cohort study; n=2630[22]	All pilots who were members of the Dutch pilot union between 1993–2003	Intervention: Pilots questioned for the occurrence of VTE, presence of risk factors for VTE, and number of flight hours per year and rank. Comparator: General Dutch population and a population of frequently flying employees of multinational organizations.	Six VTEs were reported, yielding an incidence rate of 0.3 per 1000 person-years. Standardized morbidity ratios comparing pilots to other populations: 0.8 (general population), 0.7 (all employees), 0.6 (frequently traveling employees). The incidence rate did not increase with number of flight hours per year and did not clearly vary by rank.	Failure to adequately control confounding. Differences in important prognostic factors at baseline.
MacCallum et al (2011); case-control; n=550 cases and 1971 controls[23]	Adults with confirmed VTE on anticoagulants, with sex-matched controls	Intervention: Questionnaire to ascertain basic demographic characteristics, history of VTE, air travel within the past 2 y, and surgery within the past 2 y.	Cumulative flying time >12 h within the previous 4 weeks: OR=2.75 (95% CI, 1.44–5.28). Flying time >4 h in a single leg in the previous 4 weeks: OR=2.20 (95% CI, 1.29–3.73). These risks were no longer evident by 12 wk and were similar to those of day-case or minor surgery (OR=5.35; 95% CI, 2.15–13.33).	Differences in important prognostic factors at baseline.
Philbrick et al (2007); systematic review; 25 studies[8]	Primary data concerning the risk of travel for VTE or tested preventive measures for travel-related VTE	Intervention: Risk of travel-related VTE (6 case-control studies, 10 cohort studies).	Results: Duration of travel (<6 h compared to 6–8 h, OR=0.01) and clinical risk ("higher" risk travelers compared to "lower," OR 3.6) were significantly related to VTE rate.	Quality of studies was not appraised or studies were low quality.
Pietrzyk (2016); retrospective chart analysis; n=2007[24]	Adult patients on passenger vessel who presented with suspicion of DVT after air flight >8 h	Intervention: In patients with possible DVT, Wells score, lower extremity ultrasound, and D-dimer were performed. Comparator: passengers without DVTs	Results: The study showed 3 (0.15%) patients with possible DVT (based on Wells score) of a total of 2007 passengers who have completed a flight >8 h, of whom only 2 (0.1%) had positive ultrasound and D-dimer findings.	Failure to adequately control confounding. Differences in important prognostic factors at baseline.

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Table 1 *(continued)*

Author; year published; study type; n	*Patient population or studies analyzed*	*Study intervention/comparator*	*Endpoint results/Outcome*	*Study limitations*
Schreijer et al (2009); case-control; n=11,033[21]	Consecutive patients ages 18−70 y with first episode of VTE	Intervention: Flight >4 h less than 9 wk prior to date of VTE Comparator: Patient partners	Results: Window seating compared to aisle seating increased the risk twofold (OR=2.2; 95% CI, 1.1−4.4). The risk was not affected by alcohol consumption (OR=1.1; 95% CI, 0.5−2.4). Flying business class may lower the risk but is not significant (OR 0.7; 95% CI, 0.2−1.8).	None
Trujillo-Santos et al (2008); systematic review; 9 studies[6]	Case-control studies, no language or publication date restriction	Intervention: Calculated ORs with 95% CIs for each study	Results: OR varied between 1.1 and 4.0 The studies were highly heterogeneous in methodology. Meta-analysis: plane travel only (OR=1.21; 95% CI, 0.95−1.55); all types of transport, (OR=1.46; 95% CI, 1.24−1.72).	Quality of studies was not appraised or studies were low quality. Methods and/or results were inconsistent across studies.
Lehmann et al (2009); retrospective chart review; n=57[8]	Patients with acute PE Exclusion criteria: Secondary PE after admission or admission based on a non-PE primary diagnosis	Intervention: All travel-associated PE cases, independent from the mode of transportation, were combined under economy-class syndrome. This definition includes PE due to prolonged sitting in a plane, bus, train, or car, and 1 patient in a simulation. Furthermore, they distinguished between air-travel economy-class syndrome and non-air-travel economy-class syndrome.	In general, economy-class syndrome was a rare event (1 event/5 million passengers), where long-haul flights over 5000 km lead to a 17-fold risk increase compared with shorter flights.	Failure to adequately control confounding.

OR, odds ratio; PE, pulmonary embolism; RCT, randomized control trial; RR, relative risk; VTE, venous thromboembolism.

VTE ($P<0.05$ in 4 of 6 studies).[8] In that review, low-molecular-weight heparin (LMWH) showed a trend toward efficacy in reducing VTE risk, while aspirin had no effect. Interestingly, a prospective cohort study analyzing patients with acute VTE after long travel time found that travelers with VTE used LMWH prophylaxis significantly less frequently compared to others in a VTE patient registry (2.4% vs 1.3%, OR=0.2, 95% CI, 0.1−0.3).[13]

The last systematic review only discussed one thromboprophylaxis trial due to high risk of bias among other studies and noted that use elastic compression stockings had a relative risk of 0.04 (0−0.6) for VTE.[2]

A registry study evaluating the development of edema and vein thrombosis in subjects with different levels of risk for thrombosis using prophylaxis found that a natural supplement of French maritime pine bark significantly decreased edema compared to both stockings and the control for all risk groups ($P<0.05$).[14] The authors noted no DVTs in the groups taking the supplement or wearing stockings, only in the control groups.

A prospective cohort study analyzing factors affecting popliteal venous blood flow found that blood flow was decreased by almost 40% when patients were seated without mobility and by 48% when they sat motionless without feet touching the floor. They had subjects do a series of exercises of increasing intensity and found that the most rigorous foot exercises against increased resistance increased blood flow significantly ($P<0.0001$).[15] However, no known trials have specifically studied exercises with thrombosis as an endpoint.

As with the association between length of travel and VTE, the available research is of low quality. Compression stockings have the strongest data to suggest a prophylactic benefit. Two studies both found that GCS decrease VTE risk, but as before, the quality of evidence is low due to study inconsistency.[8,12] We found no study to suggest anticoagulation is effective in travelers for preventing VTE. The nonrandomized studies were limited by failure to control confounding factors, inadequate follow-up, and differences in prognostic indicators at baseline.

PUBLISHED GUIDELINES

We analyzed guidelines on VTE prophylaxis in nonsurgical patients from 5 sources. The strength of the guidelines was generally low, with 2 sources writing conditional recommendations[16,17] and the other 2 based on low evidence grades.[18,19]

The American Society of Hematology's 2018 guideline for VTE in nonsurgical patients included conditional recommendations based on very low certainty in the evidence about effects. For long-distance travel (>4 h) in travelers without known risk factors for VTE, they recommended against prophylaxis (including GCS, LMWH, or aspirin), although they acknowledged that GCS may be used in travelers who place a high priority on VTE prevention and noted that GCS reduce edema, which may make travel more comfortable for some. In people at substantially increased risk for VTE (eg, recent surgery, history of VTE, hormone replacement therapy, pregnant or postpartum women, active malignancy, or 2 or more risk factors), they recommended prophylaxis with GCS or LMWH for travel >4 h. If neither GCS nor LMWH is feasible, they recommended using aspirin rather than no treatment.[17]

The Saudi Arabia Ministry of Health's 2017 guidelines recommended frequent ambulation, calf muscle exercise, sitting in the aisle seat, and anticoagulants for high-risk travelers on journeys >8 h. They recommended against using GCS for prophylaxis.[16]

The American College of Chest Physicians 2012 guideline recommendations were similar to the Saudi Arabian recommendations, as they suggested frequent ambulation, calf muscle exercise, and sitting in the aisle seat. They differ in that they did suggest GCS (15−30 mm Hg of pressure) for high-risk travelers. The American College of Chest Physicians recommended against GCS in non−high-risk travelers, and they recommended against the use of anticoagulants or aspirin in VTE prevention. All evidence is Grade 2C.[18]

The American College of Obstetricians and Gynecologists released a committee opinion in 2018, which recommended preventative measures such as support stockings and periodic movement of the lower extremities, avoidance of restrictive clothing, occasional ambulation, and maintenance of adequate hydration in all pregnant women flying in order to lower the potential risk of edema and DVTs. They acknowledged that there was no strong evidence associating air travel and DVTs during pregnancy.[20]

Finally, the British Society of Haematology recommended that travelers at increased VTE risk wear below-knee compression hosiery (Grade 2B). If medication is indicated, they recommended use of anticoagulants over antiplatelet agents (Grade 2C). Maintaining mobility was recommended for all travelers on journeys over 3 h due to likely pathogenesis of travel-related VTE (Grade 2B), but use of GCS or anticoagulants for all travelers was not recommended (Grade IC).[19]

In summary, there is significant discord among guideline recommendations, with all groups acknowledging that the level of evidence is very low.

Table 2. Studies assessing efficacy of thromboprophylaxis

Author (year published); study type	*Patient population*	*Study intervention comparator*	*Endpoint results/Outcome*	*Study limitations*
Clarke et al (2021); systematic review; 11 RCTs[11]	RCTs of compression stockings on 1 or both legs vs no stockings or another intervention in passengers on flights ≥4 h	Intervention: 12 randomized trials (n=2918) were included; 10 (n=2833) compared wearing stockings on both legs vs not wearing them; 1 (n=35) compared wearing a stocking on 1 leg for the outbound flight and on the other leg on the return flight. One compared compression tights (n=50).	Results: 50 participants had a symptomless DVT; 3 wore stockings, 47 did not (OR=0.10; 95% CI, 0.04–0.25; $P<0.00001$). Wearing stockings had a significant impact in reducing edema (based on 6 trials). No significant adverse effects were reported.	None
Hitos et al (2007); prospective cohort; n=21[15]	21 healthy volunteers (21 limbs) with no history of thrombosis, leg trauma, swelling, surgery, lymphedema, venous reflux, or outflow obstruction	Intervention: Popliteal vein blood flow measured with subjects sitting motionless, sitting with feet off floor performing airline-recommended activities, foot exercises, foot exercises against moderate resistance, and foot exercises against increased resistance.	Results: Blood volume flow in the popliteal vein was reduced by almost 40% with immobility of seated subjects and by almost twofold when sitting motionless with feet not touching the floor. Foot exercises against increased resistance positively enhanced volume flow ($P<0.0001$).	Incomplete or inadequately short follow-up.
Kuipers et al (2007); systematic review; 55 studies[2]	Studies of air travel with VTE	Intervention: *RCTs (n=11):* assessed the effect of various prophylactic measures on the risk of VTE after air travel.	Results: *RCTs:* Due to high risk of bias among studies, the results were not discussed in the systematic review.	Quality of studies was not appraised or studies were of low quality. Methods and/or results were inconsistent across studies.
Tsoran et al (2010); prospective cohort study; n=26,172[13]	Consecutive patients with symptomatic, acute (DVT) or PE, confirmed by objective tests	Intervention: Registry records patients' baseline characteristics; risk factors for VTE, including 6-h and longer traveling during the past 3 wk and the mode of traveling; clinical characteristics of the VTE event; usage of LMWH prophylaxis.	Results: Travelers used LMWH prophylaxis significantly less frequently than other patients in the registry (2% vs 13%; OR=0.2; 95% CI, 0.1–0.3).	Differences in important prognostic factors at baseline.

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Table 2 *(continued)*

Author (year published); study type	*Patient population*	*Study intervention comparator*	*Endpoint results/Outcome*	*Study limitations*
Philbrick et al (2007); systematic review; 25 studies[8]	Primary data concerning the risk of travel for VTE or tested preventive measures for travel-related VTE	Intervention: Prevention (9 RCTs)	Results: *Prevention:* Graduated compression stockings prevented travel-related VTE ($P<0.05$ in 4 of 6 studies), aspirin did not, and LMWH showed a trend toward efficacy in 1 study.	Quality of the studies was not appraised or studies were of low quality. Methods and/or results were inconsistent across studies.
Belcaro et al (2018); registry study; n=295[14]	Patients at different levels of DVT risk flying in economy class for more than 8 h, twice in less than 7 d	Intervention: Subjects were subdivided in 3 groups according to their risk level (low, moderate, or high). All risk groups were divided by 3 interventions: The high-risk group also received aspirin. The standard management (control) group included education about DVT and its prevention during travel, a group receiving pycnogenol (150 $mg \cdot d^{-1}$ equivalent to 3 $cps \cdot d^{-1}$ was started 3 d before the flights and stopped 3 d after the second flight), and a group wearing stockings.	Results: Low-risk group n=105 (33 pycnogenol, 36 controls, 36 stockings): Edema was reduced more ($P<0.05$) with pycnogenol and stockings compared to control. Pycnogenol reduced edema significantly more than the stockings ($P<0.05$). Ankle circumference was smaller with pycnogenol ($P<0.05$). No thrombosis was detected. Thermal imaging revealed no hot spots, indicating the absence of an inflammatory of thrombosed area. Medium-risk group n=108 (32 pycnogenol, 38 controls, 38 stockings): Edema and ankle circumference were lower in the pycnogenol group ($P<0.05$). One DVT and 1 minimal SVT was seen in controls. High-risk group n=82 (25 pycnogenol, 25 control, 32 stockings): Edema and ankle circumference were significantly reduced in the pycnogenol group ($P<0.05$) compared to both controls and stockings. There was no SVT or DVT in the pycnogenol group. One minimal DVT and 1 SVT were observed in controls.	Failure to adequately control confounding.

DVT, deep vein thrombosis; LMWH, low-molecular-weight heparin; OR, odds ratio; PE, pulmonary embolism; RCT, randomized control trial; SVT, superficial vein thrombosis.

Discussion

The best available studies find an association between VTE and travel, but the available data show only a mild to moderate increased association, with high heterogeneity among studies. Odds ratios vary from as low as 1.1[10] to 4,[6] but generally point to a link between travel and VTE, with 7 out of 10 studies showing a significant association between the two. Germane to our question, a dose-response relationship can be identified, with studies finding increased risk of VTE and severe PE after longer flights compared to shorter ones.[2,7-9] Although the studies used a variety of flight times to assess effects after "longer" flights, increased risk of VTE was noted even when the cut-off was as low as >4 h, indicating that travel does not need to be especially extensive to pose an increased risk. Although some studies attempted to identify other potential risks, there were not many clear associations between other travel factors and VTE.[21,22] For example, despite the common name of "economy class syndrome," flying business class did not significantly lower the risk, although window seating did increase the risk twofold.[21] It is difficult to come to a stronger conclusion due to the low quality of evidence and high heterogeneity within and among studies.

Although the data on thromboprophylaxis and VTE are similarly low quality, low-risk prophylactic measures such as GCS were shown to be effective.[8,12,15] The data do not elucidate the role of pharmacologic anticoagulation. LMWH showed a trend toward efficacy in one study,[8] and travelers with VTE used LMWH less frequently than others in another,[13] but no study showed a significant change in VTE risk with pharmacoprophylaxis. The available guidelines all differ slightly but largely follow the prophylaxis data. In general, the guidelines recommend against prophylactic measures in patients without known VTE risk factors. This is appropriate as clinical VTE after travel is a rare event in patients.[8] In patients with risk factors for VTE, the guidelines generally advocate for conservative interventions such as GCS[17-19] and maintaining frequent ambulation with calf exercises.[16,18,19]

The key finding of this review is the poor quality of data describing travel-associated VTE and the lack of evidence for prophylaxis. Better observational data to define risk and prospective trials of prophylaxis in high-risk patients will better answer these questions going forward. Until the time such data are available, providers must make decisions based on the limited data we have and appropriate clinical judgment.

Despite this uncertainty, the issue of thrombosis with travel is frequently brought up by both patients and providers. Until there are more robust data, the following can be recommended:

- Air travel is a risk factor for VTE and there is a dose effect starting at 4 h.
- For patients with risk factors—or those concerned about thrombosis—GCS 15 to 30 mm Hg can be recommended.
- Guidelines emphasize the role of hydration and ambulation for all passengers.

Although frequently prescribed, there is only limited data for LMWH prophylaxis—and none yet for the direct oral anticoagulants. Pharmacologic prophylaxis either with LMHW or with direct oral anticoagulants may be considered for very high-risk patients (eg, history of thrombosis, cancer), with acknowledgement of the very limited data available.

Given the vast numbers of people who travel, there is a need for solid clinical data to estimate risk of travel-related thrombosis. Important clinical trials could include examining the VTE risk at increasing flight lengths (eg, 3 vs 4 h; 4 vs 5 h) so that we could better establish a time limit above which risk is increased. This would be helpful clinically as the available data do not offer a unifying definition of what is a "longer," and thus riskier, flight. As many people travel long distances not only by plane but also by car and train, another possible trial could examine VTE risk with specific modes of transportation. Currently, the data tend to describe risk due to flight alone, to all modes of transportation, or to all modes except flight. It would be helpful to know specifically whether the increased risk we see with air travel also applies to travel by car and train. If that same risk does not exist, it not only changes clinical practice but also implies that there is some quality about air travel in particular, beyond the time spent, that increases thrombotic risk. This too could be an area of study as the pathophysiologic studies on air travel do not offer a clear mechanism of disease. Finally, studies need to be performed to better define the role—if any—of pharmacologic prophylaxis.

Conclusions

The available evidence is of low quality both for defining risk of air travel and thrombosis as well as preventive measures. We conclude air travel is a risk factor for VTE and that there is a dose relationship starting at 4 h. For patients with risk factors, GCS are effective prophylaxis. Further high-quality studies are needed both to better define the risk of and to prevent travel-related thrombosis.

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References

1. Beckman MG, Hooper WC, Critchley SE, Ortel TL. Venous thromboembolism: a public health concern. *Am J Prev Med*. 2010;38(4 Suppl):S495–501.
2. Kuipers S, Schreijer AJ, Cannegieter SC, Buller HR, Rosendaal FR, Middeldorp S. Travel and venous thrombosis: a systematic review. *J Intern Med*. 2007;262(6):615–34.
3. Louvel J. [Four cases of phlebitis due to air travel]. *Arch Mal Coeur Vaiss*. 1951;44(8):748–9.
4. Symington IS, Stack BH. Pulmonary thromboembolism after travel. *Br J Dis Chest*. 1977;71(2):138–40.
5. Kesteven PL. Traveller's thrombosis. *Thorax*. 2000;55(Suppl 1):S32–6.
6. Trujillo-Santos AJ, Jimenez-Puente A, Perea-Milla E. Association between long travel and venous thromboembolic disease: a systematic review and meta-analysis of case-control studies. *Ann Hematol*. 2008;87(2):79–86.
7. Chandra D, Parisini E, Mozaffarian D. Meta-analysis: travel and risk for venous thromboembolism. *Ann Intern Med*. 2009;151(3):180–90.
8. Philbrick JT, Shumate R, Siadaty MS, Becker DM. Air travel and venous thromboembolism: a systematic review. *J Gen Intern Med*. 2007;22(1):107–14.
9. Lehmann R, Suess C, Leus M, Luxembourg B, Miesbach W, Lindhoff-Last E, et al. Incidence, clinical characteristics, and long-term prognosis of travel-associated pulmonary embolism. *Eur Heart J*. 2009;30(2):233–41.
10. Beam DM, Courtney DM, Kabrhel C, Moore CL, Richman PB, Kline JA. Risk of thromboembolism varies, depending on category of immobility in outpatients. *Ann Emerg Med*. 2009;54(2):147–52.
11. Kuipers S, Cannegieter SC, Middeldorp S, Robyn L, Buller HR, Rosendaal FR. The absolute risk of venous thrombosis after air travel: a cohort study of 8,755 employees of international organisations. *PLoS Med*. 2007;4(9):e290.
12. Clarke MJ, Broderick C, Hopewell S, Juszczak E, Eisinga A. Compression stockings for preventing deep vein thrombosis in airline passengers. *Cochrane Database Syst Rev*. 2021;4(4):CD004002.
13. Tsoran I, Saharov G, Brenner B, Barron M, Valdes V, de la Roca Toda M, et al. Prolonged travel and venous thromboembolism findings from the RIETE registry. *Thromb Res*. 2010;126(4):287–91.
14. Belcaro G, Cornelli U, Dugall M, Hosoi M, Cotellese R, Feragalli B. Long-haul flights, edema, and thrombotic events: prevention with stockings and Pycnogenol supplementation (LONFLIT Registry Study). *Minerva Cardioangiol*. 2018;66(2):152–9.
15. Hitos K, Cannon M, Cannon S, Garth S, Fletcher JP. Effect of leg exercises on popliteal venous blood flow during prolonged immobility of seated subjects: implications for prevention of travel-related deep vein thrombosis. *J Thromb Haemost*. 2007;5(9):1890–5.
16. Al-Hameed FM, Al-Dorzi HM, Abdelaal MA, Alaklabi A, Bakhsh E, Alomi YA, et al. The Saudi clinical practice guideline for the prophylaxis of venous thromboembolism in long-distance travelers. *Saudi Med J*. 2017;38(1):101–7.
17. Schunemann HJ, Cushman M, Burnett AE, Kahn SR, Beyer-Westendorf J, Spencer FA, et al. American Society of Hematology 2018 guidelines for management of venous thromboembolism: prophylaxis for hospitalized and nonhospitalized medical patients. *Blood Adv*. 2018;2(22):3198–225.
18. Kahn SR, Lim W, Dunn AS, Cushman M, Dentali F, Akl EA, et al. Prevention of VTE in nonsurgical patients: antithrombotic therapy and prevention of thrombosis, 9th ed: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines. *Chest*. 2012;141(2 Suppl):e195S–226S.
19. Watson HG, Baglin TP. Guidelines on travel-related venous thrombosis. *Br J Haematol*. 2011;152(1):31–4.
20. ACOG Committee Opinion No. 746 summary: air travel during pregnancy. *Obstet Gynecol*. 2018;132(2):533–4.
21. Schreijer AJ, Cannegieter SC, Doggen CJ, Rosendaal FR. The effect of flight-related behaviour on the risk of venous thrombosis after air travel. *Br J Haematol*. 2009;144(3):425–9.
22. Kuipers S, Venemans-Jellema A, Cannegieter SC, van Haften M, Middeldorp S, Buller HR, et al. The incidence of venous thromboembolism in commercial airline pilots: a cohort study of 2630 pilots. *J Thromb Haemost*. 2014;12(8):1260–5.
23. MacCallum PK, Ashby D, Hennessy EM, Letley L, Martin J, Mt-Isa S, et al. Cumulative flying time and risk of venous thromboembolism. *Br J Haematol*. 2011;155(5):613–9.
24. Pietrzyk WS. Air travel-related symptomatic deep venous thrombosis in cruise ship passengers. *Int Marit Health*. 2016;67(2):66–71.

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ORIGINAL RESEARCH

Early Sport Specialization and Past Injury in Competitive Youth Rock Climbers

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Introduction—Sport specialization has been shown to have negative effects on athletes but has not been studied within rock climbing. This study seeks to evaluate the proportion and impact of specialization in pediatric climbers.

Methods—Climbers (ages 8–18 y) were recruited from throughout the United States to complete a 1-time survey regarding climbing experience, training patterns, and injury history. The main outcome of proportion of climbers suffering an injury was assessed within the last 12 mo and within their entire climbing experience (defined as "lifetime" injury). Early specialization was defined as exclusive participation in climbing, with training for >8 mo·y^{-1}, prior to age 12 y (late specialization if after age 12 y).

Results—Participants (n=111, 14±3 y [mean±SD], 69 females) were high-level climbers. Fifty-five percent of participants specialized in climbing, and 69% of those specialized early. Hand and ankle injuries occurred most commonly. Seventy-eight percent of late specialized climbers had a lifetime injury. Late specialized climbers were 1.6 times (95% CI: 1.1–2.3) more likely than early specialized climbers to have had a lifetime injury and 1.8 times (95% CI: 1.1–2.8) more likely to have had an injury in the last 12 mo. No difference in overuse injuries was found between specialization groups.

Conclusions—Early specialization is common among youth climbers but was not associated with an increase in injuries. Late specialization was associated with a higher likelihood of having had a climbing injury in the last 12 mo and during an entire climbing career.

Keywords: adolescent, youth sports, athletes, mountaineering

Introduction

In recent years, there has been an increase in the number of youth participating in adventure and extreme sports.[1] The popularity of adventure sports is expected to rise after the inclusion of rock climbing in the 2018 Youth Olympic games[2] and the debut of 3 new adventure sports in the 2020 Olympic games: rock climbing, skateboarding, and surfing.[3,4] The mean age of adventure sport athletes in the highest levels of competitions has decreased in recent decades.[5] While participation in adventure sports, including rock climbing, is associated with numerous benefits,[5-9] more youth may be specializing at earlier ages, potentially leading to higher injury rates and burnout. Sport specialization has been defined as intensive training and/or competing at a young age in a single sport for more than 8 mo of the year to the exclusion of other sports.[10] Athletes who specialize in their sport prior to puberty (often functionally defined as prior to age 12 y) are classified as early sport specializers.[11]

While eventual sport specialization may be necessary to achieve elite levels of performance,[12-16] current recommendations encourage delaying single sport specialization until mid to late adolescence.[10,11,15,17,18] Compared to athletes who participate in multiple sports,

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early sport specialization has been associated with a higher incidence of injury, decreased psychological well-being, and premature withdrawal from sport.[18-20] However, early specialization in highly technical sports, such as rhythmic gymnastics, may be important for achieving elite levels.[21] Similar to gymnasts, rock climbers may reach peak performance prior to full skeletal maturation, since lower body fat and high strength-to-mass ratio are beneficial.[22-25] While there are multiple publications on injury patterns and risk factors in youth climbers,[22-24,26,27] to the best of our knowledge, no studies to date have examined sport specialization within youth rock climbing.

Reasons to suspect high rates of specialization within climbing include a year-round youth climbing competition season and the ability to climb indoors throughout the year. Rock climbing places unique physical demands on young athletes, such as a particular emphasis on leanness,[23] as well as a high incidence of physeal overuse injuries.[22,23,28,29] However, the effects of specialization on injuries in youth climbing are currently unknown.

The purpose of our study was to examine the proportion of non-, early, and late specializers and the impact of this specialization on injuries among youth rock climbers. Secondary aims were to explore injury characteristics and factors associated with past injuries among elite youth climbers. We hypothesized that those who specialized early (prior to age 12 y)[11] were more likely to have had injury compared to their peers.

Methods

This cross-sectional survey study was deemed exempt by the institutional review board of record due to the inclusion of only deidentified data. Prior to completion of the survey, participants were presented a letter that informed them of the purpose of the study, procedures, potential risks, and contact information for the principal investigator and the institutional review board. Participants, and their legally authorized representative if younger than 18 y, indicated their agreement to participate in the study and proceeded to the survey questions. All research procedures conformed to the guidelines set forth by the Declaration of Helsinki.

The 1-time survey (see online Supplemental Material) was administered using an online survey link and was completely anonymous. The survey was developed and data were managed using REDCap electronic data capture tools. REDCap (research electronic data capture)[30,31] is a secure, web-based software platform designed to support data capture for research studies, providing 1) an intuitive interface for validated data capture; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for data integration and interoperability with external sources.

The survey contained 40 items and included the following sections: demographics, climbing experience, training characteristics, and injury history. Demographic items included age, gender, height, and weight, along with state of residence. Climbing level and experience included questions regarding years climbing, bouldering and sport climbing grade, and competition level (eg, local, regional, national). Training characteristics included questions regarding sport specialization derived from extant literature,[10,11] training methods (eg, hangboarding, campus boarding, systems wall), and injury prevention methods (eg, core strengthening, scapular strengthening, cardiorespiratory training). Injury history items assessed the total number of climbing-related injuries, along with a self-reported description of the most recent injury and time loss from climbing (see online Supplemental Material for climbing and training terminology definitions).

The survey was designed by the study team and face-validated for readability and appropriate climbing terminology by youth climbers and coaches. The target reading level of the survey was aimed at capturing the youngest climbers (8–12 y). The survey was also piloted on a group of 10 climbers in this age range, with favorable descriptive feedback. The average time to complete the survey was 10 min.

Currently, no universal definition of sport specialization exists in the literature.[32] Thus, the early-specialized group was defined based on the American Orthopaedic Society for Sports Medicine consensus statement as exclusive participation in climbing at the time of survey response, with training for greater than 8 mo out of the year, at the age of 12 y or under.[10] Those who specialized after age 12 y were defined as late-specialized. Those who reported participation in more than 1 sport, including climbing, were defined as nonspecialized. Participants were categorized as having "high training load" if they reported >16 $h \cdot wk^{-1}$ of training, or $h \cdot wk^{-1}$ > age.[10] An injury was defined as "any pain or injury that impacted your ability to climb or train or caused you to stop climbing for any period of time."

Injuries were characterized as "acute" or "overuse" based on reported injury mechanism. Reported mechanisms of "falling," "hard move while climbing," or "equipment broke" were considered acute. Injuries with a reported mechanism of "I don't remember a specific event that caused me to be injured" and "training for climbing" were considered overuse. Injuries with a reported mechanism of "other" were categorized based on the written description of the injury.

Table 1. Demographics and select characteristics of youth rock climbers

Characteristics	*Total*	*Male (n=41)*	*Female (n=69)*
Demographic characteristics			
Age (y)	14±3 (8–18)	14±3 (8–18)	14±3 (8–18)
Height (cm)	158±23 (122–188)	165±15 (122–188)	155±23 (127–178)
Weight (kg)	50±13 (23–82)	53±14 (23–77)	49±13 (27–82)
BMI ($kg \cdot m^{-2}$)	19±3 (13–32)	19±3 (14–32)	20±4 (13–32)
Climbing characteristics			
Hours per week	10±4 (2–25)	10±4 (4–21)	10±4 (2–25)
Months per year	12±1 (9–12)	12±1 (9–12)	12±1 (9–12)
V6 or higher (%)	68	73	64
5.12 or higher (%)	68	73	65
National or international competition (%)	36	27	41

Data presented as mean±SD (range).

The online survey link was distributed via email to youth climbing team coaches, including contacts of the study team and coaches identified by an online search for youth climbing teams in the United States. Coaches were asked to distribute the survey to team members for voluntary participation. No incentive was offered to coaches or survey participants. The survey link was also posted on competitive youth climbing-related social media pages. This approach was used to target climbers regularly involved in training and competition, rather than recreational climbers. Inclusion criteria for the study included participation in rock climbing, being ages 8 to 18 y, and the ability to read, write, or speak in English. The only exclusion criterion for this study was not meeting inclusion criteria.

SAS statistical software (version 9.4; SAS Institute, Cary, NC) was used to perform statistical analyses. The main outcome of proportion of climbers suffering an injury was assessed both within the last 12 mo and within their entire climbing experience (defined as "lifetime" injury). Chi-squared tests and risk ratio (RR) calculations were used to compare differences in the primary outcome between specialization groups. T-tests and Fisher's exact tests were used to compare differences in survey responses before and after March 2020. Participant demographics and climbing characteristics were presented with descriptive statistics mean±SD (range). The overall injury incidence was estimated by dividing total injuries reported by total climbing hours reported. Total climbing hours was estimated based on reported hours per week and months per year of climbing. A P value of ≤ 0.05 was used as the threshold for statistically significant difference.

Table 2. Number of months per year focused on climbing type

Please state the number of months of the year that you focus (spend most of your time) on each of the following types of climbing:	$Mo \cdot y^{-1}$
Indoor: Bouldering	7.5±2.9 (0–12)
Indoor: Sport	5.7±2.8 (0–12)
Indoor: Speed	2.2±3.2 (0–12)
Outdoor: Bouldering	1.1±1.8 (0–10)
Outdoor: Sport	0.8±1.6 (0–9)

Data presented as mean±SD (range).

Results

One hundred forty-seven survey responses were collected during the data collection period (11/2019–9/2020). Thirty-six survey entries were not included in the final analysis due to either no survey data entered (n=23), no climbing or training data entered (n=3), inappropriate age (n=9), or duplicate survey response (n=1). One hundred eleven youth climbers from around the United States completed the required sections on training and climbing experience (demographics through training section; see online Supplemental Material for full) and were included in the final analysis. Any missing data values were excluded from the corresponding statistical analysis. Due to the open nature of recruitment, researchers were unable to calculate a response rate. However, 111 surveys were ultimately included out of 136 age-appropriate survey respondents who opened the survey (81%).

Sixty-three percent of participants were female. The age was 14±3 (8–18) y (Table 1). Overall, participants were high-level climbers, with 36% having competed at the national or international level. The majority of time climbing was focused indoors, with more time focused on bouldering than sport climbing (Table 2).

Sport specialization was common, with 55% of all participants specializing in rock climbing and 38% of all climbers specializing early (≤12 y). The age of specialization was 11±2 (7–16) y. Participants climbed 10±4

Table 3. Number of climbers using training or injury prevention method at least once per week

Do you participate in any of the following consistently (at least once every week): (check all that apply)	*Number selected*	*% selected*
Hangboarding	55	50
Systems wall training	50	45
Campus board training	20	18
Hangboarding with weights	14	13
What injury prevention strategies do you do consistently (at least once every week)? (Please select all that apply)		
Core strengthening	85	77
Other strengthening (eg, push-ups, squats)	85	77
Complete rest day	80	72
Static stretching	79	71
Dynamic stretching	71	64
Cardio	51	46
Scapular strengthening	46	41

(2–25) h·wk^{-1} for 12±1 (9–12) mo·y^{-1}. No participant climbed for less than 9 mo·y^{-1}. Twenty-one percent of participants were categorized as having "high training load."[10] Many climbers regularly used climbing-specific training methods, with hangboarding and systems wall training being most common (Table 3). Participants reported starting campus board training at an age of 12±2 (8–16) y. Thirteen percent of climbers engaged in weighted hangboarding, beginning at an age of 14±3 (11–18) y. All climbers used at least 1 injury prevention technique consistently (at least once per week), with core and other strength exercises being the most common (Table 3).

Table 4. Distribution of injuries

Location of injury	*Number*
Hand/Finger	16
Ankle	15
Shoulder	7
Back	7
Knee	5
Wrist	4
Arm	4
Foot	2
Skin	2
Elbow	2
Hip/Groin	2
Neck	1
Total	**67**

Table 5. Analysis of specialization and injury in youth climbers

Group	*Lifetime injury (%)*	*Injury last 12 mo (%)*
Early-specialized (n=42)	50	41
Late-specialized (n=18)	78	72
Nonspecialized (n=41)	59	37
Risk ratio (95% CI): Late vs early	1.6 (1.1–2.3)	1.8 (1.1–2.8)
	***P*= 0.045**[a]	***P*=0.024**[a]
Risk ratio (95% CI): Late vs Non	1.3 (0.9–1.9)	2.0 (1.2–3.2)
	P=0.155[a]	***P*=0.012**[a]

[a]Chi-squared test.

Fifty-three percent of participants sustained at least 1 lifetime injury (during their climbing experience), with 40% having an injury within the last 12 mo. The estimated overall injury incidence in this study was 1.3 injuries per 1000 h of climbing or training.

Injuries to the hand and fingers were most common, followed by ankle injuries (Table 4). Most injuries occurred during bouldering (see online Supplemental Table 1). The most common mechanism of injury was falling. Thirty-nine percent of injuries resulted in <7 d of time lost from climbing (see online Supplemental Figure 1). Twelve growth plate injuries were reported, 4 of which involved the fingers. Other growth plate injuries involved the ankle (n=5), wrist (n=2), and knee (n=1). Three out of the 4 climbers who reported epiphyseal finger fractures in our study also reported consistent (at least once a week) use of campus board training. Three pulley injuries were reported: 1 to the A2, 1 to the A3, and 1 unspecified. Most ankle injuries were reported as sprains (9/15), although 1 peroneal subluxation and 3 fractures were described, including 1 injury resulting in a comminuted talus and medial malleolus fracture.

Late-specialized climbers were more likely to have suffered an injury within the last 12 mo compared to those who specialized early or not at all (Table 5). Late-specialized climbers were also 1.6 times (95% CI: 1.1–2.3) more likely to have had a lifetime injury than early-specialized climbers. There was no significant difference in proportion of injured climbers when comparing all specialized climbers vs nonspecialized climbers. Similarly, there was no significant difference in the proportion of injured climbers who were categorized as high training load and those who were not.

Twenty-nine percent of injuries with reported mechanisms (16/56) were categorized as overuse injuries.

Table 6. Responses before and after March 2020, data presented as mean±SD (range)

	Pre-COVID (n=83)	*Post-COVID (n=28)*	P-*value*
Climbing ($h \cdot wk^{-1}$)	9.8±4.1 (4–21)	9.9±4.7 (2–25)	0.96[a]
Climbing ($mo \cdot y^{-1}$)	11.7±0.7 (9–12)	11.4±1.0 (9–12)	0.12[a]
Total injuries	1.4±1.6 (0–10)	1.8±1.9 (0–6)	0.3[a]
Injuries last 12 mo	1.1±1.1 (0–6)	1.5±0.8 (0–3)	0.26[a]
High training load (%)	77	86	0.33[b]
Overuse injury (%)	29	24	0.32[c]
Specialization			0.29[b]
Early (%)	42	44	
Late (%)	18	20	
Nonspecialized (%)	41	36	

[a]t-test.
[b]Fisher's exact test.
[c]Chi-squared test.

There was no difference in the proportion of overuse injuries between early and late specialized climbers (RR 0.7, 95% CI 0.2–2.2) or between early and nonspecialized groups (RR 0.6, 95% CI 0.2–1.6). There was also no difference between late and nonspecialized groups (RR 0.9, 95% CI 0.3–2.4).

Twenty-five percent of survey responses were collected after March 1, 2020, the month when many states in the United States began stay-at-home orders due to the COVID-19 pandemic that may have affected access to climbing gyms. There were no statistically significant differences in reported training patterns, injuries, or sports specialization between responses received prior to March 2020 ("pre-COVID") and those after (Table 6).

Discussion

Sport specialization, including early sport specialization, was common in our study, which follows with recent trends in youth sports in the United States.[33,34] A high proportion of participants were high-level climbers, with 36% having competed at the national or international level. Based on USA Climbing rules, only 12% (6/52) of climbers at the regional competition (first level of competition after general qualifying) advance to nationals (the highest level of competition).[35]

Fifty-five percent of our participants were single sport specialized in rock climbing, a higher percentage than previously reported in tennis (47%), gymnastics (30%), and dance (26%).[36] The age of specialization in surveyed climbers (11±2 y) was older than that reported in gymnastics and men's golf and younger than seen in men's basketball or football.[34,36]

In this study, late specialization was associated with an almost 2 times greater likelihood of having suffered an injury in the last 12 mo, compared to early or nonspecialized athletes. Late specialization was also associated with an increased likelihood of having had a lifetime injury, compared to early specializers. However, no difference was seen in the proportion of overuse injuries between specialization groups.

This finding differs from previous literature regarding early specialization in other sports.[20,34,36-39] A 2016 systematic review of 3 studies on sport specialization and overuse injuries (none of which included rock climbers) found an increase in overuse injuries in specialized athletes (OR range: 1.3–4.0).[38] However, these studies did not specifically look for differences between those who specialized at early vs later ages.

The discrepancy between our findings and those discussed above may be due to differing patterns of injury seen in rock climbing compared to other sports. Many studies regarding early sport specialization focus on overuse injuries.[20,34,36-38] However, the most common injuries in this study were of an acute nature. The smaller number of overuse injuries reported in this study makes it difficult to assess for differences between specialization groups. Further research is needed to examine whether climbers who specialized early may have better landing or climbing techniques that are protective against acute injuries, compared to those who specialize at a later age.

The overall injury incidence for our study was 1.3 injuries per 1000 h of climbing and training. This is less than that previously found in a review of 8 studies, which estimated an injury incidence of $2.71 \pm 4.49 \cdot 1000\ h^{-1}$.[40] Eighty percent of injuries in our study occurred during bouldering, a higher rate than previously described in another study on

pediatric climbers (58%).[26] Nearly half of reported injuries were to the ankle, a higher proportion than previously described; previous studies have reported lower extremity injuries to make up 13 to 28% of all injuries.[41-45]

Ankle injuries in this study were primarily from falling during bouldering, suggesting that development of injury prevention strategies targeted at reducing ankle sprains may be warranted. High-level climbers typically wear climbing shoes that are very tight and force the ankle into supination and interphalangeal joints into mild flexion.[44,46] The tight fit of these shoes also makes it difficult to fit a traditional ankle brace inside. Incorporation of ankle proprioceptive and strength training may be strategies to reduce these injuries. Further research is needed to evaluate the potential effects of ankle taping and bracing, as well as any influence of the type of landing surface on injury.

Four climbers in our study reported epiphyseal finger fractures, previously described as the most common injury among youth rock climbers.[22,23,27-29] These injuries most commonly affect the long finger, followed by the ring finger.[28] There has been a 600% increase in reported epiphyseal finger fractures among youth rock climbers in the past decade, with the vast majority due to overuse.[29] However, despite being described for many years, many youth climbers are unaware of these specific injuries[47] and allow these injuries to go untreated.[23] One previously described risk factor to these injuries is campus board training.[22,48] Thus, it has been suggested that campus board training, along with weighted hangboarding, should be limited in youth climbers.[23,27,49] Despite this, many of our participants used these training methods at least once a week, with several starting at a young age. Three out of the 4 climbers who reported epiphyseal finger fractures in our study also reported consistent use of campus board training. These findings further emphasize the need for proper education in youth climbers and coaches regarding these injuries and potential risk factors.

Twenty-one percent of participants were categorized as having high training load.[10] However, a high training load was not found to be associated with an increase in injuries as has been reported in previous studies involving youth tennis players.[50]

LIMITATIONS

This study was a cross-sectional survey and therefore had limitations consistent with its design, including an inability to assess temporal relationships or causation between observed associations. Additionally, potential long-term effects of sport specialization could not be assessed in this study. Description of injuries was based on self-report, without the ability to verify based on medical records, owing to the anonymous nature of the study. Recall bias may have resulted in more significant injuries or more recent injuries being reported over minor or remote injuries. Survey fatigue may have led to skipped questions and missing data.

In this study, specialization was not categorized into low, moderate, high categories, as has been used previously in the literature.[11,34,37] Additionally, part of the data collection period (11/2019−9/2020) was affected by the COVID-19 pandemic, which may have influenced the ability of athletes to climb and train at a normal volume. Survey questions were written pre-pandemic and remained the same throughout the recruitment period, which may have led to challenges in reporting "average" training behaviors that may have changed during the pandemic. However, no significant differences were noted in data collected before and after March 2020.

Conclusions

In this study investigating sport specialization within youth climbing, early sport specialization was found to be common, although it was not associated with an increase in injuries. Specialization at a later age was associated with a higher likelihood of injury.

The overall injury incidence in our study was lower than in previous climbing studies.[26,51] Ankle, hand, and finger injuries were the most common. Potential areas to target for injury prevention in youth climbing include ankle injuries from falls during bouldering, and overuse hand and finger injuries. Young climbers should be educated further regarding safe training methods, as campus boarding at a young age persists despite its links to growth plate fractures of the fingers.

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Supplemental Material(s)

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References

1. Caine DJ. The epidemiology of injury in adventure and extreme sports. *Med Sport Sci*. 2012;58:1–16.
2. Steffen K, Soligard T, Mountjoy M, Dallo I, Gessara AM, Giuria H, et al. How do the new Olympic sports compare with the traditional Olympic sports? Injury and illness at the 2018 Youth Olympic Summer Games in Buenos Aires, Argentina. *Br J Sports Med*. 2020;54(3):168–75.
3. Lutter C, El-Sheikh Y, Schöffl I, Schöffl V. Sport climbing: medical considerations for this new Olympic discipline. *Br J Sports Med*. 2017;51(1):2–3.
4. Wheaton B, Thorpe H. Action sports, the Olympic Games, and the opportunities and challenges for gender equity: the cases of surfing and skateboarding. *J Sport and Social Issues*. 2018;42(5):315–42.
5. Caine DJ, Provance AJ. Pediatric and adolescent injury in adventure and extreme sports. *Res Sports Med*. 2018;26(sup 1):5–19.
6. Balas J, Bunc V. Short-term influence of climbing activities on strength, endurance and balamce within school physical education. *Int J Fit*. 2007;3:33–42.
7. Balas J, Strejcová B, Maly T, Malá L, Martin A. Changes in upper body strength and body composition after 8 weeks indoor climbing in youth. *Isokinet Exerc Sci*. 2009;17(3):173–9.
8. Siegel SR, Fryer SM. Rock climbing for promoting physical activity in youth. *Am J Lifestyle Med*. 2017;11(3):243–51.
9. Siegel S, Robinson JM, Johnston S, Lindley M, Pfeiffer K. Health-related fitness and energy expenditure in recreational youth rock climbers 8–16 years of age. *Int J of Exerc Sci*. 2015;8(2):8.
10. LaPrade RF, Agel J, Baker J, Brenner JS, Cordasco FA, Cote J, et al. AOSSM early sport specialization consensus statement. *Orthop J Sports Med*. 2016;4(4):2325967116644241.
11. Jayanthi N, Pinkham C, Dugas L, Patrick B, Labella C. Sports specialization in young athletes: evidence-based recommendations. *Sports Health*. 2013;5(3):251–7.
12. Feeley BT, Agel J, LaPrade RF. When is it too early for single sport specialization? *Am J Sports Med*. 2016;44(1):234–41.
13. Post EG, Thein-Nissenbaum JM, Stiffler MR, Brooks MA, Bell DR, Sanfilippo JL, et al. High school sport specialization patterns of current Division I athletes. *Sports Health*. 2017;9(2):148–53.
14. Malina RM. Early sport specialization: roots, effectiveness, risks. *Curr Sports Med Rep*. 2010;9(6):364–71.
15. Brenner JS. Sports specialization and intensive training in young athletes. *Pediatrics*. 2016;138(3):e2016218.
16. Padaki AS, Popkin CA, Hodgins JL, Kovacevic D, Lynch TS, Ahmad CS. Factors that drive youth specialization. *Sports Health*. 2017;9(6):532–6.
17. Bergeron MF, Mountjoy M, Armstrong N, Chia M, Côté J, Emery CA, et al. International Olympic Committee consensus statement on youth athletic development. *Br J Sports Med*. 2015;49(13):843–51.
18. DiFiori JP, Benjamin HJ, Brenner JS, Gregory A, Jayanthi N, Landry GL, et al. Overuse injuries and burnout in youth sports: a position statement from the American Medical Society for Sports Medicine. *Br J Sports Med*. 2014;48(4):287–8.
19. Matos NF, Winsley RJ, Williams CA. Prevalence of nonfunctional overreaching/overtraining in young English athletes. *Med Sci Sports Exerc*. 2011;43(7):1287–94.
20. Bell DR, Post EG, Biese K, Bay C, Valovich McLeod T. Sport specialization and risk of overuse injuries: a systematic review with meta-analysis. *Pediatrics*. 2018;142(3):e20180657.
21. Hume PA, Hopkins WG, Robinson DM, Robinson SM, Hollings SC. Predictors of attainment in rhythmic sportive gymnastics. *J Sports Med Phys Fitness*. 1993;33(4):367–77.
22. Hochholzer T, Schöffl VR. Epiphyseal fractures of the finger middle joints in young sport climbers. *Wilderness Environ Med*. 2005;16(3):139–42.
23. Morrison AB, Schöffl VR. Physiological responses to rock climbing in young climbers. *Br J Sports Med*. 2007;41(12):852–61.
24. Schöffl VR, Hochholzer T, Imhoff AB, Schöffl I. Radiographic adaptations to the stress of high-level rock climbing in junior athletes: a 5-year longitudinal study of the German Junior National Team and a group of recreational climbers. *Am J Sports Med*. 2007;35(1):86–92.
25. Watts PB, Joubert LM, Lish AK, Mast JD, Wilkins B. Anthropometry of young competitive sport rock climbers. *Br J Sports Med*. 2003;37(5):420–4.
26. Woollings KY, McKay CD, Kang J, Meeuwisse WH, Emery CA. Incidence, mechanism and risk factors for injury in youth rock climbers. *Br J Sports Med*. 2015;49(1):44–50.
27. Bärtschi N, Scheibler A, Schweizer A. Symptomatic epiphyseal sprains and stress fractures of the finger phalanges in adolescent sport climbers. *Hand Surg Rehabil*. 2019;38(4):251–6.
28. Bayer T, Schöffl VR, Lenhart M, Herold T. Epiphyseal stress fractures of finger phalanges in adolescent climbing athletes: a 3.0-Tesla magnetic resonance imaging evaluation. *Skeletal Radiol*. 2013;42(11):1521–5.
29. Schöffl V, Popp D, Küpper T, Schöffl I. Injury trends in rock climbers: evaluation of a case series of 911 injuries between 2009 and 2012. *Wilderness Environ Med*. 2015;26(1):62–7.
30. Harris PA, Taylor R, Minor BL, Elliott V, Fernandez M, O'Neal L, et al. The REDCap consortium: building an international community of software platform partners. *J Biomed Inform*. 2019;95:103208.
31. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)–a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42(2):377–81.
32. Bell DR, Snedden T, Biese K, Nelson E, Watson A, McGuine T, et al. Consensus definition of sport specialization in youth athletes using a delphi approach. *J Athl Train*. 2021;56(11):1239–51.
33. Ahlquist S, Cash BM, Hame SL. Associations of early sport specialization and high training volume with injury rates in National Collegiate Athletic Association Division I athletes. *Orthop J Sports Med*. 2020;8(3):2325967120906825.
34. Bell DR, Post EG, Trigsted SM, Hetzel S, McGuine TA, Brooks MA. Prevalence of sport specialization in high school athletics: a 1-year observational study. *Am J Sports Med*. 2016;44(6):1469–74.
35. USA Climbing Rulebook 2021–2022 v1.0-20211015, sections 18–20. USA climbing. Available at: https://usaclimbing.org/wp-content/uploads/2021/10/USA_Climbing_Rulebook_2021-2022_v10_202110151.pdfng.org. Accessed December 23, 2021.
36. Pasulka J, Jayanthi N, McCann A, Dugas LR, LaBella C. Specialization patterns across various youth sports and relationship to injury risk. *Phys Sportsmed*. 2017;45(3):344–52.
37. Jayanthi NA, LaBella CR, Fischer D, Pasulka J, Dugas LR. Sports-specialized intensive training and the risk of injury in young athletes: a clinical case-control study. *Am J Sports Med*. 2015;43(4):794–801.
38. Fabricant PD, Lakomkin N, Sugimoto D, Tepolt FA, Stracciolini A, Kocher MS. Youth sports specialization and musculoskeletal injury: a systematic review of the literature. *Phys Sportsmed*. 2016;44(3):257–62.
39. Hall R, Barber Foss K, Hewett TE, Myer GD. Sport specialization's association with an increased risk of developing anterior knee pain in adolescent female athletes. *J Sport Rehabil*. 2015;24(1):31–5.

40. Jones G, Schöffl V, Johnson MI. Incidence, diagnosis, and management of injury in sport climbing and bouldering: a critical review. *Curr Sports Med Rep*. 2018;17(11):396–401.
41. Bollen SR. Soft tissue injury in extreme rock climbers. *Br J Sports Med*. 1988;22(4):145–7.
42. McDonald JW, Henrie AM, Teramoto M, Medina E, Willick SE. Descriptive epidemiology, medical evaluation, and outcomes of rock climbing injuries. *Wilderness Environ Med*. 2017;28(3):185–96.
43. van Middelkoop M, Bruens ML, Coert JH, Selles RW, Verhagen E, Bierma-Zeinstra SM, et al. Incidence and risk factors for upper extremity climbing injuries in indoor climbers. *Int J Sports Med*. 2015;36(10):837–42.
44. Cole KP, Uhl RL, Rosenbaum AJ. Comprehensive review of rock climbing injuries. *J Am Acad Orthop Surg*. 2020;28(12):e501–9.
45. Neuhof A, Hennig FF, Schöffl I, Schöffl V. Injury risk evaluation in sport climbing. *Int J Sports Med*. 2011;32(10):794–800.
46. Buda R, Di Caprio F, Bedetti L, Mosca M, Giannini S. Foot overuse diseases in rock climbing: an epidemiologic study. *J Am Podiatr Med Assoc*. 2013;103(2):113–20.
47. Meyers RN, Hobbs SL, Howell DR, Provance AJ. Are adolescent climbers aware of the most common youth climbing injury and safe training practices? *Int J Environ Res Public Health*. 2020;17(3):812.
48. Bollen SR, Wright V. Radiographic changes in the hands of rock climbers. *Br J Sports Med*. 1994;28(3):185–6.
49. McMullen CW, Mugleston BJ, Booker LN. Coaches' attitudes toward campus board training in adolescent climbers in the United States. *Wilderness Environ Med*. 2021;32(2):168–75.
50. Jayanthi N, Dechert A, Durazo R, Dugas L, Luke A. Training and specialization risks in junior elite tennis players. *J Med Sci Tennis*. 2011;16:14–20.
51. Backe S, Ericson L, Janson S, Timpka T. Rock climbing injury rates and associated risk factors in a general climbing population. *Scand J Med Sci Sports*. 2009;19(6):850–6.

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ORIGINAL RESEARCH

Nonfreezing Cold Injury and Cold Intolerance in Paddlesport

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Introduction—Nonfreezing cold injury (NFCI) occurs when tissues are subjected to prolonged cooling that causes tissue damage, but not freezing. Long-term effects include cold intolerance, with allodynia, pain, or numbness of the affected limb. Those who participate in outdoor paddlesports are at particular risk.

Methods—This is an epidemiological study that aimed to determine the risk factors for paddlesport athletes developing NFCI and chronic cold intolerance in their hands. Secondary outcomes were to correlate cumulative cold exposure with the development of cold intolerance and to identify risk factors for developing NFCI or cold intolerance. Six hundred nine athletes responded to a survey distributed by their national governing body obtaining demographic and activity details, symptoms of NFCI, and a cold intolerance severity score (CISS).

Results—Twenty-three percent reported symptoms consistent with acute NFCI. The median CISS was 31 y (interquartile range 25–43), and 15% had a pathological CISS defined as >50. Females and individuals with Raynaud's phenomenon or migraines had a significantly higher CISS ($P<0.05$). Regression analysis found that females, smokers, and those with Raynaud's phenomenon or a previous nerve injury had a significantly higher risk of developing pathological cold intolerance (CISS >50). There was no correlation between cumulative cold exposure and CISS.

Conclusions—A large proportion of paddlesport athletes undertaking activity in cold conditions have a pathological CISS or episodes consistent with NFCI. Cumulative cold exposure was not associated with a pathologically high CISS. The risk factors were female sex, smokers, and those suffering from either Raynaud's phenomenon or nerve injury.

Keywords: cold exposure, cold, canoeing, thermal injury, immersion injury, sports injury

Introduction

Nonfreezing cold injury (NFCI) occurs when tissues are subjected to prolonged cooling that causes damage, but does not cause freezing.[1,2] This typically occurs during exposure to cold and wet environments, affecting the hands and feet.[2] First recognized in World War II, numbness of peripheral limbs upon prolonged cold exposure followed by painful hyperemia upon rewarming was described, lasting from 30 min up to several days.[2] A final chronic phase has subsequently been recognized, which can last from several years to a lifetime.[3,4] Long-term effects commonly include cold intolerance, with allodynia, pain, or numbness of the affected limb upon exposure to cold.[2,5,6] The exact pathogenesis of NFCI is poorly understood but is hypothesized to be a combination of vascular and neural dysfunction.[6-8] Prolonged exposure to cold with subsequent vasoconstriction results in tissue ischemia.[9] This ischemia is thought to result in damage to the vascular endothelium, compromising its ability to initiate vasodilation.[10] However, neurological examination of those with chronic NFCI has suggested a neurological component to the syndrome.[7]

NFCI continues to be a problem for military personnel in cold environments.[11,12] Civilians undertaking outdoor sports during cold conditions in temperate climates, such as the UK, exposes them to

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similar conditions and hence places them at risk. Those who participate in outdoor paddlesports, such as outdoor canoeing and kayaking, are a prime example. The hands are exposed to a cold, wet environment and are frequently immersed in cold water. This can be up to several hours of duration at a time. Anecdotally, many have experienced symptoms consistent with an NFCI and have over time developed cold intolerance as a result of their activities.

The relationship between NFCI, repeated cold exposure, and the subsequent development of chronic cold intolerance is poorly understood and complex and has not yet been fully defined. Military studies have found that individuals with certain traits, such as Afro-Caribbean ethnicity, low body mass index, and smoking, are more susceptible to NFCI and developing cold intolerance.[11,12] Pathological cold intolerance has also been associated with other neurovascular conditions such as previous limb injury, Dupuytren's disease, diabetes mellitus, peripheral vascular disease, and migraines.[13] However, it is thought that increased and repeated cold exposure and NFCI increase the risks of developing chronic symptoms such as neuropathic pain and pathological cold intolerance.[4,7]

This study aimed to:

1. Determine if paddlesport athletes who are regularly exposed to cold conditions suffer from NFCI and develop chronic pathological cold intolerance in their hands.
2. Correlate repeated cold exposure with development of chronic cold intolerance.
3. Identify risk factors for developing chronic cold intolerance and NFCI.

Methods

This was an epidemiological study of paddlesport athletes in the United Kingdom conducted during March 2021. An online survey was created using SurveyMonkey software (Momentive Inc, San Mateo, CA). This was distributed by the national governing body in the United Kingdom (British Canoeing) via their Twitter page in a series of 2 tweets spaced 2 wk apart. All respondents were included in the final analysis.

Participants completed the survey on a voluntary basis, which included permission to use any personal data provided for the purposes of research and education in accordance with General Data Protection Regulation. The study was registered with the audit and research department at the Pulvertaft Hand Centre and deemed not to require ethical approval.

Demographic information such as age, sex, ethnicity, smoking status, and medical comorbidities was obtained. Comorbidities associated with cold intolerance were screened for in order to assess for bias and any correlation. A further option was given in free text to allow participants to volunteer any other comorbidities that may be relevant.

Exposure to conditions below 10°C has previously been associated with a significantly higher risk of cold injury and is commonly used as the definition of cold exposure.[14,15] Historical meteorological office data were consulted to identify for which months the mean air temperature was <10°C. These data were used to define a time period during which outdoor sports would have resulted in cold exposure; this was found to be between November and March. A cumulative exposure to cold was estimated by multiplying the number of years spent participating in paddle sports during this time period, with the number of times the activity was completed in a week and the average length of the activity in hours.

Data on the use of protective clothing and what conditions prompted users to wear it were collected. Protective clothing was considered to be anything covering the hands, preventing exposure to cold air; this included gloves, mitts, or specific hand coverings that attach to the paddle shaft, termed "pogies" or paddle mitts.

Previous studies have defined NFCI as a history of significant cold exposure causing sensory symptoms in an extremity lasting over 30 min and as often painful upon rewarming.[1] Should participants report episodes with symptoms fitting these criteria, they were considered to have sustained an acute NFCI. Chronic NFCI is not as well defined, but the most common symptom reported is that of cold intolerance.[1,6] The cold intolerance severity score (CISS) has not been validated as a tool for the diagnosis of chronic NFCI. However, it is an established and validated method for the assessment of cold intolerance.[16] CISS was calculated using the method outlined in Table 1 to quantify symptoms reported by respondents rather than for the diagnosis of chronic NFCI. Two previous studies investigated the CISS of a normal population. They defined the upper 95th percentile as having pathological rather than physiological symptoms of cold intolerance. One study found this to be 30 and the other 50.[17,18] The higher of the 2 published values was used to avoid a type 1 error. Therefore, for the purposes of this study, a CISS of >50 was defined as pathological.

Data were analyzed using SPSS statistics program version 24. Nominal variables are presented as proportions. Numerical variables were tested for normality and presented as either mean or median with interquartile range, as appropriate. Univariate analysis was performed to determine which demographic and cold exposure-related factors were associated with a higher CISS. For nominal variables this was performed using a Mann-Whitney *U* test or Kruskall-Wallis analysis of variance,

Table 1. Cold intolerance severity score

Question	*Score*
Which of the following symptoms of cold intolerance do you experience in your injured limb on exposure to cold? Pain, numbness, stiffness, weakness, aching, swelling, skin color change (white/bluish white/blue)	Not scored
How often do you experience these symptoms?	
Continuously/All the time	10
Several times a day	8
Once a day	6
Once a week	4
Once a month or less	2
Never	0
When you develop cold-induced symptoms, on your return to a warm environment are your symptoms relieved…	
Within a few minutes	2
Within 30 min	6
After more than 30 min	10
I do not get any symptoms	0
What do you do to ease or prevent your symptoms from occurring?	
Take no special action	0
Keep hand in pocket	2
Wear gloves/pogies/mitts in cold weather	4
Wear gloves all the time	6
Avoid cold weather/stay indoors	8
Other	10
On a scale of 0–10, how much does cold bother your hand in the following situations?	
Holding a glass of water	0–10
Holding a frozen package from the freezer	0–10
Washing in cold water	0–10
When you get out of a hot bath/shower with air at room temperature	0–10
During cold wintery weather	0–10
On a scale of 0–4, please state how each of the following activities have been affected as a consequence of cold-induced symptoms in your injured hand and score each	
Domestic chores	0–4
Hobbies and interests	0–4
Dressing and undressing	0–4
Tying your shoelaces	0–4
Your job	0–4

as appropriate. Chi-squared analysis was performed for each variable to correlate it with a pathological CISS, defined as >50. Numerical variables were correlated through the calculation of a Pearson rank coefficient. Multivariate analysis was performed by constructing a binary logistic regression model to identify any correlations between demographic and cold exposure factors and a pathological CISS. Based on existing literature, this was defined as a CISS ≥50 to generate odds ratios for developing a pathological cold intolerance adjusting for the above variables. A P value of <0.05 was considered statistically significant.

Results

The survey was completed by 609 paddlers. The results are summarized in Table 2. Almost 95% of participants undertook activity during cold conditions (n=576), with the majority (78%) having over 2 h of cold exposure per week for an average of 12 y. Between 60 and 75% report either pain or numbness to their hands upon cold exposure, occurring at least weekly in 60% of participants. Twenty-three percent report ongoing pain and edema lasting over 30 min after their hands had been rewarmed, consistent with an acute NFCI (Table 2). Overall, the median CISS was 31 (interquartile range 25–43), and 15% (86) of participants had a CISS of over 50.

Univariate analysis was performed for each variable to determine its correlation with CISS. Among the demographic characteristics, female sex was associated with a significantly higher CISS in comparison to male sex (male 25.5: female 40, P<0.05). Those with Raynaud's phenomenon or migraines also had a significantly higher CISS (Raynaud's 46 vs no Raynaud's 28, P<0.005; migraines 37.5 vs no migraines 29, P=0.002). A significantly higher proportion of females, smokers, and those with Raynaud's phenomenon or migraines had a pathological CISS (27% females, 30% smokers [P=0.04], 40% Raynaud's phenomenon [P<0.005], 27% migraines [P=0.03, Table 3]).

There was no significant difference in CISS between those who undertook activity during cold conditions and those who did not (P=0.15) (Table 3). Cumulative cold exposure did not correlate with CISS (Pearson r=−0.03 P=0.47) (Figure 1). However, the choice of clothing did correlate with CISS. Those who wore protective clothing in warmer temperatures had a significantly higher CISS than those who did not (P<0.005) (Table 3).

A binary logistic regression model was constructed defining a CISS of >50 as pathological to identify any correlations between either demographic or activity variables and a pathological CISS (Table 4). Female individuals were 3.5 times more likely to have a pathological CISS. Other factors significantly associated with a pathological CISS were smoking (OR 4.8),

Table 2. Survey results summarizing participant demographic characteristics, cold exposure activity, and symptoms upon cold exposure

Question	*Summary of responses*
Participant Demographics	
1. What is your age?	35 (25–50) y
2. Are you male or female?	
Male	392 (64%)
Female	217 (36%)
3. What is your ethnicity?	
White	601 (99%)
Asian	3 (0.5%)
Black/African/Caribbean	1 (0.2%)
Other	4 (0.7%)
4. Do you smoke?	
Smoker	20 (3%)
Nonsmoker	589 (97%)
5. Do you have any of the following?	
Previous fracture of hand	165 (27%)
Raynaud's syndrome	82 (13%)
Migraines	60 (10%)
Previous surgery to hand	35 (5%)
Nerve injury to hand/upper limb	27 (4%)
Carpal tunnel syndrome	25 (4%)
Rheumatoid	12 (2%)
Diabetes	10 (2%)
Dupuytren's disease	7 (1%)
Hand arm vibration syndrome	5 (0.8%)
Peripheral neuropathy	2 (0.3%)
Peripheral vascular disease	1 (0.2%)
None	418 (67%)
6. Have you been diagnosed with any other medical conditions? If none leave blank.	
None	485 (80%)
7. How many years have you been canoeing?	12 (7.5–22) y
Participant exposure and response to cold conditions	
8. Do you paddle on open water at least once a month during the winter season between November and March?	
Yes	576 (95%)
No	33 (5%)
9. On average how long do you spend canoeing a week?	
0.5 h	42 (7%)
1 h	90 (15%)
2–4 h	117 (29%)
4–8 h	151 (25%)
8–12 h	87 (14%)
12–16 h	19 (3%)
16–20 h	23 (4%)
20+ h	20 (3%)
10. What canoeing disciplines do you take part in?	
Recreational	330 (54%)
Whitewater	338 (56%)
Slalom	78 (13%)
Wildwater racing	49 (8%)
Surfski/Sea kayak	137 (22%)

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Table 2 *(continued)*

Question	*Summary of responses*
Surf lifesaving	15 (2%)
Marathon	187 (31%)
Canoe sprint	111 (18%)
Canoe polo	50 (8%)
Freestyle	98 (16%)
11. What weather conditions make you wear gloves, pogies, or paddle mitts?	
I never wear them	105 (17%)
Below freezing	150 (26%)
<5°C	231 (38%)
<10°C	113 (19%)
Rain	90 (10%)
High wind	194 (32%)
12. When canoeing, do your hands	
a) Ever go so cold they become white or pale?	
Never	72 (12%)
Once or twice	138 (23%)
Several times	156 (26%)
It happens frequently	243 (40%)
b) Become so cold you cannot open your fingers?	
Never	178 (29%)
Once or twice	185 (30%)
Several times	139 (23%)
It happens frequently	107 (18%)
c) Become swollen and painful once warm after you have finished canoeing?	
Never	145 (24%)
Once or twice	174 (29%)
Several times	157 (26%)
It happens frequently	133 (22%)
Cold Intolerance Severity Score	
13. Which of the following symptoms do you get when your hand is exposed to cold?	
Pain	367 (60%)
Numbness	437 (74%)
Stiffness	387 (64%)
Aching	207 (34%)
Swelling	128 (21%)
Skin color changes (eg, white/blue)	400 (66%)
I never get any symptoms	18 (3%)
14. How often do you experience these symptoms? (during the winter/present time)	
Continuously/All the time	41 (7%)
Several times a day	85 (14%)
Once a day	88 (14%)
Once a week	156 (26%)
Once a month or less	210 (35%)
Never	29 (5%)
15. When you develop cold-induced symptoms, on your return to a warm environment are your symptoms relieved:	
Within a few minutes	142 (23%)
Within 30 min	309 (51%)

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Table 2 *(continued)*

Question	*Summary of responses*				
After more than 30 min			141 (23%)		
I do not get any symptoms			17 (3%)		
16. What do you do to ease or prevent your symptoms occurring?					
Take no special action			141 (23%)		
Keep hand in pocket			79 (13%)		
Wear gloves/pogies/mitts in cold weather			326 (54%)		
Wear gloves all the time			21 (3%)		
Avoid cold weather/Stay indoors			3 (0%)		
Other			39 (6%)		
17. On a scale of 0–10, how much does cold bother your hand in the following situations?					
Holding a glass of water			1 (0–3)		
Holding a frozen package from the freezer			3 (1–5)		
Washing in cold water			2 (1–4)		
When you get out of a hot bath/shower with air at room temperature			0 (0–2)		
During cold wintery weather			5 (2–7)		
18. On a scale of 0–4, please state how each of the following activities have been affected as a consequence of cold-induced symptoms in your injured hand and score each	0	1	2	3	4
Domestic chores	423 (69%)	111 (18%)	43 (7%)	26 (4%)	6 (1%)
Hobbies and interests	216 (35%)	135 (22%)	121 (20%)	95 (16%)	42 (7%)
Dressing and undressing	298 (49%)	137 (22%)	98 (16%)	56 (9%)	20 (3%)
Tying your shoelaces	277 (45%)	131 (21%)	111 (18%)	57 (9%)	33 (5%)
Your job	408 (67%)	95 (16%)	44 (7%)	41 (7%)	21 (3%)

Data are presented as n (%) or median (IQR).

previous nerve injury (OR 4.7), and Raynaud's phenomenon (OR 5.3).

Discussion

This was an epidemiological study performed on paddlesport athletes with a wide age range and varied time spent undertaking paddlesport, at varied intensity, from recreational paddlers having occasional exposure to those spending over 20 h·wk^{-1} exposed to cold conditions. This is likely to be representative of the population within the United Kingdom that undertakes paddlesport.

We have found that a large proportion (23%) report episodes consistent with NFCI. Our findings also suggest that paddlers have a significantly higher CISS than a normal population; 14% reported a pathological CISS score of >50 in comparison to 5% reported by other studies performed on the general population.[17,18] There was no correlation between cumulative cold exposure and the development of cold intolerance. Females and those with either Raynaud's phenomenon or migraines had a significantly higher CISS. Regression analysis found that the only significant risk factors for developing pathological cold intolerance were female sex, smoking, or having medical comorbidities, specifically Raynaud's phenomenon or a nerve injury.

Females were at significant higher risk (odds ratio 3.5) of developing pathological cold intolerance. The relationship between female sex and cold sensitivity is well described, with many possible contributing factors from vascular to homornal and neural mechanisms.[13,14,19] Males have larger hands and a higher body mass index, which are thought to be protective against cold injuries.[13] The female vasculature is also thought to be of smaller diameter with a higher resting sympathetic tone, resulting in reduced resting digital blood flow.[20] Hormonal factors may also have a role; high levels of estrogen are

Table 3. Univariate analysis of cold intolerance severity scores for demographic and activity variables

Variable		*CISS (median)*		*N (%) with a pathological CISS (>50)*		*Chi squared analysis*
Demographic Variables						
Sex						
Male		25.5	***P*<0.05 MWU**	**27 (7)**		***P*<0.005**
Female		40		**59 (27)**		
Ethnicity						
White		31	*P*=0.114 KWA	86 (17)		*P*=0.72
Asian		9		0 (0)		
Black/African/Caribbean		-		0 (0)		
Other		42.5		0 (0)		
Smoking status						
Smoker		34.5	*P*=0.326	**6 (30)**		***P*=0.04**
Nonsmoker		30	MWU	**80 (14)**		
Comorbidity	**CISS if disease present**	**CISS if disease not present**		**Present**	**Not Present**	
Previous fracture of hand	31	31	*P*=0.595 MWU	23 (14)	63 (14)	*P*=0.94
Raynaud's syndrome	46	28	***P*<0.005 MWU**	33 (40)	53 (10)	***P*<0.005**
Migraines	37.5	29	***P*=0.018 MWU**	16 (27)	70 (13)	***P*=0.03**
Previous surgery to hand	31	31	*P*=0.888 MWU	6 (17)	80 (14)	*P*=0.59
Nerve injury to hand/ upper limb	28	31	*P*=0.849 MWU	7 (26)	79 (14)	*P*=0.07
Carpal tunnel syndrome	31	31	*P*=0.780 MWU	4 (16)	82 (14)	*P*=0.78
Rheumatoid	39	30	*P*=0.313 MWU	1 (8)	85 (14)	*P*=0.56
Diabetes	30.5	31	*P*=0.197 MWU	0 (0)	86 (14)	*P*=0.20
Dupuytren's disease	25	31	*P*=0.854 MWU	1 (14)	85 (14)	*P*=0.99
Hand arm vibration syndrome	33	31	*P*=0.798 MWU	1 (20)	85 (14)	*P*=0.70
Peripheral neuropathy	42	31	*P*=0.363 MWU	1 (50)	85 (14)	*P*=0.14
Peripheral vascular disease	51	31	*P*=0.188 MWU	1 (100)	85 (14)	*P*=0.14
Activity Characteristics						
Participates in paddlesport during the winter		35	*P*=0.146 MWU	78 (14)		*P*=0.09
Does not participate in paddlesport during the winter		30		8 (24)		
Frequency of paddlesport ($h \cdot wk^{-1}$)						

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Table 3 *(continued)*

Variable	*CISS (median)*		*N (%) with a pathological CISS (>50)*	*Chi squared analysis*
0.5	33.5	*P*=0.334 KWA	11 (26)	*P*=0.15
1	28		16 (18)	
2–4	29		18 (10)	
4–8	31		21 (14)	
8–12	29		14 (16)	
12–16	38		3 (16)	
16–20	30		1 (4)	
20+	32.5		2 (10)	
Conditions that prompt the use of protective clothing (gloves)				
Never	23	***P*<0.005**	9 (9)	***P*<0.005**
Below freezing	28	**KWA**	**10 (6)**	
Below 5°C	32		**36 (16)**	
Below 10°C	40		**31 (27)**	

Factors with statistical significance have been highlighted in bold.
ANOVA, analysis of variance; CISS, cold intolerance severity score; KWA, Kruskall Wallis ANOVA; MWU, Mann Whitney U test.

associated with other vasospastic disorders such as Raynaud's phenomenon, and estrogen has been directly linked to increased adrenoceptor-mediated vasoconstriction.[21] Finally, some studies suggest that females report pain differently; females not only have a higher density of cutaneous nerve fibers but also greater temporal summation of painful stimuli.[19,22]

Smokers and those with Raynaud's phenomenon or a prior nerve injury also had a significantly higher risk of developing pathological cold intolerance. NFCI and cold intolerance are thought to be due to neurovascular dysfunction, which shares a pathophysiological mechanism with the aforementioned conditions.[9] The correlation between Raynaud's phenomenon and pathological cold intolerance is well described and unsurprising, given that both have overlapping symptoms that are induced by cold exposure and so would result in a high CISS regardless of the etiology. Smoking is known to cause peripheral vascular disease with subsequent constriction of the peripheral vascular through atherosclerosis.[23] Nicotine has been shown to alter the metabolic and hormonal responses to cold exposure.[23,24]

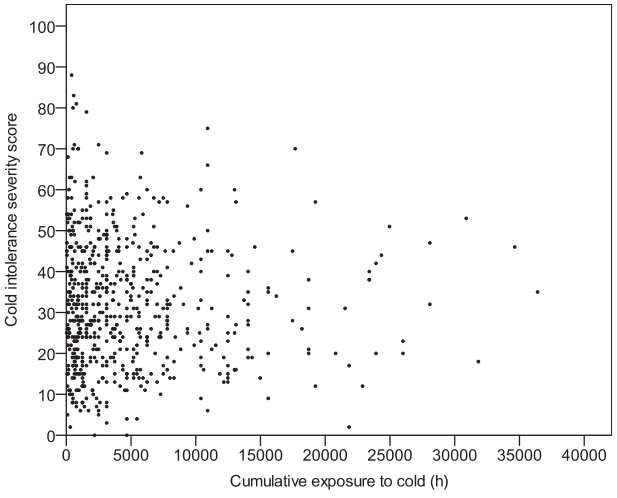

Figure 1. Scatterplot correlating cold intolerance severity score with cumulative cold exposure.

Those with migraines had a significantly higher CISS and pathological cold intolerance upon univariate analysis; regression analysis did not find this correlation to be statistically significant. Migraines are also thought to be a neurovascular disorder. Changes in cerebral blood flow have been observed in those suffering from migraines, and vasoactive medications such as triptans can also be effective for relief of symptoms.[25] Migraines have been associated with cold intolerance and other vascular disorders such as Raynaud's phenomenon, peripheral vascular disease, and coronary artery spasm.[13] They are also more common in women and can be precipitated by menstruation, stress, or sleep deprivation, thus suggesting not only neurovascular but also hormonal factors in its etiology, similar to those described for Raynaud's phenomenon.[13,25,26]

There was no correlation between cumulative cold exposure and cold intolerance found in this study. This is in contrast to previous studies finding a positive

Table 4. Binary logistic regression identifying factors associated with a pathological cold intolerance severity score (>50)

	P value	*Odds ratio*	*95% CI for odds ratio*	
			Lower	*Upper*
Female sex	**0.000**	**3.60**	**2.02**	**6.40**
Smoker	**0.010**	**4.75**	**1.45**	**15.60**
Previous fracture	0.958	1.02	0.55	1.89
Previous surgery	0.946	1.04	0.33	3.28
Previous nerve injury	**0.044**	**4.66**	**1.04**	**20.91**
Rheumatoid arthritis	0.640	0.58	0.06	5.60
Migraines	0.172	2.15	0.72	6.46
Carpal tunnel syndrome	0.532	0.65	0.17	2.50
Raynaud's disease	**0.005**	**5.36**	**1.67**	**17.22**
Fit and well (no comorbidities)	0.925	1.06	0.31	3.69
Undertakes paddlesport during winter	0.526	0.72	0.26	2.01
Never wears gloves	0.087	–	–	–
Wears gloves <10°C	0.315	1.66	0.62	4.42
Wears gloves <5°C	0.540	1.32	0.54	3.23
Wears gloves <0°C	0.215	0.53	0.19	1.46
Wear gloves in wind	0.445	1.28	0.68	2.38
Wear gloves in rain	0.236	1.64	0.72	3.73

P<.0005. Nagelkerke R^2=0.293. Variables with few events per variable, such as Asian/Afro-Caribbean ethnicity, diabetes, Dupuytren's, hand arm vibration syndrome (HAVS), peripheral neuropathy, and peripheral vascular disease, are excluded due to sparsity of data.
Factors with statistical significance have been highlighted in bold.

relationship between cold exposure and intolerance.[5,11,13] This may be due to the effect of self-selection among paddlers, with those who suffer from significant cold intolerance choosing not to participate in paddlesports. Exercise is thought to be protective against cold injury, and the correlation between cold exposure and intolerance has been observed in populations undertaking more static duties. Exertion raises the core body temperature and enhances the cold-induced vasodilation response, both of which are thought to prevent peripheral cold injury.[27] Other sources of cold exposure and data to evaluate exertion were not collected in this study, preventing the effect of exercise from being analyzed. Many participants had significant cold exposure over many years, yet had a low CISS, suggesting that genetic and physical attributes may be the significant determinants of developing chronic cold intolerance rather than the duration of cold exposure itself.

Both the Wilderness Medical Society and the American College of Sports Medicine have made recommendations for the management and prevention of cold injuries.[28,29] Primary prevention is the recommended approach, given the limited treatment options. Principally, these are maintaining peripheral perfusion through adequate clothing, nutrition, and hydration. Appropriately assessing and compensating for current weather conditions when choosing appropriate protective clothing is important. Common practice among paddlesport athletes is to use protective clothing during the winter months, notably when the air temperature drops below 5°C. It is accepted that individuals personally decide what clothing is appropriate for them and the nature of the activity. A greater understanding of the long-term risk linked with NFCI within paddlesport would be pivotal to assist in national governing bodies' advice and guidance around participating in activities during winter months.

LIMITATIONS

The self-reporting, self-selecting, and retrospective design of the study does limit the conclusions that can be drawn due to potential selection and recall bias. The size of the study population is unknown. The number of people undertaking paddlesports in cold conditions cannot be calculated and hence neither can incidence. Participants were required to estimate their weekly exposure over many years, the variable nature of activity and the time frame in which it was undertaken will prevent accurate reporting of data. Participants were therefore provided with time categories to aid their estimation. This combined with recall bias will prevent accurate reporting of exposure and as such can only be used as an estimate. Releasing the survey online allowed it to be disseminated widely and generated a large number of responses but prevents a response rate from being calculated.

Despite a large sample size in comparison to existing studies on the topic, analysis of certain variables was limited due to their rarity and the resultant low numbers within the study population. Such low numbers resulted in certain variables being excluded from regression analysis to avoid rare-event bias, thus limiting both the statistical power of the study and the strength of conclusions that can be drawn from it. For example, the predominantly Caucasian population of the study prevented any analysis on the effect of ethnicity, a factor well known to impact the risk of NFCI and cold intolerance.[11]

Future research by undertaking a larger study recruiting participants across multiple sports that have similar exposure, such as sailing, rowing, or surfing, would allow more detailed analysis and confidence in the conclusions drawn. Furthermore, the inclusion of a control group of similar age, sex, ethnicity, and comorbid status would help quantify the relative risk of

developing cold intolerance due to participation in paddlesports.

Conclusions

A large proportion of paddlesport athletes undertaking activity in cold conditions have symptoms of cold intolerance or episodes consistent with an NFCI. Cumulative cold exposure was not associated with developing a pathologically high CISS. The only significant risk factors were female sex, smoking, and Raynaud's phenomenon or nerve injury. Further research looking into the effect of preventative measures, such as protective clothing, would be beneficial to the paddlesport community.

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Author contributions: Study concept and design (BO, LCB, NJ); questionnaire design (all authors); acquisition of data (HB); analysis of data (all authors); drafting of manuscript (BO, HB); revision of manuscript (all authors); approval of final manuscript (all authors).

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References

1. Kuht JA, Woods D, Hollis S. Case series of non-freezing cold injury: the modern clinical syndrome. *BMJ Mil Health*. 2020;166(5):324–9.
2. Ungley CC, Channell GD, Richards RL. The immersion foot syndrome. *Br J Surg*. 1945;33(129):17–31.
3. Arvesen A, Wilson J, Rosén L. Nerve conduction velocity in human limbs with late sequelae after local cold injury. *Eur J Clin Invest*. 1996;26(6):443–50.
4. Jørum E, Opstad PK. A 4-year follow-up of non-freezing cold injury with cold allodynia and neuropathy in 26 naval soldiers. *Scand J Pain*. 2019;19(3):441–51.
5. Eglin CM, Costello JT, Tipton MJ, Massey H. Previous recreational cold exposure does not alter endothelial function or sensory thermal thresholds in the hands or feet. *Exp Physiol*. 2021;106(1):328–37.
6. Eglin CM, Golden FS, Tipton MJ. Cold sensitivity test for individuals with non-freezing cold injury: the effect of prior exercise. *Extrem Physiol Med*. 2013;2(1):16.
7. Vale TA, Symmonds M, Polydefkis M, Byrnes K, Rice ASC, Themistocleous AC, et al. Chronic non-freezing cold injury results in neuropathic pain due to a sensory neuropathy. *Brain*. 2017;140(10):2557–69.
8. Anand P, Privitera R, Yiangou Y, Donatien P, Birch R, Misra P. Trench foot or non-freezing cold injury as a painful vaso-neuropathy: clinical and skin biopsy assessments. *Front Neurol*. 2017;8:514.
9. Alba BK, Castellani JW, Charkoudian N. Cold-induced cutaneous vasoconstriction in humans: function, dysfunction and the distinctly counterproductive. *Exp Physiol*. 2019;104(8):1202–14.
10. Hope K, Eglin C, Golden F, Tipton M. Sublingual glyceryl trinitrate and the peripheral thermal responses in normal and cold-sensitive individuals. *Microvasc Res*. 2014;91:84–9.
11. Kuht JA, Woods D, Hollis S. Case series of non-freezing cold injury: epidemiology and risk factors. *J R Army Med Corps*. 2019;165(6):400–4.
12. Burgess JE, Macfarlane F. Retrospective analysis of the ethnic origins of male British army soldiers with peripheral cold weather injury. *J R Army Med Corps*. 2009;155(1):11–5.
13. Stjernbrandt A, Carlsson D, Pettersson H, Liljelind I, Nilsson T, Wahlström J. Cold sensitivity and associated factors: a nested case-control study performed in Northern Sweden. *Int Arch Occup Environ Health*. 2018;91(7):785–97.
14. Raza N, Sajid M, Suhail M, Haroon-Ur-Rashid. Onset of chilblains in relation with weather conditions. *J Ayub Med Coll Abbottabad*. 2008;20(2):17–20.
15. International Organization for Standardization (2008) ISO 15743: 2008—Ergonomics of the thermal environment—Cold workplaces—Risk assessment and management. Available at: https://www.iso.org/standard/38895.html Acessed: April 26 2022.
16. Carlsson I, Cederlund R, Höglund P, Lundborg G, Rosén B. Hand injuries and cold sensitivity: reliability and validity of cold sensitivity questionnaires. *Disabil Rehabil*. 2008;30(25):1920–8.
17. Carlsson IK, Nilsson JA, Dahlin LB. Cut-off value for self-reported abnormal cold sensitivity and predictors for abnormality and severity in hand injuries. *J Hand Surg Eur*. 2010;35(5):409–16.
18. Ruijs AC, Jaquet JB, Daanen HA, Hovius SE. Cold intolerance of the hand measured by the CISS questionnaire in a normative study population. *J Hand Surg Br*. 2006;31(5):533–6.
19. Hendrich J, Alvarez P, Joseph EK, Ferrari LF, Chen X, Levine JD. In vivo and in vitro comparison of female and male nociceptors. *J Pain*. 2012;13(12):1224–31.
20. Greenstein D, Jeffcote N, Ilsley D, Kester RC. The menstrual cycle and Raynaud's phenomenon. *Angiology*. 1996;47(5):427–36.
21. Serizawa I, Iwasaki N, Ishida H, Saito SY, Ishikawa T. G-protein coupled estrogen receptor-mediated non-genomic facilitatory effect of estrogen on cooling-induced reduction of skin blood flow in mice. *Eur J Pharmacol*. 2017;797:26–31.
22. Fillingim RB, Maixner W, Kincaid S, Silva S. Sex differences in temporal summation but not sensory-discriminative processing of thermal pain. 1998;75(1):121–7.
23. Lu L, Mackay DF, Pell JP. Meta-analysis of the association between cigarette smoking and peripheral arterial disease. *Heart*. 2014;100(5):414–23.
24. Cheatham CC, Caine-Bish N, Blegen M, Potkanowicz ES, Glickman EL. Nicotine effects on thermoregulatory responses of men and women during acute cold exposure. *Aviat Space Environ Med*. 2004;75(7):589–95.
25. Jacobs B, Dussor G. Neurovascular contributions to migraine: moving beyond vasodilation. *Neuroscience*. 2016;338:130–44.
26. Linstra KM, Perenboom MJL, van Zwet EW, van Welie FC, Fronczek R, Tannemaat MR, et al. Cold extremities in migraine: a marker for vascular dysfunction in women. *Eur J Neurol*. 2020;27(7):1197–200.
27. Keramidas ME, Musizza B, Kounalakis SN, Mekjavic IB. Enhancement of the finger cold-induced vasodilation response with exercise training. *Eur J Appl Physiol*. 2010;109(1):133–40.
28. Castellani JW, Young AJ, Ducharme MB, Giesbrecht GG, Glickman E, Sallis RE. American College of Sports Medicine position stand: prevention of cold injuries during exercise. *Med Sci Sports Exerc*. 2006;38(11):2012–29.
29. McIntosh SE, Freer L, Grissom CK, Auerbach PS, Rodway GW, Cochran A, et al. Wilderness Medical Society Clinical Practice Guidelines for the Prevention and Treatment of Frostbite: 2019 Update. *Wilderness Environ Med*. 2019;30(4S):S19–32.

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ORIGINAL RESEARCH

Avalanche Preparedness and Accident Analysis Among Backcountry Skier, Sidecountry, and Snowmobile Fatalities in the United States: 2009 to 2019

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Introduction—While avalanche fatalities have remained relatively steady per year, data suggest a possible increase in sidecountry use and snowmobile fatalities. Limited information is known regarding the accident details and preparedness among different groups of backcountry users including snowmobiles, sidecountry, and backcountry skiers, and what specific factors could contribute to their fatalities.

Methods—Avalanche fatality reports covering all US states posted by the Colorado Avalanche Information Center available online for 10 seasons (2009–2010 through 2018–2019 seasons) were analyzed for group size, specific equipment carried, burial depth, burial time, and other details. Only reports in the 3 following categories were included in the analysis: backcountry ski/snowboard, sidecountry ski/snowboard, and snowmobile/snowbike. These aspects were compared among the 3 tourer types using statistical analyses (ANOVA).

Results—Two hundred and five fatalities were analyzed (n=32 sidecountry, n=91 skier/snowboard, n=82 snowmobile/snowbike). Using 2 preparedness scores, the ski/snowboard group had the greatest distribution of high scores when evaluated by equipment carried and group size, with significant differences per group ($P<0.01$). Of the fatalities that were buried, burial time was related to the tourer group ($P=0.04$), with the ski/snowboard group having the highest proportion of burials <15 min. Burial depth was significantly different among the 3 tourer groups, with snowmobiles buried the deepest on average ($P<0.01$).

Conclusions—Despite limited data available on fatalities, an analysis of preparedness suggests that backcountry skiers and snowboarders are more prepared for avalanche accidents compared to snowmobiles and sidecountry users when evaluated by equipment carried and group size.

Keywords: snow burial, avalanche rescue, beacon, accident report, out of bounds, lift served backcountry

Introduction

Backcountry winter recreation including backcountry skiing and snowboarding, and the use of motorized vehicles such as snowmobiles, has increased in recent years. Throughout the past decade, there has been an increase in snowmobile related avalanche deaths; snowmobiles are now the largest group making up 23%, with backcountry skiers making up 22%. Previously, skiers composed the largest group but the recent increase in snowmobile-related fatalities has been observed in both the United States and Canada. The proportion of snowmobile deaths has increased 7% per decade in addition to snowboarders at 2% per decade. Potential causes could include the increase in snowmobile use and sales.[1] In the winter of 2020 to 2021, US snowmobile sales increased 16% from the previous year, which were the highest sales since 2008.[2] In addition, newer snowmobiles are more powerful with more

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Table 1. Point breakdown for preparedness score 2

Equipment (beacon, shovel, probe)	*Points per item*	*Group size*	*Points*
No group members	0	×1	1
Some group members	1	≥2	2
All group members	2		

horsepower, which has allowed for "high pointing" or "high marking," which can release an avalanche.[1]

Sidecountry skiing and snowboarding, also known as out-of-bounds or lift-served-backcountry, is another category of increasing popularity among outdoor recreationists.[3] Sidecountry is defined as the area adjacent to but out of bounds of winter resorts, which is accessed from a resort by a paying customer; sidecountry is part of the backcountry. This can provide skiers with a backcountry experience utilizing less physical effort but can create a false sense of security. Since skiers begin in bounds, it can be associated with the safety of the ski resort and a quick response by local ski patrol, even though there can be extreme hazards such as avalanche zones, unmarked obstacles, and cliffs.[3,4]

Although backcountry use has increased, the number of avalanche fatalities has remained steady at an average of 27 deaths per year over the past 10 winters in the United States.[5] Possible factors such as carrying equipment and skill in avalanche rescue could be contributing to reducing the number of fatalities; however, there are likely many additional factors that are unknown. To lower the risk of morbidity and mortality, avalanche safety equipment can be used to assist in the case of a burial. Beacons (transceivers), shovels, and probes are considered standard avalanche safety equipment that should be carried by all members of a group.[6] In victims who were completely buried, beacons were seen to reduce burial time and mortality significantly.[7] Group size is also an important aspect of avalanche rescue. Studies have shown an increased avalanche risk in groups of 4 or more and lower risk in groups of 2. Traveling alone is against recommendations due to the risk of no available rescuers.[8]

When surveying backcountry users in Utah, significant differences were found in the percentage who carried beacons, shovels, probes, and those who took an avalanche education course among different user types. Backcountry skiers were found to have the highest proportion of users carrying beacons, shovels and traveling with a partner; snowmobiles had a much lower proportion, and out-of-bounds skiers had the lowest among the 3 groups. Among those who took an avalanche safety course, snowmobiles had the lowest proportion of the 3 groups.[9] Furthermore, equipment data among fatality victims have been sparsely reported in the literature. In a study of avalanche fatalities in Utah among all user types, avalanche beacons were only mentioned in the autopsy reports of 38% (n=12) of fatalities, and among those, only 50% (n=6) of victims were carrying a beacon. There are limited studies examining these traits in fatalities among different user types to determine how behaviors could differ in fatal avalanche accidents.[10] The aim of this study was to assess if a difference in avalanche preparedness, assessed by group size and equipment carried, and accident details including burial time and depth, exists among different types of backcountry users.

Methods

Data for all US avalanches was obtained through the Colorado Avalanche Information Center avalanche fatality reports available online for 10 seasons, from 2009 to 2010 through the 2018 to 2019 season. Reports from individual US Forest Service avalanche center websites were used to supplement the Colorado Avalanche Information Center reports.

Victims were divided into 3 categories: sidecountry, ski/snowboard, and snowmobile/snowbike. Victims who began their trip skiing or snowboarding in bounds of a resort and then exited the resort into the backcountry were included in the "sidecountry" category. Some studies have referred to this category as "out-of-bounds," but the term sidecountry was used in this study. Those who were skiing or snowboarding in the backcountry for the entirety of their trip were included in the "ski/snowboard" category. Those using snowmobiles and or motorized snowbikes in the backcountry were included in the "snowmobile/snowbike" category. All other avalanche fatalities that did not fall into these 3 groups, including inbounds skiers and snowboarders, snowshoers, hikers, climbers, highway control, and roof avalanches were excluded from the study.

Fatality reports were analyzed for: date, method of travel, group size, number of deaths, number of group members carrying a beacon, shovel, probe, number of group members who had taken an avalanche education course, burial time, and burial depth. Several reports documented victims with beacons that were turned off; these were counted as not having a beacon. Equipment that was reported in snowmobiles, rather than on a person, was also not counted as snowmobile operators can become detached from sleds in an avalanche, resulting in their equipment being buried or unable to locate. Therefore, having equipment on the snowmobile was not counted as the rescuer or victim did not have

access to these items. In cases where groups split up, only the immediate group of those with the victim at the time of the accident were counted. In addition, when other parties were nearby or witnessed the accident and came to assist, they were not counted. For burial depth, if a range was reported, the average was used. The time buried was estimated based on the times given in the reports.

The analysis was computed using R (version 4.0.2).[11] All statistical hypothesis tests were performed at $\alpha=0.05$ level of significance. Preparedness was assessed using a scoring method; 2 scores were used. The first preparedness score (score 1) accounted for each piece of equipment; all members of the group involved in the fatality were assessed using the data recorded from fatality reports. Beacon, shovel, and probe were coded as ordinal variables. The variables were coded per item as: no one in the group having the item (0 points), some of the group members having it (1 point), and all group members having it (2 points). Missing values for these variables

None	0
Some	1
All	2

were imputed to be the mean of the observations within corresponding tourer category.

Another score (score 2) was considered in which size of the group was factored in by multiplying the equipment value (score 1) by a group size score: solo traveler (1 point) and 2 or more group members (2 points) (Table 1). Several diagnostic tests were run to justify the statistical model including the Bartlett test for homogeneity of variance, the Fligner-Killeen's test, and the Levene's test. Since the preparedness scores did not follow a normal distribution, the Fligner-Killeen's test was more appropriate. All 3 diagnostic tests for homogeneity of variance concluded that score 1 did not satisfy the homogeneity of variance condition. The analysis of variance (ANOVA) with type-III sum of squares was preferred in such cases. This was used in presenting the results for score 1. For score 2, a Bartlett test ($P=0.20$) did not suggest violation of homogeneity of variance assumption, whereas the Fligner-Killeen test did ($P=0.02$). We fit a classical ANOVA and Welch's ANOVA model.

Burial time data had a large range due to the timing and conditions of the rescue. A 1-way ANOVA model was run to determine if there was a significant difference in burial time among tourer groups. An additional analysis of burial time was conducted evaluating the proportion of fatalities uncovered in <15 min using a

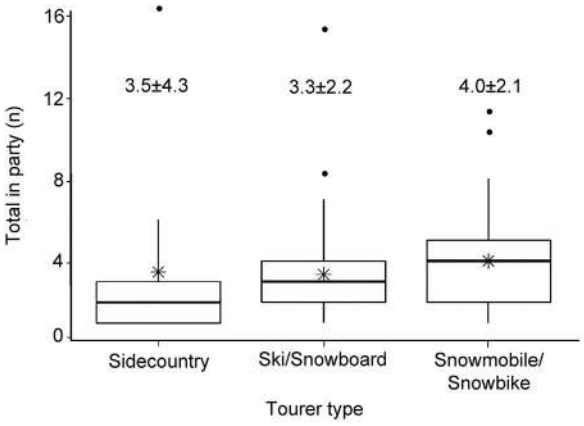

Figure 1. Boxplot of victims' group size categorized by tourer type. The lines of the boxplot represent the quartiles. The lower vertical line starts at the minimum and extends for the distribution of the first quartile. The horizontal thin lines represent the boundaries of quartile 1 (lower) and quartile 3 (upper). The thick horizontal line is the median and the * symbol is the mean. The upper vertical line extends through the fourth quartile. The individual dots are outliers. Mean±SD are listed on the figure.

Pearson's chi-squared test. A 1-way ANOVA was used to compare the 3 mean burial depths. For the burial time, we used the ratio of <15 to >15 min compared among the tourer groups. The variable did not follow a normal distribution. We acknowledge that median (interquartile range [IQR]) is the best descriptive statistic for this variable. The burial depth moderately deviated from normality and we used ANOVA to compare the means among the tourer groups. For such violation, we think the median (IQR) and mean±SD together gave a clearer picture than any of these 2 descriptive statistics which led us to report both median (IQR) and mean±SD. For consistency of the figures of these 2 variables, we used box plots with mean.

Results

In analyzing 258 case reports in the United States over 10 seasons between the 2009 to 2010 season through the 2018 to 2019 season, 205 fatalities were included in the analyses, with 53 fatalities excluded based on criteria. The 205 fatalities were broken down into the following categories: 32 sidecountry, 91 skier/snowboard, and 82 snowmobile/snowbike. Avalanche education was unreported in 78% of case reports and therefore was not included in this analysis. Among 205 fatalities, the presence or absence of a beacon was unreported in 31 fatalities, shovel was unreported in 81 fatalities, and probes were unreported in 78 fatalities. Group size was

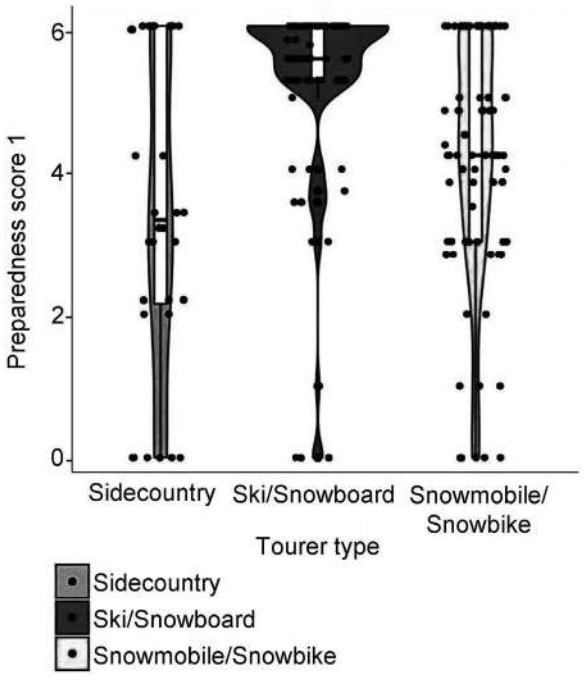

Figure 2. The distribution of preparedness by tourer category using score 1. The dots represent scores for each group (using score 1), and the outlined shape of the graph represents the trend of scores overall. The shading corresponds to each tourer group as seen in the key.

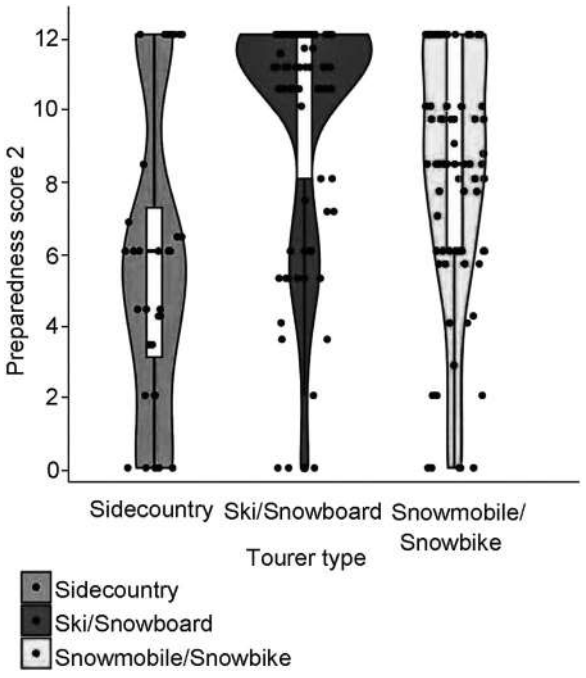

Figure 3. The distribution of preparedness by tourer category using score 2. The graph shape shows the overall trend in preparedness broken down by score using score 2. The dots show the individual scores. The shading represents each tourer group depicted in the key.

unreported in 5 fatalities. Among the reports including group size, 38% of sidecountry fatalities traveled alone, while 14% of ski/snowboard and 4% of snowmobile/snowbike were solo travelers. From the Welch 1-way test and boxplot, the data did not suggest a significant difference in average group size (P=0.15). The group size per fatality group was: sidecountry 3.5±4.3, ski/snowboard 3.3±2.2, and snowmobile/snowbike 4.0±2.1 persons (Figure 1).

Among safety equipment, beacons had the highest percentage of all members of a group carrying 1 in each category of tourer, compared to shovels or probes. Preparedness score 1 was significantly different between the 3 groups of tourers (P<0.01 with ANOVA with type-III test). The ski/snowboard group scores had the greatest number of high scores of the 3 groups (Figures 2 and 3). Preparedness within the sidecountry group was distributed evenly from low to high scores, meaning some fatalities had no or little equipment and some had close to all. In the snowmobile/snowbike group, the majority of scores fell within the middle range of scores per scoring criteria, meaning most groups had some but not all equipment. There was no difference in preparedness scores between solo travelers and groups. Using the model for score 2, there was also a significant difference between tourer groups (classical ANOVA P<0.01, Welch's 1-way ANOVA P<0.01). Tukey HSD test determined that each tourer group had significantly different preparedness scoring from each other. Figures 2 and 3 reveal a greater distribution of higher preparedness scores for the ski/snowboard group using both scores 1 and 2 as compared to the other groups.

Nineteen victims were not buried and therefore were not included in the burial time analysis; 162 fatalities were reported with a burial time. Burial time was different among tourer groups (P=0.04). Burial time for a solo traveler was higher than victims in a group, with all categories combined. The range in burial time was extensive due to rescues requiring additional support other than original group members and delays for safety and avalanche mitigation. In some instances, rescues were unsuccessful and victims were buried for several months until the snow melted or the victim was found incidentally. Therefore, burial time ratio was used to evaluate burials <15 min to burials >15 min. Burial time in <15 min was dependent on the tourer group (P<0.01). The ski/snowboard group had the highest proportion that were buried in <15 min compared to the other 2 groups at 39%, followed by sidecountry at 24% and snowmobile/snowbike at 14%. Burial depth was recorded in 139 reports. Based on the

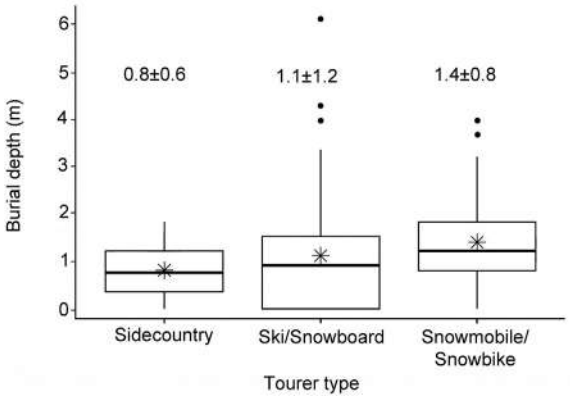

Figure 4. Boxplot of burial depths per tourer category, with the mean burial depth in meters. Vertical lines represent the first and fourth quartiles. The lower box represents the second and the upper box is the third quartile, with the thick line being the median. The individual dots at the top are outliers. The * symbol is the mean. Mean±SD burial depths are listed on the figure.

Welch 1-way test, burial depth was significantly different among the 3 tourer groups ($P<0.01$). Snowmobile/Snowbike victims were buried the deepest at 1.4±0.8 m, followed by ski/snowboard at 1.1±1.2 m, and sidecountry at 0.8±0.6 m (Figure 4).

Discussion

This analysis works to understand the subtle differences among different backcountry user groups that could contribute to avalanche fatalities. Overall preparedness in our study was assessed using 2 scores. A previous study[9] evaluated preparedness by surveying different user types, not caught in avalanches, at trailheads in Utah. Each piece of equipment (beacon, probe, and shovel), and traveling with a partner were evaluated separately and then together as "minimum safety practices," which included partner, beacon, and shovel. There was a significant difference among the backcountry user type of those who carried beacons, probes, shovels, and avalungs, and those who were carrying out "minimum safe practices." Backcountry skiers and snowboarders had the highest percentage of those carrying beacons, probes, shovels, and the combination, while snowmobiles had fewer, and out-of-bounds skiers and snowboarders had the least.[9] Although it is inaccurate to define these measures as minimum safety practices, this category consisting of avalanche equipment and inclusion of at least 1 partner was most similar to score 2 in our study. Our score also included having a probe and assessed the group of the victim, rather than an individual user who was not caught in an avalanche. Our results correlate in that both scores 1 and 2 had a significant difference between the 3 groups in terms of preparedness. The ski/snowboard group in our study also had the highest preparedness followed by snowmobile/snowbike, and then sidecountry users.

Group size was a critical component affecting avalanche rescue. One previous study[9] found no significant difference among different backcountry users regarding the number of people traveling with a partner. Among the 3 groups we studied, there was not a significant difference among group size with mean group sizes: sidecountry 3.5, ski/snowboard 3.3, and snowmobile/snowbike 4.0 people. However, the sidecountry group had the most that traveled alone with 38% of fatalities, whereas the snowmobile group had the least at 4%. This was seen in other studies comparing backcountry and sidecountry skiers, with 15% of backcountry skiers going alone compared to 30% of sidecountry skiers.[3] This may suggest a trend in sidecountry tourers going alone and snowmobiles traveling in groups more often.

The reason behind the differences in equipment and traveling with a partner among groups, assessed in our preparedness scores is unknown. One aspect that is commonly attributed to avalanche preparedness is avalanche education. Snowmobilers have been associated with lower levels of avalanche education, however, there has been an increased effort in the past decade toward tailoring avalanche courses to motorized users.[12,13] Another consideration is that snowmobile behavior is different than skiers and snowboarders. Snowmobiles travel faster, cover larger areas, can involve hill-climbing, steep descents, catching big air, and ascending tight chutes. Observing subtle clues of avalanche danger can be more challenging.[1,13] When comparing snowmobile riding patterns to backcountry skiers using global positioning system data, snowmobiles spent significantly less time in avalanche terrain, but encountered more potentially hazardous terrain features.[14] In addition, when surveyed, snowmobiles had the highest percentage of participants underestimating the avalanche danger compared to skiers, snowboarders, and out-of-bounds skiers and snowboarders, and the highest odds ratio of these groups when compared to skiers.[15] These factors could contribute to the differences in preparedness scores found between groups. Furthermore, in a study comparing backcountry and sidecountry skiers, there was a difference in perceptions of how backcountry terrain is classified. They found that sidecountry skiers had a variety of opinions regarding terrain, skills, and backcountry preparedness compared to backcountry skiers having a common mindset among the group, which is similar to our findings with fatality data. The difference between the classification of sidecountry and backcountry

suggests that sidecountry terrain is safer, requiring less skill, knowledge, and equipment.[3] This could contribute to the changes in preparedness among these groups. Among sidecountry users at the backcountry gates at Jackson Hole Mountain Resort, factors such as expertise level and residency status (living in the area of the recreation) were associated with increased likelihood of carrying standard avalanche safety gear.[6] Studies have found that sidecountry users also had a lower proportion who checked the avalanche forecast and this group had a need for increased education.[3] In addition, factors such as gender, backcountry experience, and knowledge of avalanche mitigation influenced travel behavior and decision-making tendencies of backcountry skiers.[16] Therefore, there are many factors likely contributing to why user groups exhibit different tendencies in the backcountry regarding avalanche preparedness.

Burial time was a significant factor among survival of avalanche victims. Depending on the study, 65 to 72% of deaths in Colorado and Utah were due to asphyxia, which consistently accounts for the majority of avalanche fatalities.[10,17] A previous study[18] determined that beacons reduced burial time from 102 to 20 min and reduced mortality from 68 to 54% in avalanche accidents in Austria. A significant finding of our study was the difference among user types when comparing the ratio of burial <15 min to >15 min. We found that the ski/snowboard group had the greatest proportion of burial time <15 min and also had highest preparedness scores. There may be a link between ski/snowboarders having reduced burial time and increased equipment. Another study[19] suggests that increased extrication time could be due to a shift into more avalanche prone terrain. Some groups venture into more remote uncontrolled areas, resulting in long or difficult rescues.[19] Reducing burial time is important for preventing avalanche fatalities, especially due to asphyxiation. Burial time is expected to be longer for solo travelers than victims in a group due to lack of rescuers. In our study, sidecountry had the largest proportion of solo travelers. Beyond equipment carried and traveling with a partner, many other factors could contribute to burial time such as avalanche education, practicing recovery techniques, quality of equipment, group size, rider ability level, familiarity with area and partners, and more. Further studies are needed to determine if there is a correlation to equipment carried and other factors that could contribute to this difference among user groups.

Our study determined that on average snowmobile victims were buried the deepest, at an average of 1.4 m compared to 1.1 m in ski/snowboard, and 0.8 m in sidecountry victims. There was a significant difference in burial depth between these groups which could be due to several factors. One could be that snowmobiles traverse into deeper, more remote or consequential areas and the mechanics of the snowmobile cause the victim to be buried deeper due to the weight of the snowmobile.[20] Another factor could be that the ski/snowboard and snowmobile groups were able to rescue victims who were buried in shallower areas, therefore not leading to a fatality. Since there were not uniform data on nonfatal avalanches, the average depth of these groups in victims who survived accidents is unknown. One study[21] determined that burial depth differed between trauma and asphyxiation fatalities. The median burial depth for trauma was 0.9 m compared to asphyxiation at 1.5 m,[21] which could suggest that the location and degree of injury occurring in the accident could contribute.

LIMITATIONS

Avalanche data are inherently troublesome due to the lack of uniformity in reporting. There is no standard reporting among fatalities resulting in some avalanche centers including more or less information. Data were sourced from several avalanche centers, which resulted in some centers providing more details than others. In terms of burial depth and time, it is understood that these are not exact measurements as they were taken in the field. Several variables relevant to backcountry user's behavior such as avalanche education and experience were unable to be analyzed due to the lack of reporting. Furthermore, although some avalanche centers allow for public reporting of nonfatal avalanches, the uniformity of these data is unknown and therefore is difficult to use in comparison to fatal avalanches.[5] Because nonfatal avalanches are not uniformly reported, this study was retrospective and only analyzed fatal avalanches. Future studies are needed observing all fatal and nonfatal avalanches with uniform reporting of all variables to determine possible differences in behavior among victims in fatal accidents.

Conclusions

The ski/snowboard user group had the highest preparedness based on equipment carried and group size among fatalities. The ski/snowboard group had the highest proportion of burials in <15 min, whereas the snowmobile/snowbike group had the highest proportions of burials >15 min. The snowmobile/snowbike group was on average buried the deepest; sidecountry the shallowest. Statistical differences were found among the 3 groups in preparedness scores, burial time ratio of <15 min and >15 min, and in burial depth. These differences in preparedness and accident details suggest there are factors among the user groups that are different and

should be further investigated to understand their impact on avalanche fatalities.

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References

1. Jekich BM, Drake BD, Nacht JY, Nichols A, Ginde AA, Davis CB. Avalanche fatalities in the United States: a change in demographics. *Wilderness Environ Med*. 2016;27(1):46–52.
2. International Snowmobile Manufacturers Association. New snowmobile sales data for winter of 2020-2021. Available at: https://www.snowmobile.org/snowmobile-sales-data-2020-2021.html. Accessed December 29, 2021.
3. Fitzgerald KR, Kay JM, Hendrikx J, Johnson J. Backcountry and sidecountry users: an intercept survey approach. International Snow Science Workshop Proceedings, Breckenridge, CO; 2016:1057–1063.
4. van Tilburg C. Sidecountry rescue—who should respond to ski resort out-of-bounds rescues? *Wilderness Environ Med*. 2010;21(2):100–2.
5. Colorado Avalanche Information Center. Statistics and reporting. Available at: https://www.avalanche.state.co.us/accidents/statistics-and-reporting/. Accessed December 29, 2021.
6. Nichols TB, Hawley AC, Smith WR, Wheeler 3rd AR, McIntosh SE. Avalanche safety practices among backcountry skiers and snowboarders in Jackson Hole in 2016. *Wilderness Environ Med*. 2018;29(4):493–8.
7. Brugger H, Etter HJ, Zweifel B, Mair P, Hohlrieder M, Ellerton J, et al. The impact of avalanche rescue devices on survival. *Resuscitation*. 2007;75(3):476–83.
8. Zweifel B, Procter E, Techel F, Strapazzon G, Boutellier R. Risk of avalanche involvement in winter backcountry recreation: the advantage of small groups. *Wilderness Environ Med*. 2016;27(2):203–10.
9. Silverton NA, McIntosh SE, Kim HS. Avalanche safety practices in Utah. *Wilderness Environ Med*. 2007;18(4):264–70.
10. McIntosh SE, Brant-Zawadzki G, Milliner BH, Christensen ED, Nyberg AA, Grissom CK, et al. Cause of death in Utah avalanche fatalities, 2006-2007 through 2017-2018 winter seasons. *Wilderness Environ Med*. 2019;30(2):191–4.
11. R Core Team. R: A language and environment for statistical computing. Available at: https://www.R-project.org/. Accessed February 20, 2021.
12. Hanke J, Savage C. Throttle decisions: an example of furthering avalanche awareness in the mountain snowmobile community through use of social comparison. International Snow Science Workshop Proceedings, Banff, AB; 2014:1220–3.
13. Haegeli P, Strong-Cvetich L. Using discrete choice experiments to examine the stepwise nature of avalanche risk management decisions—an example from mountain snowmobiling. *J Outdoor Recreat Tour*. 2020;32:100165.
14. Haworth C, Hendrikx J, Johnson J, Sykes J. Snowmobilers terrain preferences and exposure to avalanche terrain. International Snow Science Workshop Proceedings, Austria; 2018:1681–3.
15. Silverton NA, McIntosh SE, Kim HS. Risk assessment in winter backcountry travel. *Wilderness Environ Med*. 2009;20(3):269–74.
16. Sykes JM. Travel behavior and decision-making biases of lift access backcountry skiers on saddle peak, bridger mountains, Montana, USA. (Thesis). Montana State University, Bozeman; 2018.
17. Sheets A, Wang D, Logan S, Atkins D. Causes of death among avalanche fatalities in Colorado: a 21-year review. *Wilderness Environ Med*. 2018;29(3):325–9.
18. Hohlrieder M, Mair P, Wuertl W, Brugger H. The impact of avalanche transceivers on mortality from avalanche accidents. *High Alt Med Biol*. 2005;6(1):72–7.
19. Page CE, Atkins D, Shockley LW, Yaron M. Avalanche deaths in the United States: a 45-year analysis. *Wilderness Environ Med*. 1999;10(3):146–51.
20. Spencer JM, Ashley WS. Avalanche fatalities in the western United States: a comparison of three databases. *Nat Hazards*. 2011;58:31–44.
21. Boyd J, Haegeli P, Abu-Laban RB, Shuster M, Butt JC. Patterns of death among avalanche fatalities: a 21-year review. *CMAJ*. 2009;180(5):507–12.

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ORIGINAL RESEARCH

Latency of Symptom Progression in Mild *Daboia palaestinae* Envenomation

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Introduction—*Daboia palestinae* is the most common venomous snake in Israel. In most cases, snakebite does not develop into a systemic disease. Since the introduction of specific antivenom therapy, the mortality rate has declined sharply. Nevertheless, there is still no uniform therapeutic protocol in Israel for patients who have been envenomated, and there is no current data regarding latency of symptom development. We aimed to evaluate the latency of symptom development after *D palaestinae* snakebite in patients presenting to the emergency department (ED) with local reaction.

Methods—This was a retrospective single-center study of all patients who presented following a snakebite from 2015 to 2020. Patients with confirmed or suspected *D palaestinae* bite were included. Demographical and clinical data were extracted from each electronical medical record and subjected to descriptive and comparative analysis.

Results—Sixty-two patients met the inclusion criteria. Their median (IQR) age was 30 (17−48) y, and 75% were male. Forty-one percent presented with local reactions to the snakebite, 29% presented with advanced local reaction, and 29% presented with systemic symptoms. Antivenom was given to 22% of patients with advanced local reaction and 89% of patients with systemic reaction. The median (IQR) time from bite to antivenom and from ED arrival to antivenom were 2 (1.5−2.5) h and 1 (0.75−1.5) h, respectively. Antivenom was administered at the latest 3.5 h after presentation to the ED for progression of local symptoms.

Conclusions—Our study may support a 4- to 6-h observation period in the ED for patients with mild clinical presentation after *D palaestinae* bite. Further larger prospective studies are needed.

Keywords: snakebite, emergency department, antivenom, pediatric, adult

Introduction

In Israel there are 3 venomous snake families with 8 different species: Viperidae (*Montivipera bornmulleri*, *Cerastes vipera, Daboia palaestinae, Echis coloratus, Cerastes gasperettii, Pseudocerastes fieldi*), Atractaspididae (*Atractaspis engaddensis*), and Elapidae (*Walterinnesia aegyptia*).[1] *D palestinae* is the most common among them, accounting for 100 to 300 reported cases of envenomation in adults and children every year.[2]

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D palestinae venom is composed of neurotoxins, hemorrhagins, angioneurin growth factors, and different types of integrin inhibitors.[3] These enzymes can cause local and systemic manifestations. In most cases, the snakebite does not cause systemic manifestations and is limited to local symptoms. The most common local tissue reaction includes pain and edema, while the most common systemic reactions include abdominal pain, nausea and vomiting, tachycardia, and hypotension.[4-8] However, gastrointestinal symptoms may reflect nonspecific symptoms present in medically insignificant snakebite as well. Snakebite presentations are usually classified based on local and systemic findings. Local symptoms can be further classified based on the distance from the snakebite (simple vs advanced), and systemic symptoms can be classified as mild moderate or severe based on the treating physician's judgment.[4] There are other classifications, also based on the clinical severity

at the time of presentation[5]: mild, only local involvement confined to the site of the bite; moderate, systemic manifestations of gastrointestinal involvement; and severe, patients admitted with hemodynamic shock (systolic blood pressure <fifth percentile for age). Since the introduction of specific antivenom therapy, the mortality rate has declined sharply from 6 to 10% to 0.5 to 2%.[3] Nevertheless, there is still no uniform therapeutic protocol in Israel for patients who have been envenomated, and particularly for envenomated children.[6] It has been suggested that patients with systemic manifestations and progressive local signs be treated with the specific antivenom,[7,9-11] although a recent local study suggests antivenom treatment for only moderate or severe systemic reactions.[4]

There is no current data regarding latency of symptom development after *D palestinae* bite. Some authors suggest admission to the hospital for 72 h regardless of the severity of initial symptoms, with observation in the intensive care unit for the first 48 h.[8] Others suggest 6 h of surveillance for children with mild clinical presentation.[6]

In our study, we aimed to evaluate the latency of symptom development after *D palestinae* snakebite in patients presenting to the emergency department (ED) with local reaction or no symptoms.

Methods

This was a retrospective single-center study of all patients who presented to Ha'emek Medical Center ED following a snakebite between 2015 and 2020. Ha'emek Medical Center is a regional hospital serving northeastern Israel, with 110,000 annual presentations distributed among separate EDs (87,000 to the general ED and 23,000 to the pediatric ED).

All patients with an ICD-9 discharge diagnosis of "Venomous snakes and lizards causing poisoning and toxic reaction" and "Bite of nonvenomous snakes and lizards" (E905.0, E906.2) were extracted from the electronical medical records.

After chart review, only patients with confirmed or suspected *D palestinae* bite were included. Diagnosis of *D palestinae* bite was made based on the snake itself, brought in alive or dead, a photo, or confirmed by individuals familiar with local snakes. Suspicion of *D palestinae* bite was based on geographical distribution of the snake and clinical findings.

Each chart was reviewed for the date and time of bite, age, sex, time of presentation to the hospital, time of antivenom administration, length of stay (LOS) in the ED, disposition, hospitalization time, clinical signs and symptoms on presentation and during hospitalization, complication evaluation and management, follow-up in the wards, and return visits to the ED after discharge from the hospital.

Snakebite presentations were classified based on the clinical presentation on admission: *local*, involvement confined to the site of the bite (eg, swelling, pain, discoloration, ecchymosis); *local advanced* (rapid extension of swelling, enlarged tender lymph node draining the bitten limb, swelling involving more than half the bitten limb or more than 1 joint); and *systemic* (eg, gastrointestinal, cardiovascular, central nervous system, hematological).[11]

Indications for treatment with *D palestinae*–specific antivenom (Kamada, Israel) were rapid progression of local signs proximal to the site of the bite and systemic manifestations such as circulatory shock or gastrointestinal symptoms.[2,5] The antivenom currently used is a monovalent whole immunoglobulin. Since 2012, it has been produced by Kamada, Beit-Kama, using good manufacturing practice, according to the methods developed by the Felsenstein (previously Rogof) institute. It is equine based, 100 PD50/mL^{-1}.

Patient data were transferred to an electronic spreadsheet (Excel 365) and subjected to descriptive and comparative analysis. Data are presented as median (IQR).

The study was approved by Ha'emek Medical Center institutional ethics review board (EMC-20-235).

Results

Overall, between 2015 and 2020, 62 patients presented to the ED after *D palestinae* bite. Figure 1 describes patient

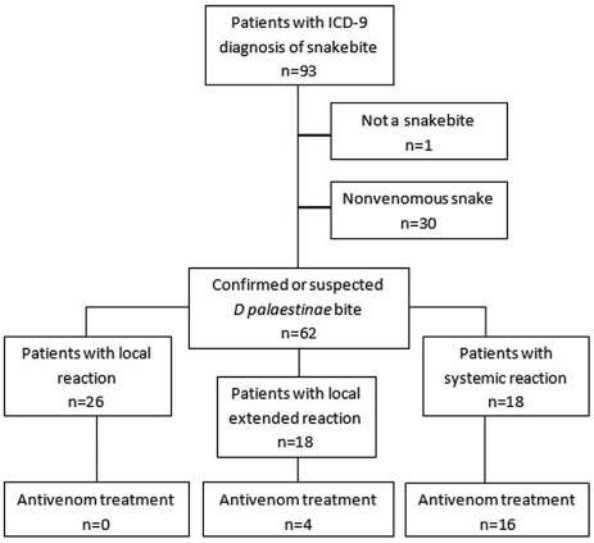

Figure 1. Patient inclusion.

Table 1. Demographics, general characteristics, and outcome of patients presenting to the ED with *D palestinae* snakebite

	Asymptomatic (n=0)	*Local reaction (n=26)*	*Local extended reaction (n=18)*	*Systemic reaction (n=18)*
Age (y), median (IQR)		30 (16–46)	30 (17–48)	31 (17–48)
Sex				
Male, n (%)		21 (81)	11 (61)	13 (72)
Female, n (%)		5 (19)	7 (39)	5 (28)
Hospitalization, n (%)	0	7 (27)	10 (55)	15 (83)
ICU admission, n (%)	0	1 (4)	3 (17)	12 (67)
ED LOS (h), median (IQR)	0	4.4 (2.4–7.5)	4.4 (2.4–7.5)	4.5 (2.4–7.6)
Length of hospitalization (d), median (IQR)	0	2 (1–3)	2 (1–3)	2 (1–2.5)
Received antivenom, n (%)	0	0	4 (22)	16 (89)

IQR, interquartile range; ED, emergency department; ICU, intensive care unit; LOS, length of stay.

inclusion. Their age was 30 y (17–48), and 75% were male (47). Most patients presented to the ED with local reactions to the snakebite (41%) while 29% presented with advanced local reaction and 29% with systemic symptoms. Antivenom was given to 22% of patients with advanced local reaction and 89% of patients with systemic reaction (Table 1). Overall, 52% of patients were admitted to the hospital with a 2-d length of hospitalization.[1,3] Sixteen patients were admitted to ICU (25%).

Overall, ED LOS was 4.5 (2.4–7.8) h. Similarly, among discharged patients ED LOS was 4.5 (2.4–7.4) h. The time from bite to antivenom and from ED arrival to antivenom were 2 (1.5–2.5) h and 1 (0.75–1.5) h, respectively. Antivenom was administered at the latest 3.5 h after presentation to the ED for progression of local symptoms. The characteristics of patients treated with antivenom are described in Table 2.

No adverse reactions were reported other than 1 patient who lost consciousness after treatment with the antivenom. She recovered with no need for intervention. One 35-y-old pregnant patient (16 wk of gestation) developed systemic reaction and was treated with antivenom with no reported adverse reactions. Four patients developed swelling progression beyond 2 joints within 24 h. Only one 57-y-old patient was treated with an additional antivenom. The others were observed, with resolution of symptoms.

Two patients with mild systemic reactions were not treated with antivenom; a 21-y-old male with local reaction and mild prolongation of prothrombin time was observed in the ED for 20 h with no progression of symptoms or of worsening coagulopathy. A 47-y-old female with limb pain, nausea, weakness, and palpitations was observed for 7 h in the ED until resolution of systemic symptoms.

One 15-y-old male with local reaction returned to the ED 17 h after discharge with worsening of pain and rash. He was admitted for observation and supportive care with no need for antivenom or surgical intervention.

Discussion

We found that most patients with *D palestinae* envenomation were treated with antivenom within an hour of presentation to the ED. The latest antivenom administration in the ED was for a patient with mild systemic reaction who was treated with antivenom 4 h after envenomation. Only 4 patients with local extended reaction and no systemic symptoms were treated with antivenom. The progressive local reaction developed within 2 h of their presentation to the ED. One patient received a second dose of antivenom 24 h after admission due to progressive local symptoms. One patient returned to the ED 17 h after bite due to worsening of pain and rash and was treated with antihistamine.

A recent study[4] supports our findings. In their cohort of 41 adult patients bitten by *D palestinae*, most patients were treated with antivenom within 90 min of presentation to the emergency department, and only 1 patient with systemic symptoms was treated 6 h after presentation. Similar findings were described among envenomated children,[7] possibly because children are more vulnerable to the toxic effect of snakebite in view of the larger dose received relative to body size.[6] In that recent evaluation of antivenom therapy for *D palestinae* bites in children, among 25 children who were treated, median time from envenomation to antivenom administration was 1 h (up to 2.5 h). One patient was treated with antivenom 24 h post bite for severe tachycardia.[7] Symptom progression in patients with late antivenom administration was not described in these studies.

Data from North America revealed similar findings. An 8-h period of observation for children with mild symptoms after pit viper bite is suggested.[12] This time frame was based on symptoms on presentation to the ED (average of 8 h from snake bite). In Israel, on the other hand, given the short distances from residential areas to hospitals in the geographical distribution of *D*

Table 2. Characteristics of patients treated with antivenom

Age (y)	*Sex*	*Clinical features on presentation*	*Time to symptom progression*	*Clinical classification*	*Time from ED arrival to antivenom (h)*	*Time from bite to antivenom (h)*	*Adverse reaction to antivenom*
19	M	Limb pain and swelling, vomiting, hoarseness and dyspnea	Edema progression beyond 2 joints within 24 h	Systemic reaction	1	2.5	
53	M	Limb pain and swelling, tachycardia	Edema progression within 2 h	Systemic reaction	2	2.5	Syncope
2	M	Vomiting, decreased LOC, limb pain, and swelling	Hypotension within 1 h	Systemic reaction	1	2	
35	F	Diarrhea, limb pain, and swelling	No progression	Systemic reaction	1	2	
29	M	Limb pain and swelling	Nausea and vomiting within 20 min	Systemic reaction	0.5	1.5	
65	M	Limb pain and swelling	Nausea and vomiting, swelling of lips within 30 min	Systemic reaction	0.5	1.5	
20	M	Limb pain and swelling, vomiting, sweating, dyspnea, and oral swelling	No progression	Systemic reaction	0	1	
52	M	Limb pain and swelling	Edema progression beyond 2 joints within 1 h	Local extended reaction	1	1.5	
57	F	Limb pain and swelling	Edema progression beyond 2 joints within 1 h	Local extended reaction	1.5	2	
57	F	Diarrhea and vomiting, limb pain and swelling	Limb edema progression beyond 2 joints within 24 h	Systemic reaction	1.5	2	
25	F	Lips swelling, limb pain, and swelling	No progression	Systemic reaction	1	2	
42	M	Limb pain and swelling	Nausea and vomiting and progression of limb edema beyond 2 joints within 1.5 h	Systemic reaction	3.5	4	
21	M	Limb pain and swelling, tachycardia	Edema progression beyond 2 joints within 1.5 h	Systemic reaction	2.5	3.5	
21	M	Vomiting, limb pain and swelling	Edema progression beyond 2 joints within 24 h	Systemic reaction	1	1.5	
47	M	Limb pain and swelling	Edema progression beyond 2 joints within 1 h	Local extended reaction	1	2	
69	M	Nausea and vomiting, hypotension, limb pain, and swelling	No progression	Systemic reaction	0	1	
45	M	Hypotension, lips swelling, limb pain and swelling	Edema progression beyond 2 joints within 24 h	Systemic reaction	0	0.75	
18	M	Limb pain and swelling	Vomiting, abdominal pain and progression of limb swelling within 30 min	Systemic reaction	0.75	1.5	

(continued on next page)

Table 2 *(continued)*

Age (y)	*Sex*	*Clinical features on presentation*	*Time to symptom progression*	*Clinical classification*	*Time from ED arrival to antivenom (h)*	*Time from bite to antivenom (h)*	*Adverse reaction to antivenom*
52	M	Limb pain and swelling	Edema progression beyond 2 joints within 30 min	Local extended reaction	0.75	2	
33	M	Limb pain and swelling	Edema progression beyond 2 joints within 1.5 h	Systemic reaction	2	2.5	

ED, emergency department; LOC, loss of consciousness; M, male; F, female.

palestinae, average time from snakebite to ED presentation is much shorter (47 min).[8] Moreover, asymptomatic patients with normal clotting lab results within 6 h of snake bite suggest no envenomation at all.[13]

Based on our findings and previous studies,[4,7] 4 to 6 h of observation in the ED for patients with mild nonprogressive symptoms post *D palestinae* envenomation may be a safe and sufficient approach. Delayed administration of *D palestinae* antivenom was already found to be effective.[9,14] All cases described had late (>24 h), progressive local manifestations, some accompanied by systemic manifestations and hematological abnormalities, and were treated effectively with antivenom. Thus, discharging patients home with clear return to ED instructions (progressive local manifestation) and after appropriate observation in the ED may decrease unnecessary hospital admissions.

In our study, 1 patient suffered from adverse reactions to the antivenom treatment (Table 2). The antivenom currently used is more purified and less immunogenic than the original antivenom, which was associated with anaphylaxis (4%) and serum sickness (4%).[2,8] Our findings differ from recent reports of no adverse reactions to the newer antivenom in envenomated adult and pediatric population,[4,7] although our patient did not need any intervention.

LIMITATIONS

Our study has several limitations. First, it was a single-center study with the inherent limitations of a low-powered retrospective study. Furthermore, there was a limited follow-up data to confirm the lack of symptoms after discharge. Some variables, such as sequestration of venom, medical comorbidities, and unknown factors, could have led to delayed symptom development. However, it can be assumed that a patient who did not re-present to the ED did not have significant symptoms requiring treatment with antivenom, which is not given outside the hospital. Second, we assumed the case to be *D palestinae* envenomation by appearance of the injury and based on the habitat of the snake. However, *D palestinae* is the most common venomous snake in northern and central Israel accounting for most envenomations.[14] In addition, adverse reactions to antivenom may have occurred, but were not documented in the medical records. Delayed reactions or long-term complications may exist.

Conclusions

Our study may support a 4- to 6-h observation period in the ED for patients with local reaction after *D palestinae* bite. These patients should be discharged only after clear return precautions if medical care is available close to the

patient's home. Further larger prospective studies are needed to confirm our findings.

Author contributions Study design (MAM, RJ); data collection (MAM); data analysis and interpretation (MAM, RP, GC, RJ); manuscript draft (MAM, RJ); manuscript revision (GC, RP, RJ); all authors approved the final version of the manuscript.

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References

1. Kochva E. Venomous snakes of Israel: ecology and snakebite. *Public Health Rev*. 1998;26(3):209–32.
2. Paret G, Ben Abraham R, Ezra D, Shrem D, Eshel G, Vardi A, et al. *Vipera palaestinae* snake envenomations: experience in children. *Hum Exp Toxicol*. 1997;16(11):683–7.
3. Momic T, Arlinghaus FT, Arien-Zakay H, Katzhendler J, Eble JA, Marcinkiewicz C, et al. Pharmacological aspects of *Vipera xantina palestinae* venom. *Toxins (Basel)*. 2011;3(11):1420–32.
4. Wang AH, Gordon D, Drescher MJ, Shiber S. Is there a benefit for administration of antivenom following local and mild systemic reactions to Daboia (Vipera) palaestinae snake bites? *Toxin Rev*. 2018;39(1):52–6.
5. Winkler E, Chovers M, Almog S, Gopalakrishnakone P, Tan CKV. Palestinae bites-clinical experience in Israel. *Recent Adv Toxicol Res*. 1992;1:329–36.
6. Abraham RB, Winkler E, Eshel G, Barzilay Z, Paret G. Snakebite poisoning in children–a call for unified clinical guidelines. *Eur J Emerg Med*. 2001;8(3):189–92.
7. Pivko-Levy D, Munchnak I, Rimon A, Balla U, Scolnik D, Hoyte C, et al. Evaluation of antivenom therapy for *Vipera palaestinae* bites in children: experience of two large, tertiary care pediatric hospitals. *Clin Toxicol (Phila)*. 2017;55(4):235–40.
8. Shemesh IY, Kristal C, Langerman L, Bourvin A. Preliminary evaluation of *Vipera palaestinae snake* bite treatment in accordance to the severity of the clinical syndrome. *Toxicon*. 1998;36(6):867–73.
9. Bentur Y, Cahana A. Unusual local complications of *Vipera palaestinae* bite. *Toxicon*. 2003;41(5):633–5.
10. Le Geyt J, Pach S, Gutierrez JM, Habib AG, Maduwage KP, Hardcastle TC, et al. Paediatric snakebite envenoming: recognition and management of cases. *Arch Dis Child*. 2021;106(1):14–9.
11. Warrell D. Guidelines for the management of snakebites, 2nd edition. 2016. Available at: https://www.who.int/publications/i/item/9789290225300. Accessed August 22, 2021.
12. Lopoo JB, Bealer JF, Mantor PC, Tuggle DW. Treating the snakebitten child in North America: a study of pit viper bites. *J Pediatr Surg*. 1998;33(11):1593–5.
13. Blackman JR, Dillon S. Venomous snakebite: past, present, and future treatment options. *J Am Board Fam Pract*. 1992;5(4):399–405.
14. Bentur Y, Zveibel F, Adler M, Raikhlin B. Delayed administration of *Vipera xanthina palaestinae* antivenin. *J Toxicol Clin Toxicol*. 1997;35(3):257–61.

WILDERNESS & ENVIRONMENTAL MEDICINE 2022; 33(2): 210–8

CONCEPTS

Mohave Rattlesnake (*Crotalus scutulatus*) Identification Revisited

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Crotalus scutulatus (Mohave rattlesnake) is a clinically significant pit viper broadly distributed across much of the arid southwestern United States and mainland Mexico. Identification of *C scutulatus* is a concern among emergency medical service and emergency department personnel owing to its reputation for severe envenomations and difficulty in visually differentiating between *C scutulatus* and other species, primarily *Crotalus atrox* (western diamond-backed rattlesnake). We contrast distinctive characteristics of *C scutulatus*, *C atrox*, and 3 other sympatric species: *Crotalus molossus*, *Crotalus ornatus*, and *Crotalus viridis* (western and eastern black-tailed rattlesnakes and prairie rattlesnake, respectively). Greenish coloration eliminates *C atrox* but does not confirm *C scutulatus.* Obvious coarse and fine speckling of the dorsal pattern and a pale postocular stripe intersecting the mouth characterize *C atrox.* Dorsal speckling is insignificant or absent in the other species, whereas the pale postocular stripe passes above the mouth in *C scutulatus* and *C viridis* and is absent in *C molossus* and *C ornatus*. Tails boldly ringed with alternating black and white or contrasting shades of gray are shared by *C atrox* and *C scutulatus*, respectively, but a lack of boldly ringed tails characterizes the other species. The proximal rattle segment is yellow and black, or entirely yellow, in *C scutulatus* but black in the others. The most reliable visual identifications are based on evaluations of multiple traits, all of which are variable to some extent. Traits such as tail ring width and the size and number of crown scales have frequently been overemphasized in the past.

Keywords: Mojave rattlesnake, Mojave green, snakebite, rattlesnake identification

Introduction

Over the 2 decades since one of us coauthored "Mojave rattlesnake (*Crotalus scutulatus scutulatus*) identification,"[1] it has become apparent that distinguishing *C scutulatus* (Mohave rattlesnake[2]), particularly from sympatric *Crotalus atrox* (western diamond-backed rattlesnake), is more complex than originally thought. After little initial interest in the original paper, it has attracted considerable recent attention, accumulating >900 reads on researchgate.net since 2014 and recently adding approximately 12 reads per week. Two additional decades of research combined with the aforementioned interest argue for an updated and expanded treatment of the subject. Herein, we explain that there is no single observable trait that will reliably identify *C scutulatus* or differentiate the species from others. Consequently, the most reliable visual identifications are based on evaluation of multiple traits, all of which are variable to some extent.

C scutulatus is distributed across much of the arid southwestern United States and deep into mainland Mexico, and its range overlaps largely with *C atrox* (Figure 1). *C scutulatus* is well known for venom that contains a presynaptic PLA_2 neurotoxin named Mojave toxin.[3] Yet in a large area of south-central Arizona (as well as some parts of Mexico), *C scutulatus* produces venom that lacks Mojave toxin but contains

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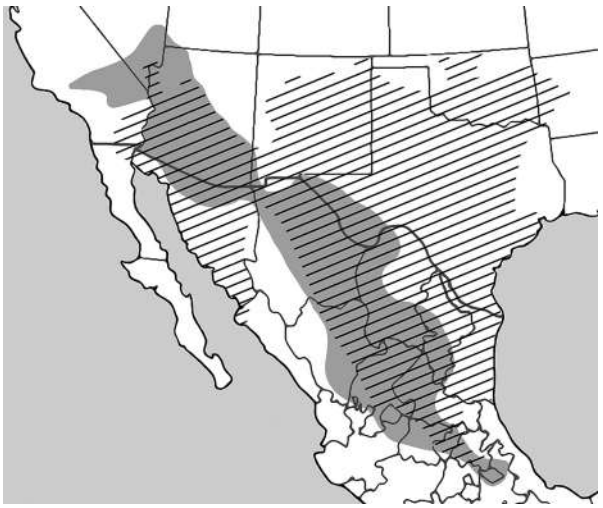

Figure 1. Distribution of *Crotalus scutulatus* (shaded area) and of *Crotalus atrox* (cross-hatched area).

tissue-destroying and hemorrhagic snake venom metalloproteinases (SVMPs) and other biologically active proteins and peptides, like *C atrox* and many other pitvipers.[4-7]

Extensive gene flow has been demonstrated between adjacent Arizona populations of *C scutulatus* with neurotoxic venom (venom-A[4] and type II[8]) and those without neurotoxin but rich in SVMPs (venom-B[4] and type I[8]), yet neither venom type appears to be spreading into the other population.[7] The poorly defined intergrade zone contains some animals that express both Mojave toxin and SVMPs, termed venom-A+B.[6,7,9]

Venomous snakes produce an average of about 6 annual fatalities in the United States, many of which occur outside the range of *C scutulatus*,[10] yet the species has a widespread but undeserved reputation for being especially deadly despite dozens of annual bites that rarely produce fatalities.[11] Anecdotal, misquoted, and sometimes fabricated accounts of *C scutulatus* hybrids are common in social media, on the Internet, and occasionally in the mainstream news media.[11] Yet despite decades of searching for wild hybrid rattlesnakes by multiple investigators, some looking for genetic evidence, only 1 small population of wild hybrids involving *C scutulatus* has been found: a well-established population of *C scutulatus* x *viridis* (Mohave x prairie rattlesnake) hybrids in Hidalgo County, New Mexico.[12] Like the intermediate venom-A+B animals in Arizona, most Hidalgo County hybrids express both Mojave toxin and SVMPs in their venom. Yet many of the traits previously suspected of indicating hybrids elsewhere have been shown by repeated investigations to be variations in unhybridized animals.[12-14]

We provide an updated assessment of how various traits compare between *C scutulatus* and *C atrox*. Additionally, we include distinguishing features of 3 other species that are occasionally, but less frequently, misidentified as *C scutulatus*: *Crotalus molossus* (western black-tailed rattlesnake) and *Crotalus ornatus* (eastern black-tailed rattlesnake), which are broadly sympatric with *C scutulatus* in Arizona, New Mexico, and Texas; and *Crotalus viridis* (prairie rattlesnake), which is sympatric with *C scutulatus* in New Mexico and Texas (summarized in Table 1). Note, however, that our identification guidelines are confined to United States populations. Some Mexican populations, especially of *C scutulatus* and *C molossus*, differ substantially from their US conspecifics, especially in color and pattern.

Safety Concerns

Live rattlesnakes can strike nearly their entire length. Dead rattlesnakes and even severed heads may reflexively bite and envenomate if handled even several hours after death.[15-17] Some snakebite patients or their companions occasionally bring the snake that delivered the bite to the emergency department. Live rattlesnakes should generally not be allowed into ambulances or clinics. Opening a container holding a live rattlesnake is extraordinarily dangerous. Apparently dead rattlesnakes should be manipulated with tools longer than the snake, and severed heads should never be manipulated by hand, even with gloves.

Countless references, both popular and scholarly, describe identifying characteristics that often include fine-scale traits that cannot be examined safely on a live rattlesnake. We have divided our comments into gross traits that can be observed and photographed from a safe distance (≥ twice the length of the snake) and fine-scale traits that can be used when examining a dead snake, a high-quality photograph, or occasionally a live animal secured in a transparent glass or plastic container. In the latter case, care must be taken to avoid allowing fingers or other body parts to touch air holes and other places where a fang might protrude if the snake inside strikes. Attempting to put a live rattlesnake into a transparent container to facilitate close examination should never be considered.

Gross Identifying Characteristics

The tail of nearly all rattlesnakes terminates in a hard keratinous "rattle." Baby rattlesnakes have a single hard button, like the eraser on a pencil. Older rattlesnakes have segmented rattles of varying lengths. Rattlesnakes with

Table 1. Comparison of most significant distinguishing traits with (corresponding figures noted)

Trait	*Crotalus scutulatus*	*Crotalus atrox*	*Crotalus molossus/Crotalus ornatus*	*Crotalus viridis*
Greenish color	Sometimes	No	Sometimes	Often
Pattern speckling	Little or none (2A)	Obvious, coarse and fine (2B)	Little or none	Little or none
Tail color and caudal rings	Dark gray, black, or brown rings on pale gray or white background (3)	High-contrast black rings on white background (4)	Tail uniformly black, gray, or dark brown, with occasional faint pale rings (5A)	Narrow dark and pale rings, same colors as dorsum, with little or no whitish color (6A)
Proximal rattle segment	Yellow or bicolor (yellow and black) (3,8A)	Black with occasional brush of white (4,8B)	Black (5A)	Black (6A)
Pale postocular stripe	Passes above the mouth (7A)	Intersects the mouth (7B)	Absent (5B)	Passes above the mouth (6B)
Crown scales	Large and irregular, spilling out onto parietal area (10)	Small and granular, indistinct from parietal area (11)	Large and square anteriorly, others small and uniform	Small and granular, indistinct from parietal area

deformed or missing rattles, caused by either genetic deformity or trauma, are encountered on rare occasions. Invariably, such deformed rattlesnakes have a blunt stub for a tail, with or without a deformed rattle. Even the so-called "rattleless" rattlesnake, *Crotalus catalinensis*, has a single rattle segment on a blunt tail. Thus, regardless of potentially atypical color or markings, no sympatric rattlesnake has a tapered pointed tail.

C scutulatus is a heavy-bodied snake, with typical adults averaging about 60 to 90 cm in length with a single row of large, roughly diamond-shaped blotches along the dorsal midline, an unmarked white or pale-yellow ventral surface, and alternating dark and pale rings on the tail. The greatest verified length is 124 cm. Neonates are perfect miniatures of the adults, averaging about 29 cm long.[11,14] *C atrox* looks broadly similar, and most adults are similar in size to *C scutulatus*, although *C atrox* can be much larger (largest recorded=226 cm).[18] *C molossus* and *C ornatus* are similar to *C scutulatus* in size and body shape, but with high-contrast dark dorsal blotches that are less diamond-shaped compared to *C scutulatus* and *C atrox*.[19] *C viridis* is similar in appearance but with more rounded dorsal blotches that are more widely spaced.[20]

DORSAL COLOR AND MARKINGS

The dorsal color of *C scutulatus* sometimes features a greenish tinge, although some animals are shades of brown, tan, gray, or even yellowish, with little or no green. The dorsal blotches typically consist of dark centers, surrounded by a single row of darker scales, with an outer margin of pale scales, all on a medium-toned background. Significantly, there is little speckling within the dorsal blotches and the colored margins are well defined, resulting in a crisp, clean pattern. The monochrome light and dark scales of the blotch edges usually give the blotches a characteristically serrated outline (Figure 2A).

The dorsal color of *C atrox* is typically a mixture of brown, tan, or gray, often blending into an orange or salmon tint near the tail. In some animals, the entire body has an orange/pink tint. Significantly, however, the authors know of no *C atrox* with a greenish dorsal color. The shape of the dorsal blotches is less well defined than in *C scutulatus*. Dark scales occur within the blotches, making the inner dark margins poorly demarcated. Some scales of the posterior portion of the pale outer margins are usually partially or entirely white (Figure 2B), unlike *C scutulatus*. Overall, the impression is often of a rather faded, washed-out pattern.

C molossus and *C ornatus* are highly variable, with background colors ranging from gray to greenish, brown, or bright yellow, with darker dorsal blotches that seldom

Figure 2. Typical dorsal colors and markings of most *Crotalus scutulatus* (A) and *Crotalus atrox* (B). Top is cranial. Although colors of individuals of both species may be darker or paler and some *C scutulatus* are not greenish, *C atrox* may be many shades of gray, brown, and pink, but not greenish, posterior margins of diamonds are edged in white, and the pattern is notably more speckled with poorly defined margins.

touch or overlap and tend to be elongated laterally. The blotches consist of a dark outline with a center of the same color as the background, and at least those on the caudal two-thirds of the body extend laterally toward the ventral surface via narrow dark zigzag bars. The blotches may have light outer edges, but these are often

Figure 3. Selection of typical caudal markings of *Crotalus scutulatus.*

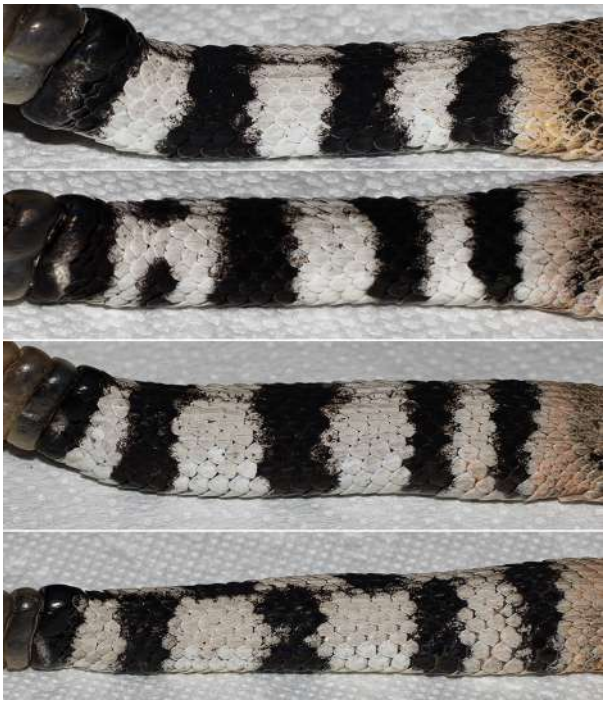

Figure 4. Selection of typical caudal markings of *Crotalus atrox.*

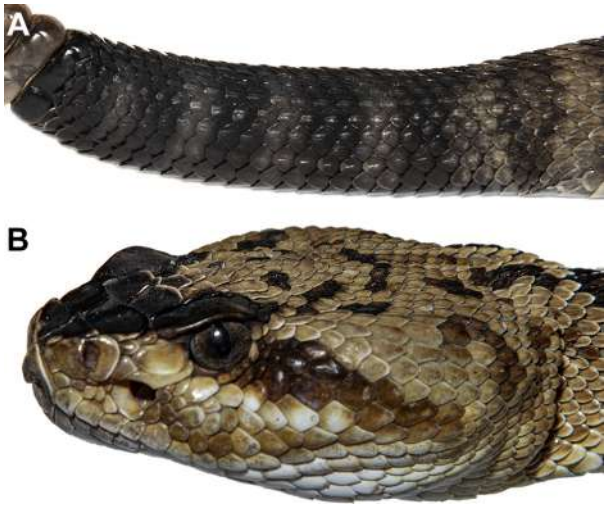

Figure 5. *Crotalus molossus*, showing faint pale caudal rings found on some animals (A) and lack of a pale postocular stripe (B). Both traits also apply to *Crotalus ornatus.*

poorly defined. Individual scales are usually monochrome, giving a serrated or pixelated outline to all pattern elements. The dorsal color of *C viridis* is usually dominated by olive green and/or brown, with rather oval or hexagonal dark dorsal blotches, usually with a thin pale outline. Greenish specimens of all 3 species are sometimes confused with *C scutulatus* owing to the mistaken belief that any greenish rattlesnake must be *C scutulatus*, stemming from the common moniker "Mohave green rattlesnake."

Figure 6. *Crotalus viridis*, showing narrow caudal rings of the same colors as the body (A) and the distinct pale postocular stripe (B) passing above the corner of the mouth.

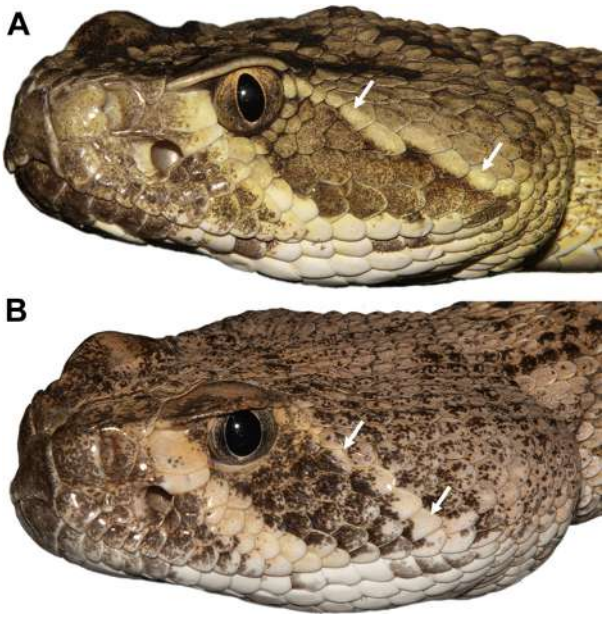

Figure 7. Facial markings of *Crotalus scutulatus* (A) and *Crotalus atrox* (B). Note that the postocular pale stripe (arrows) passes above the corner of the mouth in *C scutulatus* but intersects the mouth in *C atrox.*

Nonetheless, variations in pattern can complicate identification. Distorted, merged, and fragmented dorsal blotches are common in the nuchal area of all 5 species and, occasionally, elsewhere on the animals. Some of these variations occur regionally but are outside the scope of this account. On extraordinarily rare occasions, striped, patternless, and leucistic individuals have been encountered.

CAUDAL COLOR AND MARKINGS

The width of alternating dark and pale caudal rings is commonly suggested to distinguish between *C scutulatus* and *C atrox*, yet this trait is quite variable. Although popularly described as "rings," these markings frequently do not extend across the ventral surface of the tail in both species. Furthermore, the dark rings are often fragmented, incomplete, and sometimes offset at the dorsal midline. In *C scutulatus*, the pale color on the tail may be various shades of gray but is occasionally nearly white or even tan. The dark rings may be black, dark gray, or brownish and are usually considerably narrower than the pale spaces between them, but their number, spacing, and width are highly variable (Figure 3).

Caudal rings in *C atrox* usually consist of a bright white background and pure black rings, often about as wide as the white spaces between them. However, the

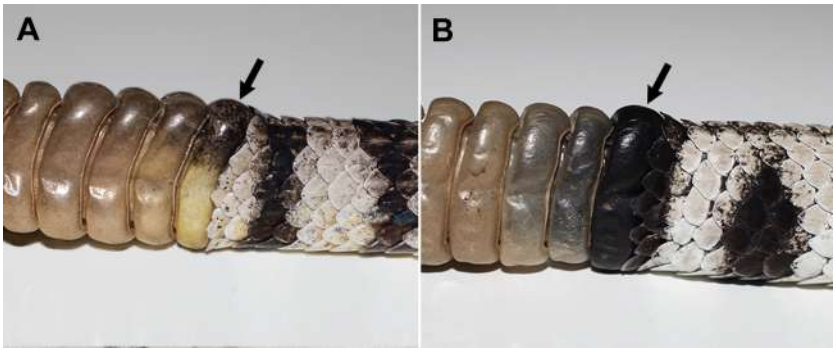

Figure 8. Live tissue is visible within the proximal rattle segment (arrows). Proximal rattle segment is light yellow or bicolor (yellow and black) in *Crotalus scutulatus* (A) but usually entirely black in *Crotalus atrox* (B).

shape and spacing of the black markings are inconsistent (Figure 4).

As their common names suggest, *C molossus* and *C ornatus* have uniformly black, brown, or dark smokey gray tails, sometimes with faint narrow pale rings (Figure 5A), especially in juveniles. The overall impression is invariably of a dark, relatively uniform tail. The dark tail alone separates them unmistakably from *C atrox* and *C scutulatus*. The tail of *C viridis* bears narrow alternating rings of the same colors as the dorsal body, with the dark body blotches morphing into dark caudal rings separated by background body color (Figure 6A).

FACIAL MARKINGS

Both *C scutulatus* and *C atrox* bear 2 pale facial stripes bilaterally, one originating just anterior to the eye and the other just posterior, termed preocular and postocular stripes, respectively. Both stripes sweep down and extend caudally. The postocular stripe passes above the corner of the mouth and sometimes extends horizontally beyond the mandibles in *C scutulatus* (Figure 7A) but drops down and intersects the mouth in *C atrox* (Figure 7B). However, it is not uncommon in both species for the postocular stripe to pass very close to or contact the corner of the mouth, which is complicated by the exact extent of the closed mouth being difficult to discern from a safe distance.

An indistinct pale preocular stripe may be visible on *C molossus* and *C ornatus,* but these species lack the pale postocular stripe (Figure 5B). *C viridis* bears a pale postocular stripe (Figure 6B) similar to that of *C scutulatus*, rendering the trait useless in differentiating between them.

COLOR OF PROXIMAL RATTLE SEGMENT

The newest rattle segment is found at the base of the rattle and contains live tissue. The color of the live tissue in the proximal segment is visible and usually bicolor (pale yellow and black) or entirely pale yellow in *C scutulatus* (Figures 3 and 8A). In adult or sub-adult *C atrox*, the proximal segment is entirely black, sometimes with a faint superficial brush of white (Figures 4 and 8B). However, the proximal segment of neonates and juveniles of *C atrox* (1–3 rattle segments) are pale, sometimes

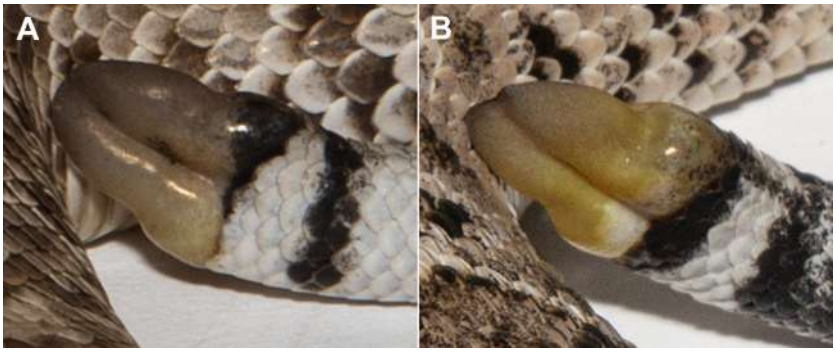

Figure 9. First rattle segments of neonate *Crotalus scutulatus* (A) and *Crotalus atrox* (B).

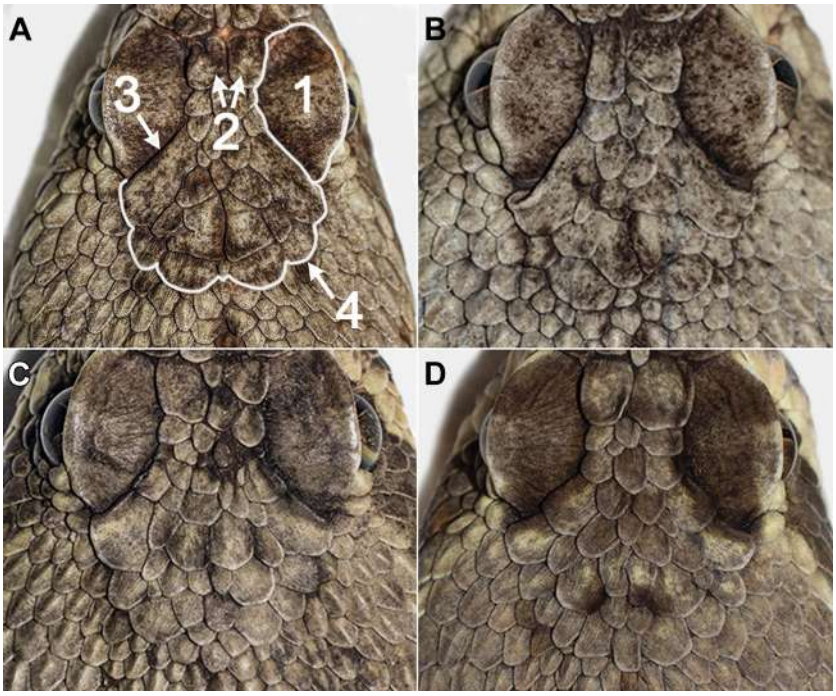

Figure 10. Crown scales on *Crotalus scutulatus* are highly variable in size, shape, number, and arrangement. Terminology (A): right supraocular scale (1), fewest crown scales separating supraoculars (2), deep furrow where enlarged crown scales overlay the supraocular (3), and posterior margin of enlarged crown scales (4). Two scales separating supraoculars (B). Three scales separating supraoculars (C). Enlarged crown scales more evenly shaped, sized, and blended than usual (D).

yellowish or reddish (Figure 9B). *C molossus*, *C ornatus*, and *C viridis* have black proximal rattle segments (Figures 5A and 6A).

Figure 11. Typical crown scales of *Crotalus atrox*. Although there are often a few irregularly sized and shaped scales, especially anteriorly, most crown scales are small and similar in size and shape to scales on the parietal region. Note the distinct dark speckling on the scales compared to *Crotalus scutulatus* (Fig. 10).

Fine-Scale Identifying Characteristics

Do not attempt examination on a live rattlesnake.

CROWN SCUTELLATION

Two large crown scales separating the supraocular scales are commonly listed as diagnostic for *C scutulatus*, yet the supraoculars are separated by 3 and occasionally 4 scales in about 14% of individuals[14] (Figure 10). The crown scales of *C atrox* and *C viridis* are more granular, with at least 4 and usually many more scales separating the supraoculars (Figure 11).

Although the small scales between the supraoculars of *C atrox* and *C viridis* merge relatively seamlessly with similar scales in the parietal region, the enlarged crown scales of *C scutulatus* are irregular in shape and size and fan out onto the parietal region of the head. Additionally, in *C scutulatus*, the medial edges of the supraoculars tuck under the enlarged crown scales, forming a deep, dark furrow (Figure 10) that is missing in most or all *C atrox* (Figure 11) and *C viridis*.

C molossus and *C ornatus* have a series of large, squarish scales on the crown forward of the eyes and the supraoculars are separated by 2 large scales

nearest the rostrum, but they lack the "fan" of enlarged crown scales extending onto the parietal region.

FINE SPECKLING ON SCALES

Many dorsal scales on *C atrox* are multicolored, with most bearing many dark speckles of varying sizes. Dorsal scales on *C scutulatus*, as well as *C molossus* and *C ornatus*, are generally monochromatic with little or no speckling. In *C viridis*, some features like the pale outlines of dorsal blotches cut across individual scales.

Conclusions

Determining whether a particular rattlesnake is *C scutulatus* or *C atrox* can be challenging, with distinction from *C molossus*, *C ornatus*, and *C viridis* being somewhat less so. All identifying traits are variable, and some highly so. Despite ample rumors, wild hybrid rattlesnakes are very rare, with variation in identifying characters being common in genetically pure animals of all species. On extraordinarily rare occasions, aberrant individuals of each species have been encountered, including striped, patternless, and leucistic animals,[11,14] but no sympatric rattlesnake has a tapered pointed tail.

In general, *C scutulatus* sometimes displays a greenish tinge, its dorsal pattern is well defined with little or no speckling, the pale postocular facial stripe sweeps rearward and usually does not intersect the mouth, caudal rings tend to be alternating shades of pale gray with narrower dark gray, and the proximal rattle segment is partially or entirely pale yellow.

C atrox is not greenish in color, margins in the dorsal pattern appear ragged or washed out with heavy speckling, the pale postocular facial stripe intersects the mouth, caudal rings are usually high-contrast black and white, and the proximal rattle segment is usually entirely black (in all but very small animals) with an occasional faint brush of white.

C molossus and *C ornatus* have uniformly dark tails, sometimes with faint narrow pale rings, and black proximal rattle segments. *C viridis* has widely separated ovoid dorsal blotches, tails ringed in the same colors as the dorsum, and black proximal rattle segments.

Although determining which species is involved can be helpful in evaluating the potential clinical course of an envenomation, specific identification is not necessary for antivenom selection, and clinicians must remain alert and prepared for unexpected sequelae. Attempting to identify a live rattlesnake is potentially dangerous, and the risk almost always outweighs any perceived benefit. Well-focused digital photographs taken by the patient or bystanders and transmitted to a poison control center can often be quickly identified by a consulting herpetologist.

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References

1. Bush SP, Cardwell MD. Mojave rattlesnake (*Crotalus scutulatus scutulatus*) identification. *Wilderness Environ Med*. 1999;10(1):6–9.
2. Crother BI, Bonett RM, Boundy J, Burbrink FT, de Queiroz K, Frost DR, et al. *Scientific and Standard English Names of Amphibians and Reptiles of North America North of Mexico, with Comments Regarding Confidence in our Understanding*. 8th ed. Society for the Study of Amphibians and Reptiles, Herpetological Circular #43; 2017:64–5.
3. Bieber AL, Tu T, Tu AT. Studies of an acidic cardiotoxin isolated from the venom of Mojave rattlesnake (*Crotalus scutulatus*). *Biochim Biophys Acta*. 1975;400(1):178–88.
4. Glenn JL, Straight R. Mojave rattlesnake *Crotalus scutulatus scutulatus* venom: variation in toxicity with geographical origin. *Toxicon*. 1978;16(1):81–4.
5. Calvete JJ, Fasoli E, Sanz L, Boschetti E, Righetti PG. Exploring the venom proteome of the western diamondback rattlesnake, *Crotalus atrox*, via snake venomics and combinatorial peptide ligand library approaches. *J Proteome Res*. 2009;8(6):3055–67.
6. Massey DJ, Calvete JJ, Sanchez EE, Sanz L, Richards K, Curtis R, et al. Venom variability and envenoming severity outcomes of the *Crotalus scutulatus scutulatus* (Mojave rattlesnake) from southern Arizona. *J Proteomics*. 2012;75(9):2576–87.
7. Zancolli G, Calvete JJ, Cardwell MD, Greene HW, Hayes WK, Hegarty MJ, et al. When one phenotype is not enough: divergent evolutionary trajectories govern venom variation in a widespread rattlesnake species. *Proc Biol Sci*. 2019;286(1898):20182735.
8. Mackessy SP. Venom composition in rattlesnakes: Trends and biological significance. In: Hayes WK, Beaman KR, Cardwell MD, Bush SP, eds. *The Biology of Rattlesnakes*. Loma Linda, CA: Loma Linda Univ Press; 2008:495–510.
9. Wilkinson JA, Glenn JL, Straight RC, Sites Jr JW. Distribution and genetic variation in venom A and B populations of the Mojave rattlesnake (*Crotalus scutulatus scutulatus*) in Arizona. *Herpetologica*. 1991;47(1):54–68.
10. Forrester JA, Weiser TG, Forrester JD. An update on fatalities due to venomous and nonvenomous animals in the United States (2008–2015). *Wilderness Environ Med*. 2018;29(1):36–44.
11. Cardwell MD. *The Mohave Rattlesnake and How It Became an Urban Legend*. Rodeo, New Mexico: ECO Publishing; 2020.
12. Zancolli G, Baker TG, Barlow A, Bradley RK, Calvete JJ, Carter KC, et al. Is hybridization a source of adaptive venom variation in rattlesnakes? A test, using a *Crotalus scutulatus* x *viridis* hybrid zone in southwestern New Mexico. *Toxins (Basel)*. 2016;8(6):188.
13. Jacob JS. An evaluation of the possibility of hybridization between the rattlesnakes *Crotalus atrox* and *C. scutulatus* in the southwestern United States. *Southwest Nat*. 1977;22(4):469–85.
14. Cardwell MD. Species accounts. Mohave rattlesnake (*Crotalus scutulatus*). In: Schuett GW, Feldner MJ, Smith CF, Reiserer RS,

eds. *Rattlesnakes of Arizona*. vol. 1. Rodeo, New Mexico: ECO Publishing; 2016:563–605.

15. Klauber LM. Experiments with decapitated rattlesnakes. In: Klauber LM. *Rattlesnakes: Their Habits, Life Histories, and Influence on Mankind*. Berkeley and Los Angeles, California: Univ Calif Press; 1956:310–4. [2nd ed. 1997:342–6]
16. Emswiler MP, Griffith FP, Cumpston KL. Clinically significant envenomation from postmortem copperhead (*Agkistrodon contortrix*). *Wilderness Environ Med*. 2017;28(1):43–5.
17. Hinze JD, Barker JA, Jones TR, Winn RE. Life-threatening upper airway edema caused by a distal rattlesnake bite. *Ann Emerg Med*. 2001;38(1):79–82.
18. Schuett GW, Repp RA, Spencer CL, Beaman KR, Painter CW. Species accounts: Western diamond-backed rattlesnake (*Crotalus atrox*). In: Schuett GW, Feldner MJ, Smith CF, Reiserer RS, eds. *Rattlesnakes of Arizona*. vol. 1. Rodeo, New Mexico: ECO Publishing; 2016:333–94.
19. Persons TB, Feldner MJ, Repp RA. Species accounts: blacktailed rattlesnake (*Crotalus molossus*). In: Schuett GW, Feldner MJ, Smith CF, Reiserer RS, eds. *Rattlesnakes of Arizona*. vol. 1. Rodeo, New Mexico: ECO Publishing; 2016:461–505.
20. Davis MA, Douglas ME. Species accounts: prairie rattlesnake (*Crotalus viridis*). In: Schuett GW, Feldner MJ, Smith CF, Reiserer RS, eds. *Rattlesnakes of Arizona*. vol. 1. Rodeo, New Mexico: ECO Publishing; 2016:289–332.

WILDERNESS & ENVIRONMENTAL MEDICINE 2022; 33(2): 219–23

CONCEPTS

Project EARTH: Lessons from 10 Years of Teaching Public Health Skills for Resource-Limited Settings

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The College of Public Health at East Tennessee State University started a program in 2011 to teach the skills needed to protect and promote health and well-being in resource-limited settings. The need to provide public health services in resource-limited settings exists in both wilderness and isolated settings and when a disaster disrupts basic societal infrastructure. In these settings, lives may depend on the ability to provide water, sanitation, hygiene, shelter, first aid, and other basic services. Over the last decade, the college expanded the program considerably into what is now known as Project EARTH (Employing Available Resources to Transform Health) that now includes several different academic courses as well as programs designed to develop innovative solutions to address the needs of people in resource-limited settings. Working in a resource-limited setting requires effectively utilizing locally available resources to improve and protect people's health and well-being. Project EARTH focuses on teaching students to design and create specific products for these situations while progressively honing those cross-cutting skills necessary to work effectively in these settings—notably teamwork, creativity, and resilience. To this end, Project EARTH implements a sequential learning process that includes significant hands-on training and simulated experiences with debriefing opportunities at the end of each activity. Project EARTH may serve as a useful model for others considering a similar training program.

Keywords: applied skills, hands-on pedagogy, practical training

Introduction

Saving lives and protecting health and well-being in resource-limited settings often requires attention to a range of basic public health interventions. Access to safe drinking water, basic sanitation, hygiene, and shelter, for example, can be essential in geographically isolated areas and post-disaster scenarios.[1]

In 2011, the College of Public Health at East Tennessee State University started a program to teach the skills needed to help people practice effectively in any resource-limited setting. The college was motivated to create this program for several reasons. As the first school of public health located in central Appalachia, graduates of the college work in rural and medically underserved communities that have inadequate housing and lack basic sanitation and hygiene. Several students, following field experiences in rural parts of Africa, reported they did not have the practical skills to reliably provide clean drinking water. Additionally, the college was motivated by reports of increased mortality occurring after natural disasters because working professionals in affected areas could not provide basic public health services.[1]

There are many aspects to the training program as it has evolved over its first decade. Project EARTH currently includes 3 interconnected components: academic coursework, a simulation facility composed of replicas of actual homes from resource-limited areas, and a creative component focusing on encouraging innovation.

The main academic course is a 15-wk, 3-credit-hour course required for all students in the bachelor of public health and bachelor of health administration degree programs, as well as those in the global health and development minor and the disaster preparedness minor.

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It teaches students to use basic tools and to make basic products while focusing on developing teamwork, creativity, and resilience.

There is also a required course for all doctor of public health students that stresses teamwork and innovation within the framework of resource-limited settings. The class challenges students to make a variety of products from recycled or repurposed materials while working together to address the public health needs of a simulated resource-limited community.

As part of their undergraduate and graduate degrees, students in the college complete an internship in their final semester. Some students opt to complete this internship in another country. For several years, students returned with concerns about the health of citizens in their host communities. The residents came to the students with needs or the students identified health challenges in the areas and did not have sufficient knowledge or skill to address them. For instance, a children's home in Rwanda and the surrounding town lacked access to clean water. A college student worked with several faculty members, including an environmental health water treatment expert, to study different types of water filters. She reached out to an artisan in Rwanda who built biosand water filters for the community.

The course faculty wanted to simulate the conditions faced by people living in resource-limited settings to prepare students to work in such areas. Working with her hosts in Rwanda, the student was able to provide the schematic of an actual house in the area, and course faculty and student workers recreated it. They built replicas of actual homes from other places where faculty and students had worked. Now including dwellings from El Salvador, Mongolia, Nicaragua, Rwanda, and South Africa, as well as a replica of a UNICEF tent from a refugee camp, the simulated community also has several types of gardens and a large tent that can be used as a resource-limited hospital. The replicas serve as a basis for a variety of simulated activities. Students use the simulated community to practice technical skills utilizing roleplaying, simulation, and problem-solving.

To encourage innovation, students participate in identifying and addressing the needs of people in resource-limited settings. With input from a colleague who works with Médecins Sans Frontières (Doctors Without Borders), course faculty began a project that guides students making toys from commonly available products. Course participants also make products from recycled bicycles and shoes from a variety of materials. Working with physical and occupational therapists and volunteer engineers, course faculty and students explore ways to retrofit electronic toys for children with significant physical limitations.

LESSONS LEARNED

Over the course of 10 y, the college learned several lessons about developing programs to teach public health skills relevant to resource-limited areas (Table 1).

Initially, some students who anticipated careers in urban centers in the United States did not see how Project EARTH would apply to their careers. Understanding the ways in which a disaster disrupts healthcare delivery helps students to see the importance of being able to work in a resource-limited setting. When students in health administration, for example, learned of the challenges Hurricane Katrina posed for both hospital administrators and leaders of long-term care facilities, they understood the importance of flexibility and creativity.

It is essential, therefore, that students start by understanding that the skills necessary to work in a resource-limited setting will be relevant to their careers. Once students comprehended this connection, their engagement in and support for the training increased. A 2007 study of Appalachian cultural values and their impact on career development indicated a preference for concrete experiences rather than theoretical concepts and found exposing students to possible work environments will benefit them more than reading or hearing about careers.[2]

Because familiarity with tools is necessary for many projects in resource-limited settings, and because learning to use tools is essential to developing a personal sense of capacity, almost all Project EARTH activities start with a basic introduction to the use of tools, with a significant focus on tool safety. The introduction to each tool starts with education in safe use or with a demonstration of proper and efficient use. Local community artisans have visited the campus and provided expertise on using certain tools and techniques.

While Project EARTH started as an effort to teach students to make the products they might need in a

Table 1. Ten lessons learned

1) Start by explaining that the skills necessary to work in resource-limited settings are relevant to all work environments.
2) Teach students to safely use tools.
3) Select a small number of representative products related to the needs of resource-limited settings.
4) Focus on hands-on experiences in lieu of formal lectures and presentations.
5) Use simulation.
6) Focus on the development of cross-cutting skills.
7) Teach cross-cutting skills in a progressive manner.
8) Encourage innovation.
9) Involve the community, but do not lose focus.
10) Always debrief.

resource-limited setting, it quickly became clear that there are more products, or variations of them, than faculty could teach in a single course. Different types of latrines, for example, work better in different types of environmental conditions. No single course in the project could reasonably teach students how to make every different type of latrine, nor teach them the various soil, water table, surface conditions, and other factors that dictate the most appropriate latrine for any given situation. By giving students the tools and the knowledge to make one type of latrine, however, it is hoped they can transfer effective practices to build an environmentally appropriate latrine when the need arises. While students are still taught to make specific products, one of the lessons learned from Project EARTH has become *it is the process, not the product*.

Focusing on applied learning, especially when taught through the modality of peer engagement activities, appears to resonate with both students and faculty. To stress the hands-on approach to learning, instructors avoid detailed instructions. Students are initially provided a basic description of a newly introduced product and some general guidance on the fabrication of the product.[3] Small groups of students are then provided the basic materials and tools they need and are encouraged to work together to create the best version of the product that they can. Through trial and error, the small groups are usually able to produce a reasonable facsimile of the desired product. Faculty guide students to self-assess, monitor, and evaluate their progress in order to promote self-regulated learning.[4]

Just as most clinical health professions use simulation as a vehicle for student learning, it is valuable for students learning to work in resource-limited settings to be exposed to realistic simulations of those settings. To this end, Project EARTH uses the replicas of homes from 8 locations around the world that simulate the student's placement into a resource-limited setting. Using the homes and other resources, the project attempts to recreate situations that someone might face working in a resource-limited setting. The simulated refugee activity, for example, is a 5- to 7-h activity where the participants

Table 2. Examples of hands-on learning experiences at Project EARTH: brief description, duration, and teamwork/creativity/resilience score

Type of experience	*Brief description*	*Usual duration*	*Teamwork score*[a]	*Creativity score*[a]	*Resilience score*[a]
Making a single product	Drive 25 nails into a board	1 h	1	1	1
	Make an adobe brick stack stove	2–4 h	3	2	2
	Build a field hand-washing station	2–3 h	2	2	2
	Build a Rus pump	3–4 h	4	3	2
	Make shoes from various materials	2–4 h	3	4	2
Complex multi-part scenarios	"The Epidemic Experience"	3–4 h	3	3	3
	Develop and implement a door-to-door tool to survey simulated participants and then recommend health-promoting interventions	2 d			
	"The Tortilla Experience"	5–6 h	5	4	3
	Make a tortilla by clearing and plowing; planting corn; building a fence; making bricks; making a stove from bricks; cooking and grinding corn; mixing and flattening the paste and cooking				
	"The Pioneer Experience"	1–3 d	4	3	3
	Replicate the lives of the "first pioneers" by building a house and creating sanitation, starting a garden, and creating appropriate trade items				
	"The Refugee Experience"	5–7 h	5	4	5
	Plan, prepare for, and respond to all needs (eg, food, water, shelter, sanitation, healthcare) of 25 refugees who will need to be housed for 24 h and who will face unexpected medical and social challenges				

[a]See Table 3.

are required to prepare for, and respond to, the needs of 25 refugees who will be on-site for 24 h. Participants purchase supplies from the simulated store with a limited budget and then create shelter, sanitation, food distribution, medical care, and other essential services for these simulated refugees. As participants are setting up their refugee camp, a small number of actors arrive, portraying refugees facing a range of medical and social challenges to which the students must respond. Table 2 outlines the various simulation activities that are part of the project.

Students engaging in Project EARTH learn more than the ability to use tools to make products. They also develop a set of cross-cutting skills essential to working in resource-limited settings. While these skills can be described in various ways, the team felt they generally fell into 3 areas: teamwork, creativity, and resilience.[3,5,6] Teamwork encompasses oral communication skills, listening skills, interpersonal and cultural sensitivity, collaboration, and other skills. Creativity includes thoughtful imagination and problem-oriented innovation. Resilience requires adaptability, flexibility, and, more colloquially, the grit necessary to work in less-than-ideal situations. Over time, the students come to understand that these skills are relevant to almost all work settings.

The goal of Project EARTH is to expose students to progressively greater demands in the products they make and the skills they demonstrate. The process of teaching students to make a physical product has an obvious sequence.[7] The team has created a sequence by which students are exposed to the cross-cutting skills. The first step in creating this sequence is to identify the ultimate expression of each of the 3 cross-cutting skills. For example, the ultimate expression of teamwork would be the ability of an individual to effectively lead a large, interprofessional team.[8,9] Then, the starting point of each cross-cutting skills was identified. For teamwork, this would logically be working alone. Finally, 3 progressive steps between the starting point and the ultimate expression were identified, creating a 5-step progression. Table 3 shows the 5-step progression for teamwork, creativity, and resilience. Each activity is given a score of 1 to 5 for each of the 3 areas (Table 2). Projects are sequenced so that participants face increasing demands in each area. Studies suggest the skills employers want and expect are not those thought to be taught in institutions of higher learning; however, Project EARTH attempts to hone these valuable workforce skills.[6,10]

Faculty discovered one of the most useful skills for working in a limited-resource setting is the ability to innovate. The ability to use a range of basic tools, when combined with an understanding of the physical needs and cultural parameters of resource-limited settings, provides students with the attributes necessary to innovate. Project EARTH focuses on 2 types of innovation: need-based and product-based. In need-based innovation, students learn to identify a challenge facing people living in resource-limited settings and then develop 1 or more approaches to address that challenge. Students have developed several dozen toys made from basic recycled or repurposed materials so children in refugee camps could have toys for play. In product-based innovation, students are asked to identify alternative uses and applications for an abundant material. For example, students developed a range of products from recycled bicycles, ranging from pedal-powered water pumps to spinning wheels to washing machines. At the highest end of need-based innovation, students have repurposed children's toys so they are usable by children with physical and developmental disabilities.

Table 3. Grading the cross-cutting skills of Project EARTH

A. Teamwork
   1. Working alone (working alone with external guidance)
   2. Working as a part of an externally guided peer group (working in a small group with external guidance)
   3. Working as a part of an independently operating peer group (working in a small group with minimal external guidance)
   4. Leading an independently operating peer group (leading a group of peers with minimal external guidance)
   5. Leading an interprofessional group (leading a diverse group of people with different cultural or professional backgrounds)

B. Creativity
   1. Replication (demonstrating a recently taught skill)
   2. Modification (modifying an existing product, as demonstrated)
   3. Adaptation (adapting a demonstrated skill or product for a new purpose)
   4. Innovation (solving an unmet need or finding a new use for an existing product)
   5. Synthesis (making a new tool or product to address an identified need)

C. Resilience
   1. Day-to-day (ability to work in a low-stress environment with adequate resources)
   2. Disruption (ability to work in a low-stress environment with limited resources)
   3. Incident (ability to work in a moderate-stress environment with adequate resources)
   4. Crisis (ability to work in a high stress or dangerous environment with adequate resources)
   5. Disaster (ability to work in a high stress or dangerous environment with limited resources)

Virtually every activity ends with a formal debriefing session. In addition to a 3-part questionnaire, most experiences end with an open-ended discussion that often focuses on the how and why of decision-making.[4,7] The formal class activities always end with an end-of-semester student assessment of instruction. In addition to the student debrief, the team frequently ends each activity with a debriefing session just for the instructors and student workers. This session provides an immediate after-action review and allows the instructors to propose and consider modifications that can improve the activity in the future.

LIMITATIONS

While each course ends with a systematic evaluation and each pilot project documents the students' ability to successfully create the specified products, there has not been a systematic mechanism to evaluate the extent to which the students have acquired the desired cross-cutting skills: teamwork, creativity, and resilience. To this end, the college of public health has partnered with other faculty at East Tennessee State University who have experience in pedagogical research to design and implement a study of the impact of the course in developing these skills.

Conclusions

The ability to provide basic public health services is an essential part of keeping people alive in wilderness, geographically isolated and resource-limited environments, and, especially, in any post-disaster setting. While students are often taught the importance of these services, they are not always taught the practical skills necessary to provide them.

Over the past 11 y, Project EARTH has taught students to make a range of products relevant to resource-limited settings, and, at the same time, focused on helping students develop the cross-cutting skills of teamwork, creativity, and resilience necessary to work effectively in those settings. Understanding the lessons learned from the Project EARTH experience may be relevant for other academic programs and related training centers who will develop and implement hands-on training programs relevant to their own mission.

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References

1. Ronald C, Southall D. Refugee health: an approach to emergency situations. *BMJ*. 1999;318(7177):200A.
2. Tang M, Russ K. Understanding and facilitating career development of people of Appalachian culture: an integrated approach. *Career Dev Q*. 2007;56(1):34–46.
3. Meeks G. *Critical soft skills to achieve success in the workplace*. [PhD thesis]. Minneapolis, Minnesota: Walden University; 2017.
4. Andrade MS. Cross-cutting skills: strategies for teaching & learning. *High Educ Pedagog*. 2020;5(1):165–81.
5. Kyllonen PC. Inequality, education, workforce preparedness, and complex problem solving. *J Intell*. 2018;6(3):33.
6. Robles MM. Executive perceptions of the top 10 soft skills needed in today's workplace. *Bus Commun Q*. 2012;75(4):453–65.
7. Fox L, Onders R, Hermansen-Kobulnicky CJ, Nguyen TN, Myran L, Linn B, et al. Teaching interprofessional teamwork skills to health professional students: a scoping review. *J Interprof Care*. 2018;32(2):127–35.
8. Leathers JS, Davidson H, Desai N. Interprofessional education between medical students and nurse practitioner students in a Global Health course. *BMC Med Educ*. 2018;18(1):200.
9. Kim TE, Shankel T, Reibling ET, Paik J, Wright D, Buckman M, et al. Healthcare students interprofessional critical event/disaster response course. *Am J Disaster Med*. 2017;12(1):11–26.
10. Hogan R, Chamorro-Premuzic T, Kaiser RB. Employability and career success: bridging the gap between theory and reality. *Ind Organ Psychol*. 2013;6(1):3–16.

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CONCEPTS

The Intersection of Telemedicine and Wilderness Care: Past, Present, and Future

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Wilderness medicine and telemedicine seemingly exist at opposite ends of the clinical continuum. However, these 2 specialties share a common history and the literature abounds with examples of successful deployment of telemedicine to resource limited settings. The recent widespread adoption of telemedicine has important ramifications for wilderness providers. Telemedicine is inherently reliant on some sort of technology. There is a wide spectrum of complexity involved, but in general these systems rely on a hardware component, a software component, and a network system to transmit information from place to place. Today, connectivity is nearly ubiquitous through access to cellular networks, Wi-Fi, or communication satellites. However, bandwidth, defined as the amount of data which can be transmitted through a given connection over time, remains a limiting factor for many austere settings. Telemedicine services are typically organized into 4 categories: 1) live/interactive; 2) store and forward; 3) remote patient monitoring; and 4) mHealth. Each of these categories has an applicable wilderness medicine use case which will be reviewed in this paper. Though the regulatory environment remains complex, there is enormous potential for telemedicine to enhance the practice of wilderness medicine. Drones are likely to transform wilderness medicine supply chains by facilitating delivery of food, shelter, and medicines and are able to enhance search and rescue efforts. Remote consultations can be paired with remote patient monitoring technology to deliver highly specialized care to austere environments. Early feasibility studies are promising, but further prospective data will be required to define future best practices for wilderness telemedicine.

Keywords: virtual health, remote care, drones, telehealth, remote patient monitoring, wilderness medicine

Introduction

Wilderness medicine and telemedicine seemingly exist on opposite ends of the clinical continuum. Care delivered in the wilderness setting is perceived as low tech and evokes images of duct tape and dirt. Telemedicine, meanwhile, is seen as high tech and is associated with gadgets and gizmos. In reality, the practice of wilderness medicine and telemedicine operationally overlap and share a rich history of serving patients in resource-limited environments.

Telemedicine has enjoyed modest but meaningful growth for decades as technology has become cheaper and regulatory barriers have eased. More recently, telemedicine utilization has exploded, driven in part by an overwhelming shift in the incentives to deliver care virtually related to the COVID-19 pandemic. Telemedicine is disrupting traditional healthcare through novel care delivery models such as remote patient monitoring and e-consults. In similar fashion, telemedicine has the potential to transform wilderness and austere care.

We will review the shared history of wilderness medicine and telemedicine and discuss how and where

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Table 1. Common telemedicine terminology

Term	*Definition*
Telemedicine	The practice of medicine from a distance
Telehealth	The delivery of healthcare from a distance; in addition to telemedicine, telehealth includes a broader scope of activities such as education, training and healthcare logistics
Virtual health	A synonym for telehealth
Originating site	The site where a patient is located at the time of a telehealth service
Hub and spoke	A telehealth operational construct where a centralized resource (the hub) can deliver care to multiple remote locations (the spokes)

these specialties currently intersect. Lastly, we will describe a vision for how telemedicine can enhance the delivery of wilderness care in the future.

DEFINITIONS, ORIGINS, AND GUIDING PRINCIPLES

Wilderness medicine is characterized by the improvised care of patients in remote locations using limited resources, with the risk of delayed evacuation to definitive care.[1] Telemedicine can be most simply defined as the delivery of medical care from afar. In practice, both specialties manage patients either across or from great distances. For those readers less familiar with telemedicine, Table 1 outlines common definitions used in this landscape. Telemedicine services are typically organized into 4 categories: 1) live/interactive; 2) store and forward; 3) remote patient monitoring; and 4) mHealth. These categories are not mutually exclusive. For instance, mHealth is characterized by the utilization of a mobile device and can be used to deliver telemedicine through each of the other categories. These categories can be further organized along an axis of whether the service is delivered in real time (eg, video conferencing or satellite phone) vs asynchronously (eg, secure messaging or photo-sharing). Table 2 summarizes these categories with an applicable wilderness medicine use case.

Telemedicine was born in a recognizable form with the telephone in the 1880s. The era of modern telemedicine began in the 1960s as the National Aeronautics and Space Administration (NASA) struggled with the problem of how to monitor the health of its astronauts in the most austere of all environments—space. It did not take long for leaders at NASA to realize that the telemedicine systems they were building had important terrestrial applications. In the 1970s, NASA collaborated with the Indian Health Services and private enterprise to form the Space Technology Applied to Rural Papago Advanced Health Care (STARPAHC) to support healthcare delivery to native tribes in rural Arizona.[2] In the 1980s, STARPAHC infrastructure formed the blueprint for a so-called "spacebridge" to support virtual disaster relief efforts after an earthquake devastated parts of Armenia.[3] In the intervening decades, these telemedicine systems have been applied to an ever-expanding scope of resource-limited settings including the developing world, natural disasters, combat medicine, Everest, the polar regions, and maritime environments.[4-12]

The rules surrounding the delivery of telemedicine services are complex, rapidly changing, and vary from country to country (or state to state). While wilderness medicine providers should seek to understand the nuanced details specific to their practice location, there are guiding principles that apply more universally:

- Telemedicine is best conceived as a set of tools to support healthcare delivery rather than a siloed

Table 2. Categories of telehealth

Category	*Description*	*Wilderness use case*
Live interactive communication	The use of a telecommunication modality such as radio or video conferencing to simultaneously connect providers to patients or other providers	An altitude specialist connects to a provider in the field to triage a possible high altitude pulmonary edema patient
Store and forward	The transfer of medical information such as pictures and texts from one location to another	A provider uses a securely transmitted picture to grade a frostbite injury in the field
Remote patient monitoring	The use of a connected or wearable device to collect and transfer medical information to a remote provider	While backpacking, a diabetic sends her blood glucose values via a bluetooth enabled glucometer to her endocrinologist
mHealth	The use of mobile or wireless technology to support the delivery of healthcare	A wilderness emergency medical technician uses a digital wilderness medicine field guide on her smartphone to guide care

Table 3. Common telemedicine regulatory pitfalls in the United States

Pitfall	*Example*	*Explanation*	*Solution*
Unlicensed care	An altitude specialist licensed in Colorado provides a video consult for a patient in Wyoming hoping to climb Everest	Telemedicine tools make it dangerously convenient to practice medicine across state lines without a license	In the United States, innovations such as the interstate medical licensure compact (www.imlcc.org) make it easier, though not cheaper, to obtain licensure
Site of practice	An academic emergency physician begins to provide volunteer telemedicine support to a local search and rescue organization without notifying her administrator	A site of practice formally dictates where a physician can practice medicine; if a provider does not specifically designate telemedicine within the site of practice, he or she risks being uncovered by malpractice coverage	Always update your supporting administrator or policy holder when delivering a new telemedicine service to ensure site of practice remains up to date
Health Insurance Portability and Accountability Act (HIPAA)	A provider relies on FaceTime to support a camp nurse at a local summer camp	Personal emails, text, and video conferencing platforms such as FaceTime are not typically secure and do expose the provider to a potential HIPAA violation	Proactively use HIPAA-compliant platforms for telemedicine delivery whenever possible
Undocumented care/ Malpractice risk	A volunteer medical director for a local search and rescue team provides a video consult to a first responder but fails to document the encounter	Malpractice claims involving telemedicine have been historically low but will likely rise in step with increased telemedicine adoption; proper documentation is critical to mitigate malpractice risk.	Preserve a written record of all telemedicine encounters for at least 7 y

subspecialty. In many cases, these tools are initially seen as cutting edge or disruptive but are eventually subsumed into "business as usual" (eg, it is not called teleradiology anymore, it is just radiology).

- The standard of care in the wilderness environment is not dependent on whether the care was delivered through telemedicine or in-person care.
- The site of care is defined by the location of the patient at the time the healthcare service was delivered.

Understanding these guiding principles can help wilderness providers navigate the complex local regulatory environment inherent to telemedicine delivery. Additionally, Table 3 outlines common regulatory pitfalls in the United States, along with practical solutions, for the aspiring austere telemedicine provider.

TECHNOLOGY

Telemedicine is inherently reliant on some sort of technology. There is a wide spectrum of complexity involved, but in general these systems rely on a hardware component, a software component, and a network system to transmit information from place to place. Each component of telemedicine technology should be both secure and reliable whenever possible. Today, connectivity in some form is nearly ubiquitous through access to cellular networks, Wi-Fi, or communication satellites. However, bandwidth, defined as the amount of data which can be transmitted through a given connection over time, remains a limiting factor for many austere settings. Live, interactive video consultations are best utilized when there is ample bandwidth and low latency (ie, delay), while asynchronous communications are more appropriate for low-bandwidth scenarios. The ideal telemedicine network is high bandwidth and low latency to best mimic an in-person interaction. It is worth reminding providers that personal emails, SMS texting, and applications such as FaceTime are not secure and, while convenient, could expose the provider to the risk of a Health Insurance Portability and Accountability Act–related fine. A summary of common telemedicine technologies along with their application to the wilderness environment is found in Table 4.

Drones, also known as unmanned aerial vehicles, merit special mention because of their potential to impact wilderness telemedicine at multiple levels. Drones can be used to provide an ad hoc communication network that is both high bandwidth and low latency to provide real-time video feeds; drones also have the potential to transform medical

Table 4. Common telemedicine technologies found in the wilderness environment

Technology	*Type*	*Application*	*Comments*
Radios	Hardware	Short-distance live interactive communication	Largely exempt from HIPAA regulations, though providers should avoid sharing private health information over radio whenever possible
Video conferencing	Software	Live interactive communications modality used to approximate an in-person visit between patient and provider, or as a consult	The current technologic standard of care for virtual visits
Satellite phones	Hardware	Communication device able to facilitate live interactive audio asynchronous or messaging/texting	Dominant telemedicine communication device when cellular or Internet not otherwise available
Secure messaging/ texting	Software	Asynchronous communication modality most often used for lower acuity medical concerns	Favored telemedicine modality of patients because of ease and convenience
Smartphone	Hardware and software	Foundational device for telemedicine used to facilitate live interactive visits, remote patient monitoring, mHealth, along with store and forward messaging	Very nearly ubiquitous, even in austere settings
Peripheral	Hardware	A device, such a digital stethoscope, used at the originating site to enhance the capabilities of the physical exam via a virtual visit	A wide-ranging set of technologies able to mimic the capabilities found in a typical doctor's office in order to perform an enhanced virtual physical exam
Wearable	Hardware	A device that transmits biometric data such as vital signs or blood glucose from the patient to a remote provider	Increasingly small, lightweight, and affordable

supply chains.[13,14] The downstream implications for the field of wilderness medicine are considerable and will be discussed in further detail in the following section.[15,16]

THE INTERSECTION OF WILDERNESS AND TELEMEDICINE

Broadly speaking, patient assessment in a wilderness environment is centered around a patient care arc which involves an initial evaluation, stabilization, ongoing monitoring, and then evacuation as necessary. We will use this condensed patient assessment paradigm to explore how wilderness medicine and telemedicine currently intersect.

Initial Evaluation

Care in a wilderness setting often begins with an evaluation of the scene. On a formal search and rescue (SAR) mission, this can involve the deployment of a hasty team to evaluate scene safety and triage the number and severity of injuries. This in turn informs the subsequent allocation of resources for the remaining mission.

Recently, drones have been used to augment this initial scene assessment with promising results. A recently published case series described the first use of a drone in an SAR mission to triage an incident as a body recovery rather than a full rescue.[17] The utilization of a drone likely reduced the overall mission risk to first responders by limiting the scope of the response. A similar case report described the use of a drone to conduct a sweep of a search area, thereby increasing the efficiency of the responding hasty team.[18] In a simulated disaster scenario, drones have been used to assess for breathing to facilitate rapid virtual triage.[19] These early feasibility reports suggest that drones will have an important role in scene assessment and triage. Following triage, telemedicine modalities such as live interactive video can be used to facilitate a patient-assisted physical exam.[20] Remotely proctored examinations through physician extenders have long been in operational use across a wide range of specialties,[21] but the efficacy of this practice has not yet been studied using wilderness first responders (or similar).

Stabilization and Management

After the initial evaluation, the wilderness provider typically pivots to the stabilization and subsequent management of the victim. In austere environments, this can involve exotic

or rare conditions where prolonged care is often required. In some cases, this care is best informed by a specialist who is not on scene. Wilderness providers have been using online medical direction through radio or phones for decades. This, of course, is a form of telemedicine. More recently, wilderness providers have begun to leverage a wide variety of digital technologies to enhance patient diagnostics, inform medical decision-making, and expand therapeutic options in resource-limited settings.

While medical diagnostics have been traditionally limited in wilderness settings, this paradigm is changing. The application of ultrasound in austere settings has been widely studied and has been shown to improve outcomes.[22] Ultrasound has been more recently combined with telemedicine tools to facilitate remotely proctored exams coupled with real-time assessments by experts.[23-25] This powerful combination has the potential to expand the utility of ultrasound in austere settings by lowering technical and experience barriers. In addition to ultrasound, a recent study has demonstrated the feasibility of capturing electrocardiograms in extreme environments; this should add to the armamentarium of diagnostics available to future wilderness providers.[26]

After the wilderness provider has taken the patient's history, performed a physical examination, and captured available data, treatment is initiated. Here, again, telemedicine is expanding the scope for what is possible in wilderness settings. Simulation studies have demonstrated the feasibility of utilizing drones to deliver automated external defibrillators to remote areas.[27] Early testing has also shown that drones can be used to deliver blood products to austere settings.[28]

Remote consultations are a common example of telemedicine in the wilderness environment; these remote "e-consults" have been in use for decades for the management of conditions such as frostbite and altitude illness.[29-31] More recently, a simulation study demonstrated the feasibility of a telementoring process to manage life-threatening hemorrhage through nonphysicians in an austere environment.[32] Remote consultations and telementoring allow direct medical support of field personnel (or patients themselves) and are helpful in delivering specialized expertise to inform treatment or the decision to evacuate (see next section). In practice, these consultations are delivered through a variety of modalities, including email, texting, videoconferencing, radio, and satellite phones. The choice of modality is typically predicated on available technology and bandwidth.

Monitoring and Evacuation

After a patient has been stabilized, the care plan transitions to a monitoring phase to detect subsequent deterioration. A decision is then made on the necessity of an evacuation. Remote patient monitoring (RPM) is a distinct category of telemedicine (Table 2) with the potential to transform the monitoring phase of wilderness care during prolonged extractions. Early studies have proven that RPM tools can function in extreme environments.[33,34] In addition to transmitting critical vital sign information, these wearable sensors also relay geolocation data which has the potential to facilitate locating victims during SAR missions. Connected devices such as continuous glucose monitors are also being deployed in wilderness environments.[35] Pairing RPM with remote consultations to handle issues such as altitude illness or diabetic emergencies is likely to be synergistic. Lastly, the utilization of telemedicine, including remote monitoring, has been shown to reduce evacuations in both civilian and military settings.[36,37] Early data suggest that similar results are possible in wilderness environments as well.[25,38]

International Telemedicine

Wilderness medicine providers have a long history of providing international telemedicine. Use cases abound, ranging from formal specialist consultations to Antarctica to less formal "advice" for expedition frostbite injuries offered through the British Mountaineering Council (https://www.thebmc.co.uk/how-to-get-expert-frostbite-advice). The rules governing remote care by an out-of-country provider vary widely by country. In Nepal, for example, telemedicine delivered by an out-of-country provider would be unsanctioned without the presence of a local licensed provider at the distant site (https://nmc.org.np/other-guide-lines). In contrast, Mexico has no specific guidance related to international telemedicine. Antarctica represents its own special use case, as it is not a sovereign nation. The general trend is that countries are more tolerant of cross border provider-to-provider consultations than for direct patient care through live, interactive medium such as video. However, just as the US-based provider needs to understand the regulatory environment at the state level, the maxim holds that providers delivering care internationally must understand the regulatory environment at the country level.

Other Telemedicine Applications

Remote second opinions have historically been used (formally or informally) to virtually manage conditions such as frostbite or altitude illness. One can think of a remote second opinion as a type of virtual curbside consultation. In this scenario, the remote expert develops a care plan, which is then relayed to a different provider licensed in the state

where the patient is located. The local provider then reviews the care plan directly with the patient. By avoiding direct interaction with the patient, the remote expert is typically not required to be licensed where the patient is located. Most US states allow this construct, but it is worth confirming with the relevant local medical board whether remote second opinions are sanctioned.

Telemedicine (known in this context as ground-based medical support) has been leveraged to support in-flight emergencies for decades. An in-depth review of in-flight emergencies is beyond the scope of this article, but excellent reviews are available elsewhere.[39] Generally speaking, the wilderness medicine provider is more likely to consume this service than provide it. Aviation telemedicine is typically audio only; because of this limitation, the telemedicine systems supporting aviation telemedicine typically lag the capabilities available through hospitals or clinics. Controversy remains on whether the regulatory jurisdiction is dictated by the airspace in which the emergency has occurred, or whether jurisdiction is predicated on the aircraft's home country. In many ways, maritime telemedicine mirrors aviation telemedicine. The rules and responsibilities surrounding telemedicine at sea are described (albeit opaquely) by the Maritime Labour Convention.[12] Interested readers can find a more comprehensive description of maritime telemedicine in this review.[40]

THE FUTURE

The future of wilderness telecare appears bright and will be driven at least in part by incremental progress to make telemedicine technology faster, lighter, and cheaper. Expansion of low-orbit satellites and 5G networks will increase both bandwidth and accessibility in austere settings. Increased interoperability between smartphones and electronic health records will better link wilderness providers to hospitals and clinics.

We predict that in short order the use of drones in SAR and disaster response will become the standard of care. Drones will be used to initially sweep remote or dangerous terrain. After a victim has been found, the drone will be used to deliver food, water, shelter, and medical supplies. Additionally, drones will be used to deliver a wearable device to the scene to facilitate wilderness RPM to relay critical physiologic data. In the future, drones will also function as a mobile lab by delivering point-of-care testing into the hands of wilderness first responders.[41] A drone-based communication network will provide a video link between incident commander, medical lead, and first responder to enhance situational awareness. If needed, this network will facilitate telementoring of life-saving procedures, from the administration of epinephrine to needle decompression of a pneumothorax. In time, drones will also be used to transport the victim from the field.[42]

In the future, low-cost wearable devices in wilderness settings will enhance geolocation of both victims and rescuers during SAR missions. These devices will relay continuous vital signs of injured patients to both first responders and medical directors and will facilitate a heat map of available resources. These data will inform predictive algorithms to drive evacuation decisions and overall risk models. Resource-limited environments are typically data limited as well. In the future, remote consultants will have the benefit of remote patient monitoring data to enhance treatment decisions. These data generated from wearable devices will be transmitted through cloud-based services directly to providers to monitor physiology and clinical status before and after interventions. Wearable devices worn by wilderness athletes will allow expedition leaders to track peak exercise performance; these data will be used to time summit bids to increase the probability of summit success. Lighter, cheaper, and more connected telemedicine technology will improve telemedicine capabilities for in-flight emergencies and telemedicine at sea.

Wilderness education will continue its pivot to a digital medium.[43] The COVID-19 pandemic has proven that large wilderness medicine conferences can be successfully delivered virtually. Hybrid conferences that offer in-person and virtual options are likely to have expanded reach. In the future, the wilderness first responder curriculum should include scenarios to practice telemedicine competencies such as applying wearable devices; using a peripheral, simulating telementored procedures; and relaying patient assessments through video. Wilderness medicine fellowships should also include telemedicine competencies such as drone operation, delivering effective remote consultation, and how to telementor life- or limb-saving procedures.

Telehealth will also drive innovations in wilderness medicine research. As the field of emergency medicine has recognized, the adoption of a virtual consent process will likely facilitate wider study recruitment in austere environments.[44] Future researchers will leverage data (responsibly) generated from smartphones and RPM to derive clinical decision support algorithms designed for austere settings. Feasibility studies will give rise to prospective research that defines the future standards of care for wilderness telemedicine best practice.

Conclusions

The widespread adoption of telemedicine is reshaping healthcare delivery in both hospitals and austere

environments. Though the regulatory environment remains complex, there is enormous potential for telemedicine to enhance the practice of wilderness medicine. Drones are likely to transform wilderness medicine supply chains by facilitating delivery of food, shelter, and medicines. Remote consultations will be paired with remote patient monitoring technology to deliver highly specialized care to austere environments. Early feasibility studies are promising, but further prospective data will be required to define future best practices for wilderness telemedicine.

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References

1. Sward DG, Bennett BL. Wilderness medicine. *World J Emerg Med*. 2014;5(1):5–15.
2. Freiburger G, Holcomb M, Piper D. The STARPAHC collection: part of an archive of the history of telemedicine. *J Telemed Telecare*. 2007;13(5):221–3.
3. Doarn CR, Merrell RC. Spacebridge to Armenia: a look back at its impact on telemedicine in disaster response. *Telemed J E Health*. 2011;17(7):546–52.
4. Gilbert BK, Mitchell MP, Bengali AR, Khandheria BK. NASA/DARPA advanced communications technology satellite project for evaluation of telemedicine outreach using next-generation communications satellite technology: Mayo Foundation participation. *Mayo Clin Proc*. 1999;74(8):753–7.
5. Garshnek V. Applications of space communications technology to critical human needs: rescue, disaster relief, and remote medical assistance. *Space Commun*. 1991;8(3–4):311–7.
6. Weinberg J, Kaddu S, Gabler G, Kovarik C. The African teledermatology project: providing access to dermatologic care and education in sub-Saharan Africa. *Pan Afr Med J*. 2009;3:16.
7. Merrell RC, Cone SW, Rafiq A. Telemedicine in extreme conditions: disasters, war, remote sites. *Stud Health Technol Inform*. 2008;131:99–116.
8. Angood PB, Satava R, Doarn C, Merrell R. Telemedicine at the top of the world: the 1998 and 1999 Everest extreme expeditions. *Telemed J E Health*. 2000;6(3):315–25.
9. Rayman RB. Telemedicine: military applications. *Aviat Space Environ Med*. 1992;63(2):135–7.
10. Pillon S, Todini AR. eHealth in Antarctica: a model ready to be transferred to every-day life. *Int J Circumpolar Health*. 2004;63(4):436–42.
11. Woldaregay AZ, Walderhaug S, Hartvigsen G. Telemedicine services for the Arctic: a systematic review. *JMIR Med Inform*. 2017;5(2):e16.
12. Horneland AM. Maritime telemedicine - where to go and what to do. *Int Marit Health*. 2009;60(1–2):36–9.
13. Harnett BM, Doarn CR, Rosen J, Hannaford B, Broderick TJ. Evaluation of unmanned airborne vehicles and mobile robotic telesurgery in an extreme environment. *Telemed J E Health*. 2008;14(6):539–44.
14. Bhatt K, Pourmand A, Sikka N. Targeted applications of unmanned aerial vehicles (drones) in telemedicine. *Telemed J E Health*. 2018;24(11):833–8.
15. Karaca Y, Cicek M, Tatli O, Sahin A, Pasli S, Beser MF, et al. The potential use of unmanned aircraft systems (drones) in mountain search and rescue operations. *Am J Emerg Med*. 2018;36(4):583–8.
16. Braun J, Gertz SD, Furer A, Bader T, Frenkel H, Chen J, et al. The promising future of drones in prehospital medical care and its application to battlefield medicine. *J Trauma Acute Care Surg*. 2019;87(1S Suppl 1):S28–34.
17. Van Tilburg C. First report of using portable unmanned aircraft systems (drones) for search and rescue. *Wilderness Environ Med*. 2017;28(2):116–8.
18. McRae JN, Gay CJ, Nielsen BM, Hunt AP. Using an unmanned aircraft system (drone) to conduct a complex high altitude search and rescue operation: a case study. *Wilderness Environ Med*. 2019;30(3):287–90.
19. Saitoh T, Takahashi Y, Minami H, Nakashima Y, Aramaki S, Mihara Y, et al. Real-time breath recognition by movies from a small drone landing on victim's bodies. *Sci Rep*. 2021;11(1):5042.
20. Benziger CP, Huffman MD, Sweis RN, Stone NJ. The telehealth ten: a guide for a patient-assisted virtual physical examination. *Am J Med*. 2021;134(1):48–51.
21. Weinstein RS, Krupinski EA, Doarn CR. Clinical examination component of telemedicine, telehealth, mHealth, and connected health medical practices. *Med Clin North Am*. 2018;102(3):533–44.
22. Canepa CA, Harris NS. Ultrasound in austere environments. *High Alt Med Biol*. 2019;20(2):103–11.
23. Otto C, Hamilton DR, Levine BD, Hare C, Sargsyan AE, Altshuler P, et al. Into thin air: extreme ultrasound on Mt Everest. *Wilderness Environ Med*. 2009;20(3):283–9.
24. Crawford I, Tiruta C, Kirkpatrick AW, Mitchelson M, Ferguson J. Big brother could actually help quite easily: telementored "just-in-time" telesonography of the FAST over a smartphone. *Ann Emerg Med*. 2011;58(3):312–4.
25. Otto CA, Shemenski R, Drudi L. Real-time tele-echocardiography: diagnosis and management of a pericardial effusion secondary to pericarditis at an Antarctic research station. *Telemed J E Health*. 2012;18(7):521–4.
26. Kao WF, Huang JH, Kuo TBJ, Chang PL, Chang WC, Chan KH, et al. Real-time electrocardiogram transmission from Mount Everest during continued ascent. *PloS One*. 2013;8(6):e66579.
27. Bauer J, Moormann D, Strametz R, Groneberg DA. Development of unmanned aerial vehicle (UAV) networks delivering early defibrillation for out-of-hospital cardiac arrests (OHCA) in areas lacking timely access to emergency medical services (EMS) in Germany: a comparative economic study. *BMJ Open*. 2021;11(1):e043791.
28. Amukele T, Ness PM, Tobian AAR, Boyd J, Street J. Drone transportation of blood products. *Transfusion*. 2017;57(3):582–8.
29. Szawarski P, Hillebrandt D. Doctor won't see you now: changing paradigms in mountain medicine. *Postgrad Med J*. 2018;94(1109):182–4.
30. Handford C, Thomas O, Imray CHE. Frostbite. Emerg Med Clin North Am. 2017;35(2):281–99.
31. Skolnick AA. Taking telemedicine to the top of the world. *JAMA*. 1998;279(11):816–7.
32. Kirkpatrick AW, McKee JL, McBeth PB, Ball CG, LaPorta A, Broderick T, et al. The Damage Control Surgery in Austere Environments Research Group (DCSAERG): a dynamic program to facilitate real-time telementoring/telediagnosis to address

exsanguination in extreme and austere environments. *J Trauma Acute Care Surg*. 2017;83(1 Suppl 1):S156–63.
33. Satava R, Angood PB, Harnett B, Macedonia C, Merrell R. The physiologic cipher at altitude: telemedicine and real-time monitoring of climbers on Mount Everest. *Telemed J E Health*. 2000;6(3):303–13.
34. Satava RM. Telemedicine and real-time monitoring of climbers. *Curr Probl Dermatol*. 2003;32:141–7.
35. Malcolm G, Rilstone S, Sivasubramaniyam S, Jairam C, Chew S, Oliver N, et al. Managing diabetes at high altitude: personal experience with support from a multidisciplinary physical activity and diabetes clinic. *BMJ Open Sport Exerc Med*. 2017;3(1):e000238.
36. Nguyen C, Mbuthia J, Dobson CP. Reduction in medical evacuations from Iraq and Syria following introduction of an asynchronous telehealth system. *Mil Med*. 2020;185(9–10):e1693–9.
37. Natafgi N, Shane DM, Ullrich F, MacKinney AC, Bell A, Ward MM. Using tele-emergency to avoid patient transfers in rural emergency departments: an assessment of costs and benefits. *J Telemed Telecare*. 2018;24(3):193–201.
38. Penninga L, Lorentzen AK, Davis C. A telemedicine case series for acute medical emergencies in greenland: a model for austere environments. *Telemed J E Health*. 2020;26(8):1066–70.
39. Martin-Gill C, Doyle TJ, Yealy DM. In-flight medical emergencies: a review. *JAMA*. 2018;320(24):2580–90.
40. Sagaro GG, Amenta F. Past, present, and future perspectives of telemedical assistance at sea: a systematic review. *Int Marit Health*. 2020;71(2):97–104.
41. Poljak M, Šterbenc A. Use of drones in clinical microbiology and infectious diseases: current status, challenges and barriers. *Clin Microbiol Infect*. 2020;26(4):425–30.
42. Handford C, Reeves F, Parker P. Prospective use of unmanned aerial vehicles for military medical evacuation in future conflicts. *J R Army Med Corps*. 2018;164(4):293–6.
43. Hill AD, Pasik SD. Wilderness medicine education in the time of social distancing and COVID-19. *AEM Educ Train*. 2020;5(1):111–5.
44. Hayden EM, Davis C, Clark S, Joshi AU, Krupinski EA, Naik N, et al. Telehealth in emergency medicine: a consensus conference to map the intersection of telehealth and emergency medicine. *Acad Emerg Med*. 2021;28(12):1452–74.

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CASE REPORT

An Unusual Attack by a Blue Bull Resulting in Penetrating Horn Injuries

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Owing to multiple factors, human-wildlife interactions are increasing, and conflict can result in fatal injuries. A 21-y-old man was brought to the emergency department in critical condition with 2 puncture wounds over the thoracoabdominal region after a nilgai, or blue bull (*Boselaphus tragocamelus*), had gored him. The patient sustained double gastric perforation, which was managed laparoscopically and complicated by an abscess formation in the lesser sac 1 wk later, which required further surgical exploration. The operative culture showed growth of *Klebsiella pneumoniae*. Intravenous antibiotics were given as per the culture sensitivity report, and the patient improved. Many horn injuries are described as puncture lacerated wounds owing to the rugged nature of animal horns. However, in this case, the margins of the wound were regular and incision-like owing to the smooth and straight structure of blue bull horns. Early surgical exploration and monitoring of treatment progress are crucial in reducing morbidity in penetrating horn injuries.

Keywords: human-wildlife conflict, bovine, nilgai, penetrating injury, gastric perforation

Introduction

The blue bull, or nilgai (*Boselaphus tragocamelus*), is the largest Asian antelope and is classified in the same bovid family as domestic cattle, antelope, and buffalo. The nilgai is endemic to the Indian subcontinent and was introduced to Texas in the 1920s for trophy hunting. The average weight of an adult nilgai is 200 kg, with a shoulder height of about 130 cm.[1] They have a stable population and are considered as least concern in the International Union for Conservation of Nature red list of threatened species.[2] The adult male is blue-gray (Figure 1), and the adult female and juveniles are light brown. Only males have horns, and the usual length of an adult nilgai's horn is 15 to 20 cm.[1] Nilgai mainly inhabit scrublands, low hills, grassy plains, and near agricultural fields; hence, close encounters usually occur in agricultural settings.[3]

Although nilgai attacks have been occasionally reported in the press, none have been documented in the medical literature.[4] We present a case of an individual who sustained unexpected penetrating injuries from this wild bovine. The unusual pattern of nilgai horn injury and related medical implications are discussed.

Case Report

A 21-y-old male was brought to the emergency department unresponsive and in critical condition owing to

Figure 1. Nilgai in a farm field taken at Jodhpur, India (representational image). Photo credit: Mohanraj Kolathapilly.

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Figure 2. Two puncture wounds sustained on a single impact by the nilgai head. An elliptical shaped over the upper abdomen (A) and another slit-like in the right axilla (B).

puncture wounds in his abdomen and right axilla. Initial vital signs were as follows: blood pressure 96/60 mm Hg, heart rate 112 beats·min^{-1}, temperature 36.5°C, and oxygen saturation 100% on room air. After fluid resuscitation, the patient regained consciousness and reported that he had been attacked by a nilgai while working on his farm. The man was a farmer who had attempted to scare a nilgai away from his land, causing the animal to attack.

Physical examination revealed an elliptical-shaped puncture wound measuring 4 cm × 1 cm over the upper epigastrium. The omentum was visible in the wound gap. The margins of the wounds were clean and regular without associated contusions (Figure 2A). The epigastric wound was temporarily closed with silk suture in the emergency department. Another puncture wound measuring 2 cm × 0.5 cm, muscle deep, was present in the right axilla, with clean and regular margins (Figure 2B). The right axillary puncture wound was superficial, so simple primary closure was completed. There were grazed abrasions on the back of the right elbow (7 cm × 5 cm) and the back of the left elbow (4 cm × 3 cm). Intramuscular injections of tetanus toxoid and diclofenac were given. Intravenous ceftriaxone and metronidazole were started for empiric coverage. A computed

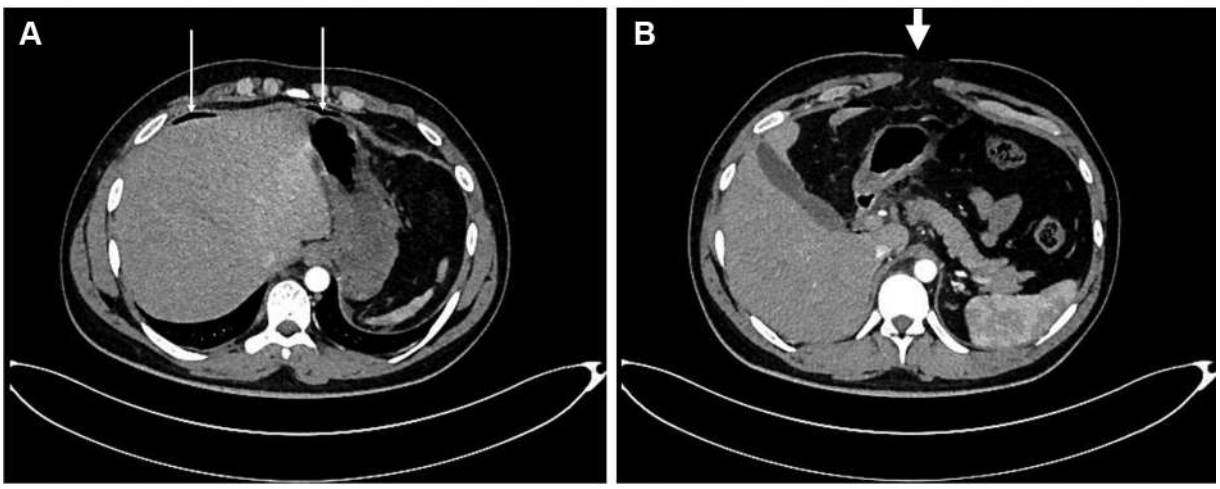

Figure 3. Computed tomography images of the abdomen. (A) Pneumoperitoneum (thin arrows). (B) The site and direction of the penetrating injury (thick arrow).

tomography scan of the thorax and abdomen revealed mild to moderate pneumoperitoneum (Figure 3A) with mild free fluid in the abdomen (along the lesser sac and gastrohepatic ligament as well as in the perihepatic and perisplenic regions). A defect of 3.4 cm × 1.1 cm with omental herniation was seen in the epigastrium 3 cm distal to the tip of the xiphoid process (Figure 3B). A suspicious rent was seen in the gastric body, with adjacent air and fluid pockets. No other visceral injuries were seen in the scan. Initial laboratory blood test results were as follows: hemoglobin 15.9 $g \cdot dL^{-1}$, white blood cell count 13,560/uL, and hematocrit 47%. After examination and investigations, the diagnosis of gastric perforation with peritonitis was made.

The patient underwent surgery on the second day and was managed with laparoscopic primary repair of gastric perforations and peritoneal wash. The gastric perforations in the anterior wall (1.5 cm × 1 cm) and posterior wall (1 cm × 1 cm) were near the lesser curvature corresponding to the anterior abdominal wall defect.

Eight days postoperatively, the patient developed abdominal pain, distension, and tenderness. His hemoglobin level fell to 10.9 $g \cdot dL^{-1}$, white blood cell count increased to 22,900/uL, and a computed tomography scan revealed a 300 mL abscess in the lesser sac. He underwent exploratory laparotomy, and a loculated pus collection in the lesser sac was removed and sent for bacterial culture and sensitivity. The culture showed growth of *Klebsiella pneumoniae*. Intravenous antibiotics piperacillin/tazobactam, amikacin, and metronidazole were given for the next 7 d. The patient was recovering well and was advised discharge on hospital day 18. The patient remained in the hospital for an additional 5 d for continued wound care and monitoring and was ultimately discharged on day 23 with no further complications.

Discussion

Human casualties from human-wildlife conflicts in India occur mainly in agricultural settings.[5] Recent data from India's national crime records bureau show that 1425 people were killed by animal attacks in 2019, excluding deaths caused by poisonous and venomous animals.[6] Elephants and tigers are responsible for most wildlife conflicts in rural India. Other wild animals such as jackals, leopards, and wild boars cause a small percentage of attacks.[5,7] Most reported attacks by Bovidae are caused by domestic bulls and cattle and are sustained by dairy workers, farmers, and people involved in the practice of bullfighting.[8] These animals usually inflict blunt trauma and penetrating injuries to the abdomen, perineum, and lower limbs.[9-11] Blunt trauma occurs when a person is butted by the animal's head or sustains a subsequent fall to the ground. Other mechanisms of blunt force trauma are kicking or trampling by the animal.[8] Penetrating injuries are due to direct goring by the animal's horns.[11]

Penetrating injuries caused by animal horns are of various sizes and shapes. These wounds are usually associated with adjacent bruising and lacerations of soft tissue.[10,11] In this case, the epigastric wound was elliptical with clean regular margins and no associated bruising. This was due to the smooth, pointed, and near-straight structure of nilgai horns.[1] Because the horns of other wild animals and domestic cattle are usually ragged or curved, they are associated with bruising and lacerations of wound margins.

In this case, the stomach's entry and exit wound were near the lesser curvature, fortunately sparing the liver and vasculature. However, the patient developed an abscess in the lesser sac 1 wk after the first surgery. He underwent exploratory laparotomy, and bacterial culture showed growth of *K pneumoniae*. *K pneumoniae* is ubiquitous in the environment and also resides in the oropharynx and gastrointestinal tract.[12] In the present case, there was a persistent gastric leak for 1 d after traumatic perforations because the patient underwent laparoscopic repair on the second day. The initial contamination from the gastric leak led to peritonitis and is the most likely cause for the subsequent abscess formation.

An overall wound infection rate of 13% was found in a study of 101 patients with bull horn injuries in south India.[9] In horn injuries, the introduction of organic contaminants such as grass and dirt into the puncture wound may contribute to the infection, although wound culture data from goring injuries are sparse. Surgical exploration with removal of foreign bodies and debris and wound irrigation is the standard of care.[11] Despite the internal organ injuries and infection risk, the prognosis is favorable in most cases.[13] In the present case, significant morbidity developed during a hospital stay, managed with surgery and appropriate medical care.

This case report highlights isolated goring injuries caused by a nilgai attack. Nilgai attacks on humans are rare because they are timid animals and quickly run away when threatened. The population of nilgai has increased in some Indian states after the introduction of the wildlife protection act in 1972.[14] This act includes provisions that prohibit wildlife hunting. Because nilgai prefer grass and herbs, they frequently migrate into agricultural areas. Conflicts occur between farmers and nilgai due to habitat loss and, more importantly, unwelcome entry into farms, where they can cause significant damage.[3]

Conclusions

Gore wounds are serious injuries owing to variable depth of penetration, risk of infection, and internal organ injuries. Computed tomography helps assess wound extension, but the standard of care if an object penetrates the peritoneum is surgical exploration of the wound. The prognosis is favorable in most cases when wounds are managed surgically. Gore wounds from nilgai may be particularly prone to cleaner margins but can result in deep penetrating injuries owing to the structure of their horns.

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References

1. Sankar K, Johnsingh AJT, Acharya B. Blue bull or nilgai. In: Sankar K, Goyal SP, eds. *Ungulates of India*. Dehradun, India: Wildlife Institute of India-ENVIS Centre; 2004:29–40.
2. IUCN SSC Antelope Specialist Group. 2016. *Boselaphus tragocamelus* (errata version published in 2017). *The IUCN Red List of Threatened Species* 2016: e.T2893A115064758. Available at: https://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T2893A50182076.en. Accessed July 13, 2021.
3. Prasad S, Singh DK, Choudhary SK. Residential population structure and abundance of Nilgai, *Boselaphus tragocamelus* (Pallas) in Bihar, India. *CJAST*. 2020;39(13):110–7.
4. Nilgai attacks village, injures two, damages houses. *The Times of India*. July 22, 2016. Available at: https://timesofindia.indiatimes.com/city/agra/nilgai-attacks-village-injures-two-damages-houses/articleshow/53343482.cms. Accessed September 13, 2021.
5. Gulati S, Karanth KK, Le NA, Noack F. Human casualties are the dominant cost of human-wildlife conflict in India. *Proc Natl Acad Sci U S A*. 2021;118(8):e1921338118.
6. National Crime Records Bureau. *Accidental Deaths & Suicides in India*. New Delhi: Ministry of Home Affairs; 2019. Available at: https://ncrb.gov.in/sites/default/files/ADSI_2019_FULL%20REPORT_updated.pdf. Accessed July 13, 2021.
7. Tumram NK, Ambade VN, Dixit PG. Human fatalities caused by animal attacks: a six-year autopsy study. *Med Leg J*. 2017;85(4):194–9.
8. Watts M, Meisel EM, Densie IK. Cattle-related trauma, injuries and deaths. *Trauma*. 2014;16(1):3–8.
9. Idikula J, Moses BV, Sadhu D, Agarwal S, Jahan G, Thomas J. Bull horn injuries. *Surg Gynecol Obstet*. 1991;172(3):220–2.
10. Wasadikar PP, Paunikar RG, Deshmukh SB. Bull horn injuries in rural India. *J Indian Med Assoc*. 1997;95(1):3–16.
11. Conrad L, Balison J. Bison goring injuries: penetrating and blunt trauma. *J Wilderness Med*. 1994;5(4):371–81.
12. Bagley ST. Habitat association of *Klebsiella* species. *Infect Control*. 1985;6(2):52–8.
13. Murphy CG, McGuire CM, O'Malley N, Harrington P. Cow-related trauma: a 10-year review of injuries admitted to a single institution. *Injury*. 2010;41(5):548–50.
14. Chauhan NPS. Agricultural crop depredation by nilgai antelope (*Boselaphus tragocamelus*) and mitigation strategies: challenges in India. *Julius-Kühn-Archiv*. 2011;432:190–1.

WILDERNESS & ENVIRONMENTAL MEDICINE 2022; 33(2): 236–8

CASE REPORT

Critical Upper Airway Edema After a Bee Sting to the Uvula

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Hymenoptera stings of the upper airway are rare events, but can result in rapid, life-threatening airway emergencies. The allergenic and toxic mediators that are released from the stings of bees, wasps, and hornets can cause local tissue inflammation and edema with subsequent upper airway obstruction. We report the case of a 15-y-old girl who suffered a bee sting to the uvula while zip-lining in Costa Rica. Shortly thereafter, she developed a choking sensation with associated dysphonia, odynophagia, drooling, and respiratory distress. She was brought to a rural emergency medical clinic where she was noted to have an erythematous, edematous, boggy uvula, with a black stinger lodged within it, as well as edema of the anterior pillars of the tonsils and soft palate. The stinger was removed with tweezers and she was treated with an intravenous corticosteroid and antihistamine. She had persistence of airway edema and symptoms until the administration of epinephrine, which resulted in clinical improvement shortly thereafter. In our review of this case and the existing literature, we emphasize the importance of early recognition and management of hymenoptera stings of the upper airway, which should always include immediate manual removal of the stinger, and in cases with significant upper airway edema, the administration of epinephrine should be considered.

Keywords: hymenoptera, oropharynx, swelling, obstruction, venom, epinephrine

Introduction

Hymenoptera include bees, wasps, hornets, and ants, and comprise over 115,000 different species. Stings from bees, wasps, and hornets are responsible for an average of 62 deaths per year in the United States.[1] A 2009 study from Costa Rica reported on hymenoptera sting fatalities over a 22-y period, with a total of 52 deaths over the study period (average 2 deaths per year).[2]

Several reports of hymenoptera stings of the upper airway have been published in the medical literature.[3-9] These events can be life threatening and require immediate recognition and emergency medical care.[10,11] Bee stingers have microscopic barbs that detach from the bee with a barbed end that enables it to remain embedded in the target tissue.[12] Proximal to the stinger, there is often an attached venom sac with a mechanism that continues to pump venom into the tissue after detachment via a piston-like muscular injection mechanism.[13]

A sting within the oropharynx is of significant concern due to the risk of upper airway obstruction induced by subsequent local tissue inflammation and edema. Rapid treatment, including manual removal of the stinger, is essential to promote positive patient outcomes.[14,15]

Case Report

A 15-y-old female with no past medical history and no known allergies was ziplining in La Fortuna, Costa Rica. While moving at high speed through the air with her mouth open, a bee flew into her oropharynx where it remained lodged for approximately 5 s, after which she coughed it out. Within minutes she developed a sensation of swelling in her posterior oropharynx with associated dyspnea, dysphonia, odynophagia, and drooling. Thirty minutes later, she arrived at a local emergency medical clinic where she was noted to be in moderate respiratory

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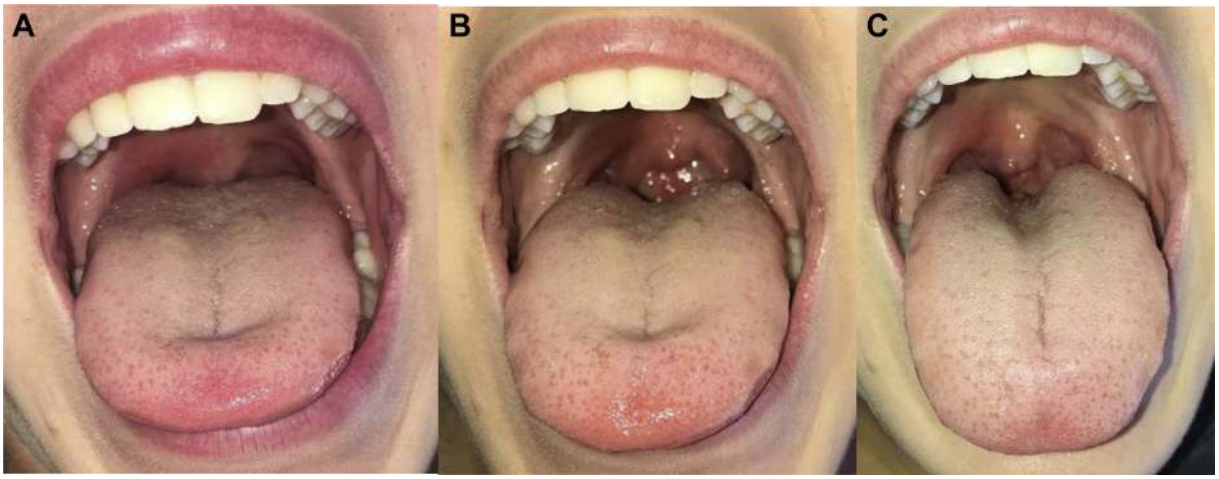

Figure 1. Edema of uvula, soft palate, and anterior pillars of tonsils. (A) After stinger extraction, prior to epinephrine. (B) Two hours after epinephrine administration. (C) Twelve hours after epinephrine administration.

distress. Blood pressure was 115/70 mm Hg, heart rate 120 beats·min^{-1}, respiratory rate 30 breaths·min^{-1} and oxygen saturation 98% on room air. Physical exam was notable for no stridor, no lip or tongue edema, clear lungs, and no skin rashes or urticaria. The posterior oropharynx was noted to have extensive edema of the uvula, anterior pillars of the tonsils, and soft palate (Figure 1A). A black stinger was noted to be lodged in the uvula, which was manually extracted with tweezers. She was treated with intravenous dexamethasone 10 mg and chlorpheniramine 10 mg, a histamine 1-receptor antagonist, with subsequent persistence of respiratory distress, choking sensation, and tissue edema. Epinephrine 0.1 mg was administered by slow intravenous push over 5 min (the intramuscular formulation of epinephrine was not available), with improvement in symptoms shortly thereafter. Over the next 2 h, the airway edema continued to diminish (Figure 1B), and she was discharged from the clinic on prednisone 40 mg and rupatadine 10 mg daily for 5 d. Mild airway edema persisted for 12 h (Figure 1C), and ultimately the patient made a full recovery.

Discussion

Although rare, awareness of the potentially life-threatening nature of hymenoptera stings to the posterior oropharynx, even in those without bee sting allergy, should be promoted among all emergency medical personnel. Clinicians should have increased suspicion of airway compromise and be exceedingly conservative in the management of oropharyngeal hymenoptera stings because even a local reaction can cause significant airway edema. It is crucial to perform a careful pharyngeal exam, and it is prudent to remove the stinger promptly. Rapidity of stinger removal with its attached venom sac is essential to prevent worsening of tissue inflammation and edema.[14,15] Additional management strategies include the administration of corticosteroids, antihistamines, and epinephrine as deemed necessary by the treating clinician.

In the case presented here, epinephrine was used due to the lack of clinical improvement after stinger removal. The primary mode of epinephrine injection for anaphylaxis is intramuscular, with the intravenous route reserved for patients with circulatory collapse or impending respiratory arrest.[16] Epinephrine acts through the stimulation of alpha and beta receptors, with the alpha-1-adrenergic effects causing vasoconstriction in the precapillary arterioles of the skin and mucosa and smooth muscle contraction in the venous vascular bed, resulting in increased peripheral vascular resistance and blood pressure and reduction in vascular permeability and tissue edema.[17] The beta-2-adrenergic effects of epinephrine result in increased bronchodilation and decreased release of mediators of inflammation from mast cells and basophils.[18] The administration of antihistamines and corticosteroids is a mainstay of therapy to reduce the local inflammation caused by venomous insect stings, but in cases of significant upper airway edema, the addition of epinephrine may also be necessary.[19,20] Additionally, after complete recovery, in vivo and in vitro diagnostic testing with skin tests utilizing hymenoptera venom extracts and analysis of serum for hymenoptera venom-specific IgE should be performed.[21] Large local reactions to hymenoptera venom

can be caused by both IgE-mediated or cell-mediated allergic mechanisms. Systemic anaphylactic reactions are usually IgE-mediated, but can rarely be due to short-term sensitizing IgG antibodies or complement activation by IgG-venom complexes.[22] Allergy testing for hymenoptera venom is important in individuals who have had a large local sting reaction, as 5 to 15% will develop a systemic reaction with a subsequent sting.[23]

Due to the potential for airway compromise, posterior oropharyngeal hymenoptera stings should receive prompt emergency medical treatment for stinger removal and the administration of potentially life-saving medications.

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References

1. QuickStats: number of deaths from hornet, wasp, and bee stings, among males and females — National Vital Statistics System, United States, 2000–2017. *MMWR Morb Mortal Wkly Rep*. 2019;68:649.
2. Prado M, Quirós D, Lomonte B. Mortality due to hymenoptera stings in Costa Rica, 1985–2006. *Rev Panam Salud Publica*. 2009;25(5):389–93.
3. Geiger CW, Roth JH. Bee sting of the uvula. *JAMA*. 1923;81(8):660.
4. Butterton JR, Clawson-Simons J. Hymenoptera uvulitis. *N Engl J Med*. 1987;317(20):1291.
5. İlhan E, Yaman H, Dost B, Köse GA, Yaman H. Unusual foreign body in the larynx: a bee. *Kulak Burun Bogaz Ihtis Derg*. 2015;25(4):237–9.
6. Forthal DN, Leong C, Overturf GD. Danger on the Los Angeles freeway. *N Engl J Med*. 1984;311(4):263.
7. Kraiwattanapong J. Uvula bee sting: a case report. *Siriraj Med J*. 2016;68(3):187–90.
8. Mikals K, Beakes D, Banks TA. Stinging the conscience: a case of severe hymenoptera anaphylaxis and the need for provider awareness. *Mil Med*. 2016;181(10):e1400–3.
9. Nusupbaev NA, Izmaĭlov NZ, Komchatov IuN. Death from wasp sting of the throat. *Sud Med Ekspert*. 1983;26(4):56–7.
10. Vaughan WC, Koch RJ. Airway obstruction caused by bee sting macroglossia. *Otolaryngol Head Neck Surg*. 2000;122(5):778.
11. Smoley BA. Oropharyngeal hymenoptera stings: a special concern for airway obstruction. *Mil Med*. 2002;167(2):161–3.
12. Snodgrass RE, ed. *Anatomy of the Honey Bee*. Ithaca, NY: Cornell University Press; 1956.
13. Vetter RS, Visscher PK. Bites and stings of medically important venomous arthropods. *Int J Dermatol*. 1998;37(7):481–96.
14. Lee JA, Singletary E, Charlton N. Methods of honey bee stinger removal: a systematic review of the literature. *Cureus*. 2020;12(5):e8078.
15. Viswanathan S, Iqbal N, Shanmugam V, Srinath G. Odynophagia following retained bee stinger. *J Venom Anim Toxins Incl Trop Dis*. 2012;18(2):253–5.
16. Simons FE, Roberts JR, Gu X, Simons KJ. Epinephrine absorption in children with a history of anaphylaxis. *J Allergy Clin Immunol*. 1998;101(1 Pt 1):33–7.
17. Barach EM, Nowak RM, Lee TG, Tomlanovich MC. Epinephrine for treatment of anaphylactic shock. *JAMA*. 1984;251(16):2118–22.
18. Westfall TC, Westfall DP. Adrenergic agonists and antagonists. In: Brunton LL, ed. *Goodman and Gilman's The Pharmacological Basis of Therapeutics*. 9th ed. New York, NY: McGraw-Hill; 2006:215–68.
19. Zirngibl G, Burrows HL. Hymenoptera stings. *Pediatr Rev*. 2012;33(11):534–5.
20. Tome R, Somri M, Teszler CB, Fradis M, Gaitini LA. Bee stings of children: when to perform endotracheal intubation? *Am J Otolaryngol*. 2005;26(4):272–4.
21. Vachová M, Panzner P, Malkusová I, Hanzlíková J, Vlas T. Utility of laboratory testing for the diagnosis of hymenoptera venom allergy. *Allergy Asthma Proc*. 2016;37(3):248–55.
22. Biló BM, Rueff F, Mosbech H, Bonifazi F, Oude-Elberink JN. Diagnosis of hymenoptera venom allergy. *Allergy*. 2005;60(11):1339–49.
23. Mauriello PM, Barde SH, Georgitis JW, Reisman RE. Natural history of large local reactions from stinging insects. *J Allergy Clin Immunol*. 1984;74(4 Pt 1):494–8.

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CASE REPORT

Death After Crevasse Rescue in Antarctica

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We present a case report of a helicopter pilot who fell into a crevasse during a fuel delivery in Antarctica. He was trapped alone in the crevasse for 3 h while waiting for a rescue team to arrive, and a further 1 h during the extrication process. His condition deteriorated during the extrication and he lost consciousness and signs of life minutes after being dragged over the lip of the crevasse. He was then loaded into the rescue helicopter and treated with intermittent cardiopulmonary resuscitation during the 39-min return flight. Initial esophageal temperature on arrival at the Davis Base medical facility was 24.2°C. After 18 h of further treatment (mechanical ventilation with warm humidified O_2, with internal and external warming) he was pronounced dead. The cause of death was hypothermia with minimal physical injury. This case highlights some of the extra challenges facing operational, rescue, and medical personnel in an isolated location. These complications include the tendency for flight crew to remove cold weather clothing during flight due to restricted mobility and excessive heat load from cabin heating; extended time for arrival of the rescue crew; extrication in a confined space; limited helicopter cabin space for transporting the rescue team and their rescue and medical equipment; and extended transport time to the nearest medical facility.

Keywords: cold exposure, insulation, hypothermia, cardiac arrest, rescue collapse

Introduction

Antarctica has many research stations with many workers deployed across the continent in harsh, potentially dangerous conditions. Risks include severe cold exposure and, in some areas, falling into a crevasse. The main threats to survival to a worker who has fallen into a crevasse are trauma, suffocation from inability to breathe, and cold exposure.[1]

All stations should be prepared to adequately manage rescue operations that are relevant to their specific location and to treat injuries and medical conditions including severe hypothermia. Until the victim is raised to the snow surface, medical care is limited to basic measures. For example, if spinal injury is suspected, spinal immobilization may be attempted before raising the victim.[2] Similarly, if the patient is hypothermic, it would be advantageous to handle the patient as gently as possible, and preferably raise the victim in a horizontal position.[3] Extreme conditions may distract rescuers from the fact that rapid and rough handling, especially if the patient is vertical, may exacerbate the patient's condition.[3]

We present a case report of a helicopter pilot who fell into a crevasse during a fuel delivery in Antarctica. He was trapped alone in the crevasse for 3 h while waiting for a rescue team to arrive, and a further 1 h during extrication. He went into cardiac arrest about 10 min after being extricated from the crevasse and was pronounced dead 18 h after transport to a base medical facility, after prolonged efforts at resuscitation. This case highlights complications facing operational, rescue, and medical personnel in an isolated location. These include the tendency for flight crew to remove their issued cold weather clothing during flight due to excessive heating; extended time for arrival of rescue personnel; rescuer safety; accessing victims in confined spaces; freeing and raising wedged victims; extricating the victim over the crevasse edge; limited helicopter cabin space for transporting the rescue team and their rescue and medical equipment; and extended transport time to the nearest medical facility.

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Figure 1. Helicopter and hole through which the pilot fell into the crevasse. The width at the surface was 60 cm.

Case Report

The Australian Antarctic Division administers and supports research operations from Davis Base, Antarctica. In the summer of 2016, 2 helicopters (each with a single pilot occupant) delivered fuel from Davis Base to a fuel cache on the West Ice Shelf. One pilot (62 y, 188 cm, 96.8 kg) delivered his load and landed the helicopter to unhook the suspension system (longline cable, swivel, and drum hooks) from the fuel drums. After disconnecting the drum hooks from the drums, he carried the cable system (total weight ~35 kg) to the helicopter rear door, where he broke through a snow bridge concealing a crevasse (Figure 1). He fell ~15 m into the crevasse (Figure 2) until he became wedged vertically between the narrowing ice walls. Much of his weight was supported by his flight helmet, which was wedged between the ice walls; this allowed him to continue breathing, although no further movements were possible. Surface air temperature was ~14°C.

Figure 2. Surface view of 60-cm wide crevasse with solid edges that allowed rescuers to stand securely near the crevasse edges.

Figure 3. Manikin demonstration showing a method to transition a hanging victim from a vertical to horizontal position, rotating in the frontal plane to be hanging on the side rather than supine; the facing wall has been removed for demonstration purposes, but the procedure can be performed in a realistic confined space. Initially, the rescue rope is attached via a self-contained haul system (in its shortened configuration) to the upper body. A second rope can then be attached via another haul system (in its extended configuration) to a sling around the legs (at mid-thigh to knee level). The upper body haul system can then be lowered, and the lower body haul system can be raised; these combined actions move the manikin from vertical to horizonal on its side.

During the incident, the cable and drum hooks also fell into the crevasse. The helmet was damaged by one of the hooks. The top of the crevasse was 60 cm wide, and it was possible to safely stand close to both edges.

The second pilot landed his helicopter nearby, approached the crevasse, conversed with the victim, and determined that he was relatively uninjured but cold and immobilized. He then departed for Davis Base to get help because he was unable to perform a rescue at the time. He immediately radioed the base to report the accident and the need for rescue.

The flight to base took 39 min. Following a 55-min turnaround, the helicopter departed with 3 field training

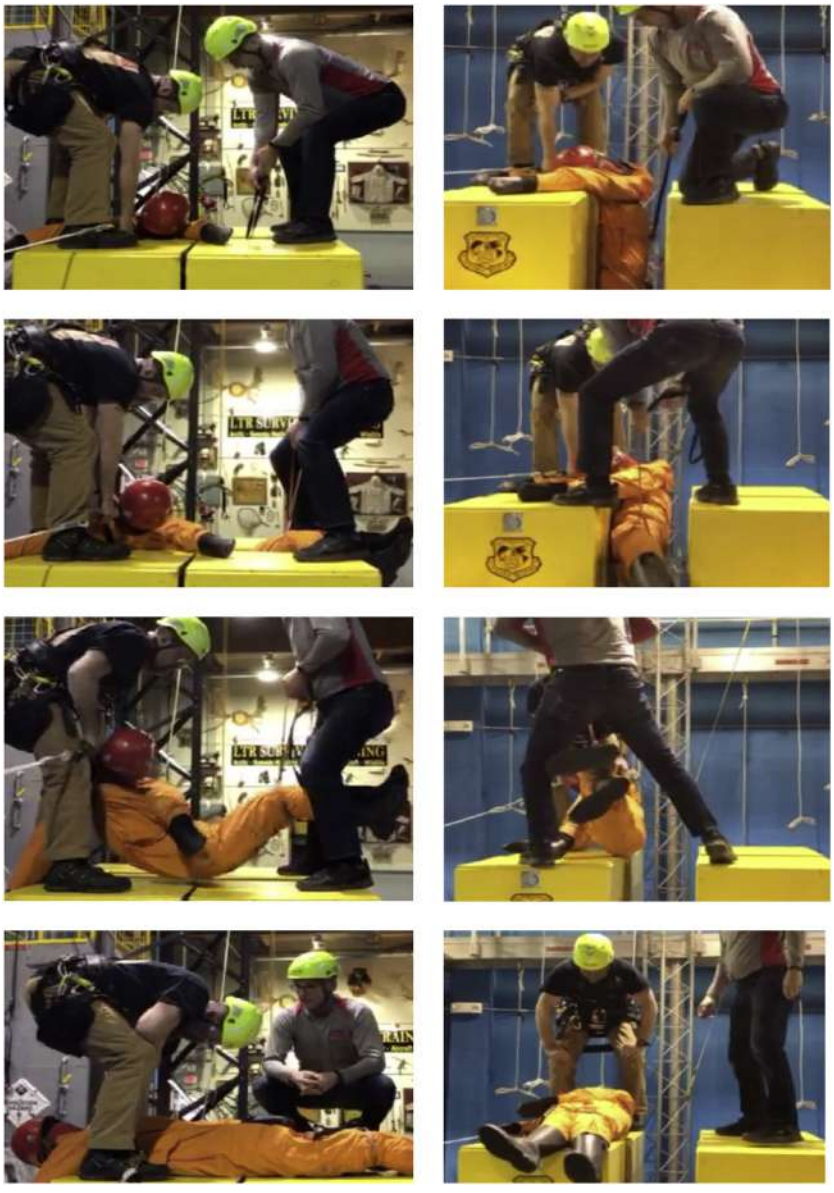

Figure 4. Perpendicular (left) and cross sectional (right) views of an extrication of a 75-kg manikin from a crevasse model (60 cm wide). If the victim must remain vertical while being raised to the ice surface, a sling or rope is placed around the legs between the mid-thigh and knee level. Both surface rescuers can then assume a straight back posture and slowly and gently lift the manikin out of the crevasse and gently place the victim gently on the surface. Top row of photos: attach sling/rope to the legs at the knees. Second row of photos: lift legs up to bring body to an approximate horizontal position. Third row of photos: lift victim slowly and gently up; rescuers may straddle the crevasse. Bottom row of photos: lay victim gently on the surface.

officers (FTOs) who were trained in rescue techniques. This flight took 64 min due to strong headwinds. It is noteworthy that a medical practitioner, who had some cross-training in rescue techniques, was not included in the team due to space constraints on the helicopter, and advanced rescue training was deemed the priority. Also left behind was the medical practitioner's equipment bag (including a monitor-defibrillator, oxygen and resuscitation equipment, and a portable automated external defibrillator).

At the accident site, extrication started following a 12-min site assessment (elapsed time in the crevasse, 179 min). The victim was conscious and "yelling" loudly enough to be heard on the surface. One FTO was lowered and inverted himself to reach the victim, who was found in a vertical position with both arms above his head. At

this point, he still had enough strength to grasp the cable so tightly that his fingers had to be pried loose.

Initial efforts to free the victim from his wedged position were made by wrapping 25 mm-wide webbing around the victim's right arm near the elbow. The sling was attached to a haul rope from an improvised hauling system, which had a 9:1 mechanical advantage. It took significant effort from the 2 FTOs and the pilot on the surface to pull hard enough to free the victim. A sling was then placed under his armpits (because he was not wearing a harness), and he was hauled to the surface in a vertical position.

During this period, the rescue team remembered from their training that if a casualty has been cold for a long time, special care must be taken during handling. Although it was preferable to place the victim in a horizontal position, this was not attempted for 2 reasons: 1) owing to the victim's deteriorating condition, it was believed that this would take too much time; and 2) the crevasse was not wide enough for the victim to lie in a supine position, which is typical when someone is supported horizontally. The option of rotating the victim in the frontal plane (eg, in a cartwheel motion) so he was horizontal, but on his side, was not considered. Once the victim reached the lip of the crevasse, he was quickly pulled by the waist over the edge onto the snow surface.

Total time for approach plus extrication was 61 min, during which the victim's condition deteriorated to being unresponsive and in respiratory distress. Soon after removal from the crevasse, he rolled into a fetal position and lost consciousness. He was placed in a hypothermia bag, put on a stretcher, and loaded into the helicopter 9 min after removal from the crevasse. Shortly thereafter, there was a change from rigidity to relaxation, eyes were open with pupils dilated, and there was no breathing or palpable pulse. During the return flight to Davis Station, one FTO performed an extended carotid pulse check and then performed intermittent cardiopulmonary resuscitation (CPR) as his endurance allowed. Three water bottles, which had been filled with warm water 2 h 40 min previously, were placed in the bag. Two FTOs remained on site because the helicopter had no room for them. Upon arrival at Davis Base, the victim's esophageal temperature (T_{es}) was 24.2°C. The base doctor immediately commenced resuscitation efforts consisting of external warming (forced-air warming), internal warming (3 L of warmed IV saline and warm bladder lavage), and intubation and ventilation with warm humidified O_2. The doctor was assisted by 4 lay surgical assistants and 6 other staff members who rotated in shifts. After ~18 h, T_{es} had increased to 32°C, but there were no signs of life and the patient was pronounced dead.

Postmortem examination indicated no significant internal or external injuries, with the exception of an area of brown/black necrotic skin over the anterior aspect of the right elbow. This was likely caused during the initial extrication process when all force was applied through the sling to the right arm. This probably caused a combination of crush damage to the muscle and an ischemic injury to his entire right forearm. The cause of death was stated as hypothermia leading to cardiac arrest.

Every ground and surface worker, as well as every pilot, is issued a high-insulation protective clothing ensemble for the Antarctic environment. In this case, the pilot had taken this suit off because it was uncomfortably warm to wear while flying. When he fell in the crevasse, he was wearing only a cotton T-shirt, a light long sleeve polar fleece jacket, heavy cotton/polyester pants, wool socks, fingerless wool mittens, rubber booties, and his carbon fiber flight helmet.

Discussion

This case provides valuable insights into the risks and difficulties in working, and providing rescue and medical care, in isolated extreme environments. The victim's condition worsened throughout the ~60-min extrication due to continued cold exposure.

We have considered the victim's signs and symptoms, in combination with the cold exposure survival model,[4] to estimate that his core temperature decreased from ~31.5°C to ~28.0°C during the extrication. At heart temperatures below 28°C, the heart may spontaneously go into ventricular fibrillation cardiac arrest, as a primary result of cooling the heart tissue. Ventricular fibrillation can also be provoked by mechanical stimulation such as rough handling during extrication and by additional toxins released from crush injuries and prolonged tissue ischemia.[5] Finally, ventricular fibrillation can also be precipitated by increasing the workload of a cold heart, as might occur during hypotension caused by blood pooling in the legs (common with cold patients in a vertical position, as well as during suspension or harness hang syndrome).[6,7] This positional hypotension can be exacerbated by decreased epinephrine output (a proposed mechanism for rescue collapse, also referred to as circum-rescue collapse).[8] Thus, the combination of raising the victim in a vertical position and quickly pulling him over the crevasse edge may have contributed to unconsciousness and subsequent lack of discernable cardiac activity. Based on these mechanisms, a cold victim should be placed in a horizontal position as soon as possible.[3] It is not known if

this procedure would have altered the outcome in this case.

Several factors might have decreased the probability of this case ending in a fatality. First, if the victim had been wearing his thermal protection suit, his rate of core cooling would have been slowed and his chance of survival would have increased. Second, anything that could have shortened the interval before the extrication process started would have decreased the exposure time and therefore the amount of core cooling. Finally, any actions to handle the victim more gently or facilitate a horizontal extrication might have delayed or prevented cardiac arrest.

The rescue team performed a very complicated rescue in a very confined space, where accessing the victim required extraordinary measures. They recalled several cold-related rescue principles, such as the need to go slow to handle cold patients gently, and the benefits of raising the victim in a horizontal position. However, both principles were very difficult to apply in these conditions.

The team did not attempt to transition the victim to a horizontal position for several reasons, including that they did not think they could spare the extra 7 to 12 min to do so, and the crevasse was not wide enough to place him in the traditional supine position. We believe, however, that in a 4-h cold exposure, taking this extra time to transition the victim to a better position would not have worsened his condition, compared to the benefits that proper positioning would provide throughout the remainder of the extrication.[3] When a crevasse is not wide enough to accommodate a horizontal supine position, placing a patient in a horizontal lateral decubitus position (eg, with the patient lying sideways) would be better than performing a raise in a vertical position. A method for transitioning a patient from a vertical position to a horizontal position is unlikely to be developed during an emergent event in harsh confined spaces. Rather, it could be developed and practiced during training in simulated or real crevasses (Figure 3).

The perceived need to extricate quickly also likely influenced the team to rush when bringing the victim over the crevasse edge. They simply grabbed him and quickly pulled him onto the snow surface. The presumed need for speed may have outweighed the risk of mechanical stimulation when roughly handling a cold patient.[3] Gentle extrication over the lip of the crevasse can also be practiced during rescue training (Figure 4).

Recommendations

This case provides valuable observations concerning several aspects of rescue and medical operations in isolated areas such as Antarctica.

WORKER SAFETY

Consideration should be given to designing high-insulation clothing ensembles that can be worn comfortably in a warm helicopter cockpit, where freedom of movement and dexterity are required.

TRAINING

A base medical practitioner could be cross-trained in rescue techniques to the necessary competency to be included in a search and rescue (SAR) event in which it is reasonably expected that the victim will need advanced medical treatment.

All SAR personnel should be trained with the principle that the colder the patient is, the more care is required to perform an extrication that is as gentle and horizontal as possible. Realistic crevasse rescue training could include techniques for transitioning a victim from vertical to horizontal in both the supine position and on the side (for narrower spaces). Training should also emphasize that, even if a victim must be raised in a vertical position, a simple technique of using an additional sling or rope under the knees allows a simple, gentle, and horizontal extrication to the snow shelf. Realistic training could be conducted in a real or simulated crevasse, as demonstrated in Figure 4.

Training should also include awareness, causes, symptoms, and prevention of rescue collapse. Trainees should consider trying to prevent mental relaxation during rescue.[8] Rescuers could use positive, upbeat instructions like “I’ve got you, but you need to keep fighting with me. We’re going to get out of this together, keep fighting.” Although this practice has not been scientifically demonstrated to be effective, it is unlikely to produce any negative effects.

If a severely hypothermic victim with signs of life is wearing wet clothing and transport to advanced medical facilities is greater than 30 min, clothing should be cut off and removed before placing the victim in a hypothermia wrap, otherwise the victim may be packaged wet.[3,9]

ORGANIZATIONAL PREPARATION FOR RESCUE

A remote base and its SAR personnel should have ready-to-go kits (for personal, technical, and medical gear) in place and establish a standard operating procedure to immediately activate the rescue response as soon as a serious event is reported.

EQUIPMENT

A medical kit for potentially severe injuries with basic resuscitation equipment (including intubation supplies, bag-valve-mask, oxygen, and an automated external

defibrillator) should always be loaded. If the patient is potentially hypothermic, a hypothermia rescue bag (or hooded sleeping bag) and a warming product that can be activated on site should be included (eg, chemical or electric heat pad or blanket). A mechanical chest compression device would be a valuable asset as patients have survived longer periods of CPR (6–9 h) than can be reasonably sustained by a single responder.[10,11] This would not only provide continuous CPR but also allow a single caregiver to provide other care such as bag-valve-mask ventilation or warming. Consideration could also be given to including IV saline and a fluid warmer.

Rescue equipment for crevassed areas could include a tripod and winch and rescue harnesses for victims who may not be wearing them. Finally, a faster, larger helicopter would have permitted a more rapid response and carriage of medical personnel and medical equipment.

Conclusions

SAR personnel should be trained to avoid the perceived choice to move quickly or have the victim die. In fact, acting too quickly may worsen the victim's condition. Rather, moving slowly and deliberately following the principles described for care of a cold patient will likely improve patient outcome, even if it takes a few minutes longer.

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References

1. Reisten O, Kreuzer O, Forti A, Brugger H. Crevasse accidents. In: Brugger H, Zafren K, Festi L, Paal P, Strapazzon G, eds. *Mountain Emergency Medicine*. Italy: Edra; 2021:269–78.
2. Winterberger E, Jacomet H, Zafren K, Ruffinen GZ, Jelk B. The use of extrication devices in crevasse accidents: official statement of the International Commission for Mountain Emergency Medicine and the Terrestrial Rescue Commission of the International Commission for Alpine Rescue intended for physicians, paramedics, and mountain rescuers. *Wilderness Environ Med*. 2008;19(2):108–10.
3. Dow J, Giesbrecht GG, Danzl DF, Brugger H, Sagalyn EB, Walpoth B, et al. Wilderness Medical Society clinical practice guidelines for the out-of-hospital evaluation and treatment of accidental hypothermia: 2019 update. *Wilderness Environ Med*. 2019;30(4S):S47–69.
4. Tikuisis P. Prediction of survival time at sea based on observed body cooling rates. *Aviat Space Environ Med*. 1997;68(5):441–8.
5. Torres PA, Helmstetter JA, Kaye AM, Kaye AD. Rhabdomyolysis: pathogenesis, diagnosis, and treatment. *Ochsner J*. 2015;15(1):58–69.
6. Weber SA, McGahan MM, Kaufmann C, Biswas S. Suspension trauma: a clinical review. *Cureus*. 2020;12(6): e8514.
7. Rauch S, Schenk K, Strapazzon G, Dal Capello T, Gatterer H, Palma M, et al. Suspension syndrome: a potentially fatal vagally mediated circulatory collapse-an experimental randomized cross-over trial. *Eur J Appl Physiol*. 2019;119(6):1353–65.
8. Golden FS, Hervey GR, Tipton MJ. Circum-rescue collapse: collapse, sometimes fatal, associated with rescue of immersion victims. *J R Nav Med Serv*. 1991;77(3):139–49.
9. Giesbrecht GG. "Cold Card" to guide responders in the assessment and care of cold-exposed patients. *Wilderness Environ Med*. 2018;29(4):499–503.
10. Lexow K. Severe accidental hypothermia: survival after 6 hours 30 minutes of cardiopulmonary resuscitation. *Arctic Med Res*. 1991;50(Suppl 6):112–4.
11. Forti A, Brugnaro P, Rauch S, Crucitti M, Brugger H, Cipollotti G, et al. Hypothermic cardiac arrest with full neurologic recovery after approximately nine hours of cardiopulmonary resuscitation: management and possible complications. *Ann Emerg Med*. 2019;73(1):52–7.

WILDERNESS & ENVIRONMENTAL MEDICINE 2022; 33(2): 245–7

CASE REPORT

Isolated Ptosis Following a *Vipera aspis* Bite

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In Spain, snakebites are uncommon medical emergencies that cause barely 100 hospitalizations annually. Most of the venomous bites are by snakes of the *Viperidae* family. Venom from *Vipera* snakes is reported to have cytotoxic and hematotoxic effects, and neurological effects have also been described. Ptosis (cranial nerve III palsy) is the most common sign, although any cranial nerve can be affected. We describe isolated ptosis, which was very likely after a *Vipera aspis* bite in the East Catalonian Pyrenees. No antivenom was administered. The ptosis resolved spontaneously within 10 h. Although neurologic findings are usually mild, they indicate a moderate or severe envenomation. Treating snakebites can be challenging for clinicians, especially when there are uncommon clinical manifestations. A toxicologist at a poison center should be consulted to help guide management. Development of local protocols may provide clinical support.

Keywords: snakebites, snakes, medical emergencies

Introduction

In Spain, bites of venomous snakes are uncommon and cause death only in 1% of all hospitalizations.[1,2] Three *Vipera* species can be found in Spain: *Vipera aspis*, *Vipera latastei*, and *Vipera seoanei*. Two other species of venomous snakes, the non-front-fanged colubroids *Malpolon monspessulanus* and *Macroprotodon brevis*, occur in Spain. However, most reported cases of envenomation are caused by snakes of the family *Viperidae*. The most common location of bites is the upper extremities. In Spain, snakebites more commonly affect males than females.[3] Signs of neurologic envenomation after *V aspis* bite have been previously reported in the southeast of France.[4] Although neurologic findings are usually mild and transient, they may indicate moderate or severe envenomation. We describe a case in which the only neurologic manifestation was bilateral ptosis after a *V aspis* bite.

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Case Report

An 85-y-old male patient was admitted to the emergency department in summer 2017 after a snakebite. He was bitten on the fourth finger of the right hand after he picked up a log while working in his orchard. The bite occurred in the East Catalonian Pyrenees at 1100 m in the small village of Fontanals de Cerdanya, near the city of Puigcerdà. *V aspis* is the only snake found at that altitude and location whose venom can cause neurologic manifestations.

The patient received no prehospital care. He was immediately driven to the hospital, a distance of less than 10 km, by his son. The family also brought in the dead snake. The emergency physicians identified it as *V aspis* based on the location at which the bite occurred and by identifying the most common features, including a length of <70 cm, a triangular head, solenoglyphous dentition (long, hollow fangs that fold into the roof of the mouth when the jaws are closed), carinate scales, and vertical pupils.

On presentation to the emergency department, the wound had already developed local edema and

Figure 1. Bite on the fourth finger of the right hand.

ecchymosis (Figure 1). The extent of the edema was outlined with a permanent marker. On the primary survey, the patient was alert and able to converse normally. The Glasgow Coma Score was 15. Vital signs were as follows: respiratory rate 12 breaths·min^{-1}, heart rate 69 beats·min^{-1}, blood pressure 128/62 mm Hg, and SpO_2 92% on room air. The patient had full range of motion of all extremities. A peripheral line was placed, and a blood sample was obtained, which showed the following: hemoglobin 15.1 g·dL^{-1}, leucocytes 5.4 × 10^3·μL^{-1}, platelets 42 × 10^9·L^{-1}, prothrombin time ratio 1.05, international normalized ratio 1.08, activated partial thromboplastin time ratio 0.99, glucose 122 mg·dL^{-1}, creatinine 0.84 mg·dL^{-1}, glomerular filtration rate >60 mL·min^{-1}, and potassium 4.3 mmol·L^{-1}. The blood tests were repeated in 12 h and still showed normal coagulation parameters but a rising leukocyte count of 13.9 × 10^3·μL^{-1}. Antibiotic treatment with 1 g of amoxicillin/clavulanate was initiated because of suspected local infection, based on an expanding area of erythema and edema with warmth. A tetanus booster was given.

The patient had sudden onset of bilateral ptosis during a repeat examination 6 h after the bite (Figure 2). The palpebral fissures were equally closed bilaterally. No other neurologic effects were observed. Cranial nerves II-XII were intact, except for the third cranial nerve palsies. Pupils were equal, round, and reactive to light. Extraocular muscles were intact. Because the patient was not able to blink, glabellar reflexes were not tested. Visual acuity was normal. Visual fields, tested by confrontation, were normal. He was unable to open his eyes for almost 10 h. The emergency physicians considered the risk-benefit ratio of administering antivenom. They did not administer antivenom because the only sign of toxicity was the isolated third cranial nerve palsies. They decided

Figure 2. Bilateral ptosis.

to wait, reassess the patient frequently, and administer antivenom if his condition worsened. The patient was admitted for observation. After 24 h of observation, he was discharged home without neurologic or other sequelae.

Discussion

Most envenomations by snakes in the Pyrenees mountains are caused by *V aspis*. Neurologic manifestations of bites from both *V aspis* subspecies living in the Pyrenees, *V aspis aspis* and *V aspis zinnikeri,* have been described,[4] although no case report of a neurologic manifestation in Spain has been previously published as far as we are aware. Venom of *V aspis* contains phospholipase A2 neurotoxins that are the likely cause of neurologic manifestations affecting pre- or post-synaptic neuromuscular transmission.[4-7] Neurologic manifestations can include generalized weakness, paralysis of extraocular muscles, diplopia, ophthalmoplegia, dysarthria, dysphagia, and flaccid paralysis. Up to 15% of European *Vipera* spp. bites can cause cranial nerve palsies.[5] Cranial nerve palsies are usually seen in the first 4 to 12 h after the bite and can be the only neurologic manifestation. The most common sign is ptosis, followed by ophthalmoplegia.

The presence of neurologic manifestations indicates moderate or severe envenomation.[8] Standard treatment for moderate or severe envenomation is immunotherapy with Fab or F(ab')2 fragments.[8-10] Viperfav, an antivenom that contains F(ab')2 fragments of purified equine antibodies, is effective against the neurologic injury caused by *V aspis.* Viperfav is most effective when administered in the first 10 h.[8]

General management includes local wound care, monitoring the spread of local edema, monitoring vital signs, and treating pain. Routine use of corticosteroids is

contraindicated. Antibiotics should only be given if an infection is suspected. Secondary infection after European *Vipera* bite occurs in fewer than 4% of cases.[5] A tetanus booster should be given if indicated.

Conclusions

Envenomation by *V aspis* can cause a broad range of manifestations, including neurologic effects. Although abnormal neurologic findings are usually mild, their presence indicates moderate or severe envenomation, requiring treatment with antivenom. The decision whether to administer antivenom can be challenging, especially when there are uncommon clinical manifestations. A toxicologist at a poison center should be consulted to help guide management. Development of local protocols may provide clinical support.

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References

1. Martín-Sierra C, Nogué-Xarau S, Pinillos Echeverría MÁ, Rey Pecharromán JM. Snakebite poisoning in Spain. *Emergencias*. 2018;30(2):126–32.
2. Martín C, Nogué S. Novedades en el envenenamiento por mordedura de víbora [Changes in viper bite poisonings]. *Med Clin (Barc)*. 2015;144(3):132–6.
3. Saz-Parkinson Z, del Pino Luengo M, López-Cuadrado T, Andújar D, Carmona-Alférez R, Flores RM, et al. Approach to the epidemiology of venomous bites in Spain. *Toxicon*. 2012;60(4):706–11.
4. Ferquel E, de Haro L, Jan V, Guillemin I, Jourdain S, Teynié A, et al. Reappraisal of *Vipera aspis* venom neurotoxicity. *PLoS One*. 2007;2(11):e1194.
5. Paolino G, Di Nicola MR, Pontara A, Didona D, Moliterni E, Mercuri SR, et al. *Vipera* snakebite in Europe: a systematic review of a neglected disease. *J Eur Acad Dermatol Venereol*. 2020;34(10):2247–60.
6. Jollivet V, Hamel JF, de Haro L, Labadie M, Sapori JM, Cordier L, et al. European viper envenomation recorded by French poison control centers: a clinical assessment and management study. *Toxicon*. 2015;108:97–103.
7. De Haro L. Manejo del envenenamiento por víbora en Europa. En Amate Blanco, JM y Conde Espejo, P. (Coords.) *Intoxicaciones por mordeduras de ofidios venenosos (I Panel de expertos en España). IPE 2012/68. Agencia de Evaluación de Tecnologías Sanitarias (AETS)*. Madrid: Instituto de Salud Carlos III; 2012.
8. Boels D, Hamel JF, Bretaudeau Deguigne M, Harry P. European viper envenomings: assessment of Viperfav and other symptomatic treatments. *Clin Toxicol (Phila)*. 2012;50(3):189–96.
9. Boels D, Hamel JF, Le Roux G, Labadie M, Paret N, Delcourt N, et al. Snake bites by European vipers in Mainland France in 2017–2018: comparison of two antivenoms Viperfav and Viperatab. *Clin Toxicol (Phila)*. 2020;58(11):1050–7.
10. de Haro L, Glaizal M, Tichadou L, Blanc-Brisset I, Hayek-Lanthois M. Asp Viper (*Vipera aspis*) envenomation: experience of the Marseille Poison Centre from 1996 to 2008. *Toxins (Basel)*. 2009;1(2):100–12.

WILDERNESS & ENVIRONMENTAL MEDICINE 2022; 33(2): 248–9

CLINICAL IMAGES

A Tall Cool Glass of Water

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A 51-y-old woman with no prior medical history presented to the emergency department complaining of itching in her throat with a sensation of throat swelling after quickly drinking a cold glass of ice water in the middle of the night. The patient stated that she had developed hives when exposed to cold weather in the past, but that she had never had a problem with her throat. On physical examination, her lower lip and uvula appeared edematous and her voice was slightly muffled, so ENT was consulted for endoscopy. Endoscopy revealed moderate edema of the right arytenoid, obscuring the view of the cords (Figures 1 and 2). A brief glimpse of the cords demonstrated a patent airway (Figure 3).

What is the diagnosis? How should this case be managed?

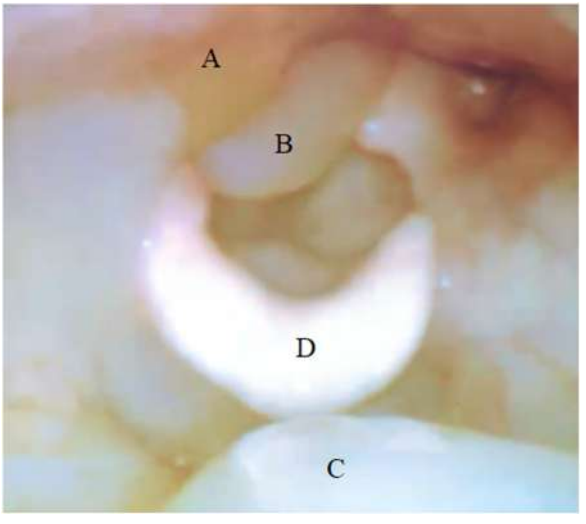

Figure 1. View of the soft palate, hypopharynx, and supraglottic region demonstrating watery edema at the inferior aspect of the right lateral pharyngeal wall (A) and the right arytenoid mucosa (B). There was no edema of the base of the tongue (C) or epiglottis (D).

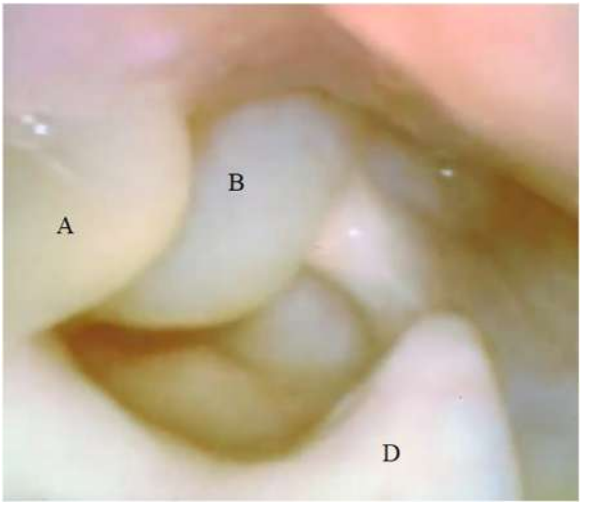

Figure 2. A close view of the posterior aspect of the epiglottis (D) and the rest of the hypopharynx illustrates watery edema of the right pharyngeal wall (A) and right arytenoid cartilage (B). The rest of the mucosa appears normal.

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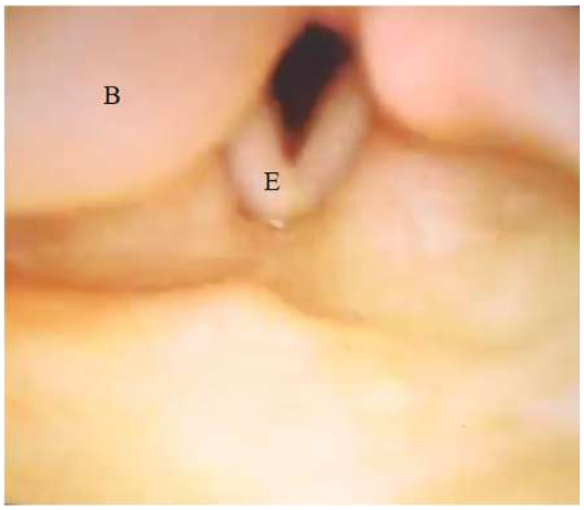

Figure 3. The supraglottic area has clear watery edema of the right arytenoid (B). However, there is space between the swelling and the abducted vocal cords (E) showing that the airway is patent.

Diagnosis

Cold-induced angioedema

Discussion

The patient's airway symptoms were managed with administration of epinephrine (0.3 mg IM), diphenhydramine (50 mg IV), dexamethasone (10 mg IV), and famotidine (40 mg IV) in the emergency department. The ENT team did not think that intubation was necessary. The patient was admitted for airway monitoring. Treatment was continued with intravenous diphenhydramine, dexamethasone, and famotidine. Her symptoms improved. She continued to breathe comfortably with a room air oxygen saturation of 100%. She was discharged after 32 h.

Isolated cold-induced angioedema is rarely seen or reported and remains a poorly understood condition. It usually occurs in patients who have a history of cold urticaria.[1] Our patient did relate a history of cold urticaria symptoms without a formal diagnosis. The prevalence of cold urticaria in the general population is thought to be 0.05%.[2] One study showed that angioedema was present in 23% of these cases.[1] In addition to airway symptoms, angioedema can be associated with systemic reactions, including anaphylactic shock. It is critical to monitor closely for airway and hemodynamic compromise. Future exposure to cold water should be discouraged.[2]

Cold-induced urticaria is thought to be due to mast cell degranulation and release of proinflammatory mediators after cold exposure of the skin or mucous membranes.[2] We treated our patient with epinephrine, dexamethasone, diphenhydramine, and famotidine with good control of her symptoms. This is consistent with a histaminergic etiology. The formal diagnosis of cold urticaria can be made with a cold stimulation test, in which an ice cube is placed on the patient's skin and the skin is allowed to rewarm. A wheal and flare reaction is considered a positive test. In addition to cold avoidance, the primary prophylactic treatment option described for cold urticaria is taking high-dose H1 antihistamines before cold exposure; a 2012 study demonstrated complete efficacy in 30%, partial benefit in 50% and no preventive benefit in 20% of patients.[3]

Our patient was discharged the following day with a prescription for an epinephrine auto-injector as recommended for cold urticaria patients at risk for systemic reactions.[4] Six months later she continued to do well. She had no recurrent episodes of airway angioedema and only rare issues with cold-induced urticaria due to thoughtful efforts at cold avoidance. Comprehensive allergen panel testing with an allergy specialist was negative.

Note: The images presented in this article were obtained using a disposable, flexible laryngoscope and monitor.

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References

1. Mathelier-Fusade P, Aïssaoui M, Bakhos D, Chabane MH, Leynadier F. Clinical predictive factors of severity in cold urticaria. *Arch Dermatol*. 1998;134(1):106–7.
2. Maltseva N, Borzova E, Fomina D, Bizjak M, Terhorst-Molawi D, Košnik M, et al. COLD-CE Steering Committee. Cold urticaria - what we know and what we do not know. *Allergy*. 2021;76(4):1077–94.
3. Magerl M, Pisarevskaja D, Staubach P, Martus P, Church MK, Maurer M. Critical temperature threshold measurement for cold urticaria: a randomized controlled trial of H(1)-antihistamine dose escalation. *Br J Dermatol*. 2012;166(5):1095–9.
4. Bernstein JA, Lang DM, Khan DA, Craig T, Dreyfus D, Hsieh F, et al. The diagnosis and management of acute and chronic urticaria: 2014 update. *J Allergy Clin Immunol*. 2014;133(5):1270–7.

Letters to the Editor

Brief Information on Nonvenomous Snakebites in Brazil

To the Editor:

Snakes have the most diverse venom-delivery system of all vertebrates. Among the advanced snakes (Caenophidia) that occur in Brazil, there are 2 families that are known as "true venomous snakes" (ie, front-fanged snakes[1])—Elapidae and Viperidae. There are also several other families that contain non-front-fanged species (NFFC[1]) commonly considered "nonvenomous"—the Dipsadidae and the Colubridae are prominent. The Brazilian NFFC are a heterogeneous assemblage of snakes with several types of oral glands, such as supralabial, infralabial, and Duvernoy's glands, which are composed of mucous and serous cells that produces toxic secretions and venom (Figure 1).[2]

From 2001, 2 Dipsadidae genera, *Philodryas* and *Clelia,* were also considered of medical importance according to the Brazilian Ministry of Health's manual for diagnosis and treatment of envenomations by venomous animals.[3] Although this classification should be due to the severity and frequency of envenomations, bites caused by these snakes are probably uncommon. The inclusion of these genera by Brazilian Ministry of Health may be due to reports in the literature of envenomations[4,5] and studies that describe the proprieties of their venom. Envenomations caused by *Philodryas* species include important local signs and symptoms, such as pain, edema, and hemorrhage, which are similar to *Bothrops* envenomations in some cases.[4] Envenomation caused by *Clelia* spp. in Brazil was only documented in a single report that describes "extreme sensitivity to touch," prominent ecchymosis, and edema.[5]

In a review developed in São Paulo state, Brazil, in 2003,[6] 16 genera of NFFC were associated with snakebites, and the species were considered by authors as "mildly venomous snakes." The clinical manifestations included abrasions (in 30% of the cases), local pain (28% of the cases), hemorrhage (15% of the cases), and swelling (10% of the cases). The review also described envenomations caused by *Erythrolamprus poecilogyrus*, whose bite causes intense pain and local hemorrhage; *Erythrolamprus miliaris,* whose bite causes a serious hemorrhage (which was treated with *Bothrops* antivenom despite no evidence of efficacy); and *Helicops angulatus*, which causes coagulopathy. However, a recent study provided formal evidence of mild coagulopathy in envenomations caused by *H angulatus.*[7]

Another study[8] identified clinical manifestations in bites caused by *Helicops, Hydrops,* and *Philodryas* that were treated at the Juruá Regional Hospital, Acre state, Brazil. Envenomation caused by *Hydrops triangularis* bites caused nonspecific symptoms, such as vomiting, headache, and local pain. Victims of envenomations by *Philodryas viridissima* envenomation reported pain, bleeding, edema, erythema, and ecchymosis.

In general, envenomation caused by the Brazilian NFFC snakes includes symptoms such as local pain, edema, erythema, hemorrhage, and other symptoms that may lead to a false diagnosis and thus be confused with bites by *Bothrops.*[6] Symptoms like gingival hemorrhage have also been reported for envenomation caused by the genus *Philodryas.*[6]

Aside from studies carried out directly in hospitals and the cases reported separately, another source of information on envenomations caused by NFFC snakes is the DATASUS platform, operated by the Brazilian Ministry of Health. Between 2007 and 2020, approximately 2.5 million snakebites occurred in Brazil, of which about 2 million reported incidents did not include identification of the snake. Only 360,000 of these reports included identification, either at the genus level (eg, *Bothrops*) or as "nonvenomous" (NFFC snakes). According to the DATASUS platform, of the more than 21,000 cases registered for NFFC snakes, 877 were considered moderate, 64 severe, and 16 were fatal. These data probably reflect snake misidentification by health teams in Brazil. On the Brazilian Ministry of Health's website, there is currently no protocol for treatment of NFFC snakebites and no robust information stating that NFFC snakes can cause envenomation. Additionally, no information on native snakes is provided for Brazilian citizens and tourists, including in the practical guide "How is Brazil taking care of tourists' health?"[9] Another important point is that, recently, social media commonly shows people freely handling snakes in Brazil. The purpose of this attitude is not clear, and it may be an attempt at environmental education or even just to show free handling.

Snakebite is a serious public health problem in Brazil. Some important steps have already been indicated to solve this problem, such as correct identification of the snake, access to treatment, and adequate treatment for victims. Given the similarity of envenomation symptoms in some

Figure 1. Brazilian non-front-fanged colubroid (NFFC) snakes involved in evenomation cases: (A) *Philodryas olfersii*, (B) *Erythrolamprus poecilogyrus*, (C) *Helicops angulatus*, and (D) *Erythrolamprus aesculapii.* Photos: N. Citeli (A and C) and A.S. Meneses (B and D).

cases, it is important to train health teams to correctly identify the genera of the snakes that cause the most severe envenomations. Hospitals should receive support from herpetologists and other biologists with familiarity of the local snake fauna, and the population should be taught about the symptoms of snakebites. In some cases, due to the similarity of the symptoms (eg, *Philodryas olfersii* envenomation), the *Bothrops* antivenom is used.[10] This is done empirically in Brazil and other South American countries. It is important to remember that, currently, there is no antivenom in Brazil for envenomations caused by NFFC snakes and that the misuse of the available antivenoms for venomous snakes of greater medical importance (eg, *Bothrops* antivenom) may cause harmful side effects such as early adverse reactions.

Finally, the Brazilian Ministry of Health must establish a treatment protocol for NFFC envenomations, including information on websites for citizens and tourists. Health education agents must provide educational measures that encourage people not to touch wildlife, especially snakes that are not traditionally known for being venomous.

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References

1. Weinstein S. Non-front-fanged colubroid snakes. In: Brent J, Burkhart K, Dargan P, et al. eds. *Critical Care Toxicology: Diagnosis and Management of the Critically Poisoned Patient*. 2nd ed. Switzerland, AG: Springer Nature; 2017:2453–92.
2. Kardong KV. The evolution of the venom apparatus in snakes from colubrids to viperids and elapids. *Mem Inst Butantan*. 1982;46:105–18.
3. Ministério da Saúde (Brasil). Fundação Nacional da Saúde. Manual de Diagnóstico e Tratamento de Acidentes por Animais Peçonhentos. 2nd ed. Brasília, DF: Fundação Nacional de Saúde, 2001.
4. da Silva MV, Buononato MA. Relato clínico de envenenamento humano por *Philodryas olfersii*. *Mem Inst Butantan*. 1984;47/48:121–6.

5. Pinto RNL, da Silva Júnior NJ, Aird SD. Human envenomation by the South American opisthoglyph *Clelia clelia plumbea*. *Toxicon*. 1991;29(12):1512–6.
6. da Graca Salomão M, Albolea ABP, Santos A, Maria S. Colubrid snakebite: a public health problem in Brazil. *Herpetol Rev*. 2003;34(4):307–12.
7. Villca-Corani H, Nieto-Ariza B, León R, Rocabado JA, Chippaux JP, Urra FA. First reports of envenoming by South American water snakes *Helicops angulatus* and *Hydrops triangularis* from Bolivian Amazon: a one-year prospective study of non-front-fanged colubroid snakebites. *Toxicon*. 2021;202:53–9.
8. da Silva AM, Mendes VKDG, Monteiro WM, Bernarde PS. Non-venomous snakebites in the Western Brazilian Amazon. *Rev Soc Bras Med Trop*. 2019;52:e20190120.
9. Ministry of Health of Brazil. How is Brazil taking care of tourists' health? Available at: https://bvsms.saude.gov.br/bvs/publicacoes/como_cuidar_saude_brasil_ingles.pdf. Accessed July 20, 2021.
10. de Medeiros CR, Duarte MR, de Souza SN. Differential diagnosis between venomous (*Bothrops jararaca*, Serpentes, Viperidae) and "Nonvenomous" (*Philodryas olfersii*, Serpentes, Dipsadidae) snakebites: is it always possible? *Wilderness Environ Med*. 2021;32(4):522–7.

Envenomation by Montpellier Snake, *Malpolon monspessulanus* Following Prolonged Bites

To the Editor:

The exact function and possible toxicity of most components of snake venoms have not been fully elucidated.[1] Clinically, the identification of potentially toxic components does not automatically translate into a human health issue. Not all venomous snakes are equal in terms of health risk. For instance, several vipers have little medical significance (eg, *Vipera ursinii ursinii*[2]), whereas some colubrids may inflict life-threatening bites (eg, *Dispholidus typus*[3]). Besides venom composition, the diversity of venom delivery systems (eg, front vs rear fangs), snake body size, and snake behavior all combine to generate a complex picture.[4] It is therefore crucial to examine to what extent snakebites generate clinical symptoms.

The Montpellier snake (*Malpolon monspessulanus*, Psammophiidae) is a large (up to 2 m) rear-fanged venomous snake present in the south of France, the Iberian Peninsula, and western Maghreb.[5] Relatively abundant, notably in agricultural areas and bushy wastelands, this snake typically flees from encounters with humans. However, when seized, the snakes can retaliate and sometimes bite. Field herpetologists are at the highest risk of being bitten, especially during field studies or rescue operations when snakes are handled. Bites are usually quick; the snakes can open their jaws wide and the fangs may penetrate the skin. Yet, envenomation is rare and poorly documented.[6,7]

Clinical cases: Two boys (A, a 16-y-old, and B, a 13-y-old) were bitten while handling adult Montpellier snakes in southeast France, in April 2018 and in February 2021, respectively. The snake's species was identified in the field by experienced professional herpetologists. The snakes maintained their grip for 1 to several minutes. The boys displayed general symptoms (A: recurrent vomiting; B: headaches) and experienced intense pain and swelling. Both patients received care at a local emergency department, with local disinfection and second-step analgesics (treatment for mild-to-moderate pain). Blood biochemistry for each patient indicated normal status (eg, blood glucose $0.7<x<1.40\ g{\cdot}L^{-1}$). Corticosteroids (cortisone) were applied to reduce swelling (3 d), although the usefulness of topical steroid application to treat local envenomation has not been demonstrated. Despite a lack of signs of infection, antibiotics were prescribed for prophylaxis (7 d); it should be noted that no zoonotic diseases from snakebites have been documented in the field (excluding infectious complications following snakebites associated with necrosis and inappropriate treatments). The patients recovered and had no sequelae. Further details are provided.

Boy A: A female snake (1.13 m total length) bit his right index finger, provoking pain. Five minutes later, according to the boy, local paralysis appeared. The edema impeded movements of the finger for several hours. At the end of the day, the pain resolved. The patient went home and the finger gradually recovered mobility. The edema extended to the wrist (Figure 1A) and persisted for 3 d post-bite.

Boy B: A male snake (1.17 m) bit the boy's wrist, leaving teeth marks with limited bleeding (Figure 1B). Edema appeared 1 h later and headaches 3 h later. At 3 h post-bite, the boy also suffered from local hypoesthesia (objectively recorded), possibly caused by local edema. Swelling extended to the wrist (4 h post-bite) and then halfway up his forearm (5 h post-bite) (Figures 1B and C). Headaches and edema disappeared 32 h post-bite; meanwhile slight swelling had spread to the entire forearm. Swelling completely disappeared 48 h post-bite.

Envenomation was benign and limited to localized clinical symptoms such as pain, numbness, and swelling. However, 2 reports from Spain (1979) and France (2007) described severe clinical signs of envenomation, including neurological disorders affecting cranial nerves (eg, ptosis, difficulty swallowing, dyspnea, trouble focusing) combined with extensive swelling.[6,7] In the first case, a man was bitten on the hand. In the second case, the victim was envenomed when he put his finger

5. Pinto RNL, da Silva Júnior NJ, Aird SD. Human envenomation by the South American opisthoglyph *Clelia clelia plumbea*. *Toxicon*. 1991;29(12):1512–6.
6. da Graca Salomão M, Albolea ABP, Santos A, Maria S. Colubrid snakebite: a public health problem in Brazil. *Herpetol Rev*. 2003;34(4):307–12.
7. Villca-Corani H, Nieto-Ariza B, León R, Rocabado JA, Chippaux JP, Urra FA. First reports of envenoming by South American water snakes *Helicops angulatus* and *Hydrops triangularis* from Bolivian Amazon: a one-year prospective study of non-front-fanged colubroid snakebites. *Toxicon*. 2021;202:53–9.
8. da Silva AM, Mendes VKDG, Monteiro WM, Bernarde PS. Non-venomous snakebites in the Western Brazilian Amazon. *Rev Soc Bras Med Trop*. 2019;52:e20190120.
9. Ministry of Health of Brazil. How is Brazil taking care of tourists' health? Available at: https://bvsms.saude.gov.br/bvs/publicacoes/como_cuidar_saude_brasil_ingles.pdf. Accessed July 20, 2021.
10. de Medeiros CR, Duarte MR, de Souza SN. Differential diagnosis between venomous (*Bothrops jararaca*, Serpentes, Viperidae) and "Nonvenomous" (*Philodryas olfersii*, Serpentes, Dipsadidae) snakebites: is it always possible? *Wilderness Environ Med*. 2021;32(4):522–7.

Envenomation by Montpellier Snake, *Malpolon monspessulanus* Following Prolonged Bites

To the Editor:

The exact function and possible toxicity of most components of snake venoms have not been fully elucidated.[1] Clinically, the identification of potentially toxic components does not automatically translate into a human health issue. Not all venomous snakes are equal in terms of health risk. For instance, several vipers have little medical significance (eg, *Vipera ursinii ursinii*[2]), whereas some colubrids may inflict life-threatening bites (eg, *Dispholidus typus*[3]). Besides venom composition, the diversity of venom delivery systems (eg, front vs rear fangs), snake body size, and snake behavior all combine to generate a complex picture.[4] It is therefore crucial to examine to what extent snakebites generate clinical symptoms.

The Montpellier snake (*Malpolon monspessulanus*, Psammophiidae) is a large (up to 2 m) rear-fanged venomous snake present in the south of France, the Iberian Peninsula, and western Maghreb.[5] Relatively abundant, notably in agricultural areas and bushy wastelands, this snake typically flees from encounters with humans. However, when seized, the snakes can retaliate and sometimes bite. Field herpetologists are at the highest risk of being bitten, especially during field studies or rescue operations when snakes are handled. Bites are usually quick; the snakes can open their jaws wide and the fangs may penetrate the skin. Yet, envenomation is rare and poorly documented.[6,7]

Clinical cases: Two boys (A, a 16-y-old, and B, a 13-y-old) were bitten while handling adult Montpellier snakes in southeast France, in April 2018 and in February 2021, respectively. The snake's species was identified in the field by experienced professional herpetologists. The snakes maintained their grip for 1 to several minutes. The boys displayed general symptoms (A: recurrent vomiting; B: headaches) and experienced intense pain and swelling. Both patients received care at a local emergency department, with local disinfection and second-step analgesics (treatment for mild-to-moderate pain). Blood biochemistry for each patient indicated normal status (eg, blood glucose $0.7<x<1.40\ g{\cdot}L^{-1}$). Corticosteroids (cortisone) were applied to reduce swelling (3 d), although the usefulness of topical steroid application to treat local envenomation has not been demonstrated. Despite a lack of signs of infection, antibiotics were prescribed for prophylaxis (7 d); it should be noted that no zoonotic diseases from snakebites have been documented in the field (excluding infectious complications following snakebites associated with necrosis and inappropriate treatments). The patients recovered and had no sequelae. Further details are provided.

Boy A: A female snake (1.13 m total length) bit his right index finger, provoking pain. Five minutes later, according to the boy, local paralysis appeared. The edema impeded movements of the finger for several hours. At the end of the day, the pain resolved. The patient went home and the finger gradually recovered mobility. The edema extended to the wrist (Figure 1A) and persisted for 3 d post-bite.

Boy B: A male snake (1.17 m) bit the boy's wrist, leaving teeth marks with limited bleeding (Figure 1B). Edema appeared 1 h later and headaches 3 h later. At 3 h post-bite, the boy also suffered from local hypoesthesia (objectively recorded), possibly caused by local edema. Swelling extended to the wrist (4 h post-bite) and then halfway up his forearm (5 h post-bite) (Figures 1B and C). Headaches and edema disappeared 32 h post-bite; meanwhile slight swelling had spread to the entire forearm. Swelling completely disappeared 48 h post-bite.

Envenomation was benign and limited to localized clinical symptoms such as pain, numbness, and swelling. However, 2 reports from Spain (1979) and France (2007) described severe clinical signs of envenomation, including neurological disorders affecting cranial nerves (eg, ptosis, difficulty swallowing, dyspnea, trouble focusing) combined with extensive swelling.[6,7] In the first case, a man was bitten on the hand. In the second case, the victim was envenomed when he put his finger

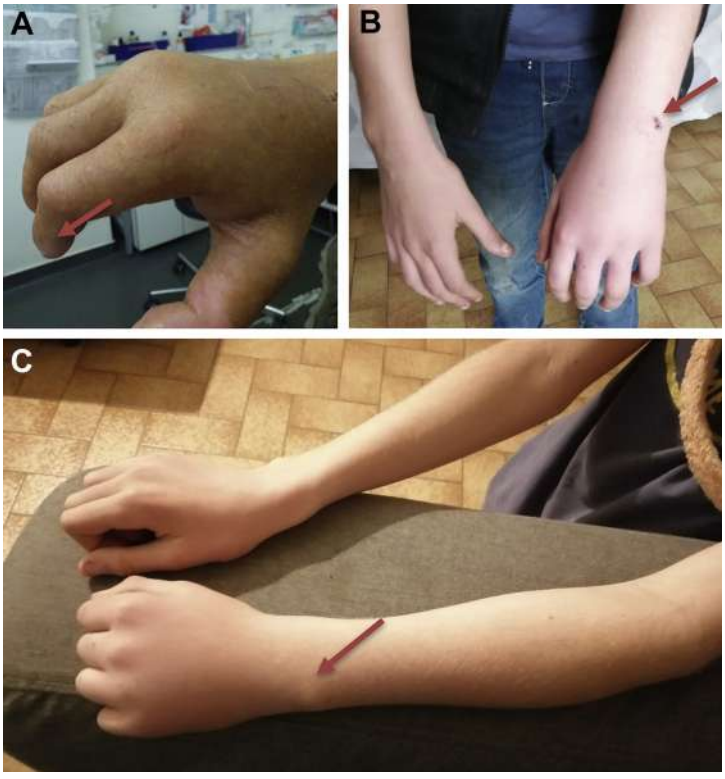

Figure 1. (A) Extension of swelling to the wrist (patient A). (B) Swelling of hand and wrist after 4 h and teeth marks indicated with arrow (patient B). (C) Extension of swelling to the forearm (patient B).

into the snake's mouth for unclear reasons. Both patients recovered completely.

These sporadic cases contrast with no reported cases of envenomation during a 10-y survey in which more than 1000 Montpellier snakes were handled. During fieldwork, 3 coauthors and coworkers (eg, students) estimated that in total there had been more than 100 bites (unreported). However, they all tended to ignore envenomation risks because they had no symptoms apart from minor pain.

We wish to emphasize that defensive bites inflicted on predators are very different from those involved in predation. To subdue their prey, Montpellier snakes hold their bite and inoculate their venom while swallowing; but during defensive strikes, they bite and rapidly release their grip to escape. The fact that the snakes maintained their bite and caused envenomation in the 2 cases reported here is puzzling. In an unsuccessful attempt to release the bite, both boys pulled the head of the snake, possibly triggering a reinforcement of the defensive bite. Whatever the case, the bite lasted more than 1 min in each instance, leaving plenty of time for the venom to penetrate through the skin.

Marked signs of envenomation recorded in inexperienced handling (2 adults and the 2 boys) contrast with the lack of symptoms in well-trained handlers who have been bitten many times. In the line of discussions regarding this issue, this may suggest a possible role of psychological factors, either aggravating and/or tempering the symptoms in inexperienced vs well-trained handlers, respectively.[8,9] Further exploration of underlying mechanisms for this difference is beyond the scope of this letter. Nevertheless, both current cases and previous reports show that envenomation caused by the Malpolon snake (*M monspessulanus*) should be taken seriously. Although this species is commonly considered harmless, it should not be handled by inexperienced people, and it is crucial not to mistreat or attempt to kill snakes because this triggers potentially dangerous defensive strikes.[10]

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References

1. Modahl CM, Mrinalini, Frietze S, Mackessy SP. Adaptive evolution of distinct prey-specific toxin genes in rear-fanged snake venom. *Proc Biol Sci*. 2018;285(1884):20181003.
2. Krecsák L, Zacher G, Malina T. Clinical picture of envenoming with the meadow viper (*Vipera* (Acridophaga) *ursinii*). *Clin Toxicol (Phila)*. 2011;49(1):13–20.
3. Kuch U, Mebs D. Envenomations by colubrid snakes in Africa, Europe, and the Middle East. *J Toxicol: Toxin Rev*. 2002;21(1–2):159–79.
4. Mirtschin PJ, Shine R, Nias TJ, Dunstan NL, Hough BJ, Mirtschin M. Influences on venom yield in Australian tiger snakes (*Notechis scutatus*) and brown snakes (*Pseudonaja textilis*: Elapidae, Serpentes). *Toxicon*. 2002;40(11):1581–92.
5. Carranza S, Arnold EN, Pleguezuelos JM. Phylogeny, biogeography, and evolution of two Mediterranean snakes, *Malpolon monspessulanus* and *Hemorrhois hippocrepis* (Squamata, Colubridae), using mtDNA sequences. *Mol Phylogenet Evol*. 2006;40(2):532–46.
6. Gonzalez D. Bissverletzungen durch *Malpolon monspessulanus* (Reptilia: Serpentes: Colubridae). *Salamandra*. 1979;15:266–8.
7. Pommier P, de Haro L. Envenomation by Montpellier snake (*Malpolon monspessulanus*) with cranial nerve disturbances. *Toxicon*. 2007;50(6):868–9.
8. Weinstein SA, Warrell DA, Keyler DE, eds. *Venomous Bites from Non-Venomous Snakes: A Critical Analysis of Risk and Management of "Colubrid" Snake Bites*. Philadelphia, PA: Elsevier, 2011.
9. Minton SA. Venomous bites by nonvenomous snakes: an annotated bibliography of colubrid envenomation. *J Wilderness Med*. 1990;1(2):119–27.
10. Whitaker PB, Shine R. Responses of free-ranging brown-snakes (*Pseudonaja textilis*: Elapidae) to encounters with humans. *Wild Res*. 1999;26(5):689–704.

Completing the Three Peaks Challenge as a Unilateral Transtibial Amputee

To the Editor:

A significant number of amputees are young and physically active. Many of these individuals wish to engage in mountain activities. Within the UK military alone, 132 people sustained an amputation within the 5-y period from April 1, 2015 to March 31, 2020.[1] However, there is currently a lack of evidence available over how safe practice in this environment can take place. We would like to describe our experience and contribute to this emerging knowledge base.

The Three Peaks Challenge (TPC) requires participants to hike to the summits of the 3 highest peaks in England (Scafell Pike, 978 m), Scotland (Ben Nevis, 1345 m), and Wales (Snowdon, 1085 m) within a 24-h period.[2] Hikers walk a horizontal distance of 37 km and ascend a height of 3064 m. The distance between the 3 mountains is 743 km and this is normally undertaken by vehicle.

The subject of this letter became a transtibial amputee in 2012 after standing on an improvised explosive device while deployed to Afghanistan with the British Army. This resulted in a traumatic amputation, and the subject was left with a short stump (11 cm in length) with minimal covering of muscle. This meant that there was a high risk of tissue damage following prolonged use. Careful consideration was therefore given to physical preparation, choice of prosthesis, and stump care in order to complete the TPC.

A high level of physical fitness is required for an amputee to complete mountain activities. It is estimated that transtibial amputees expend 20 to 40% more energy walking the same distance as those without amputation.[3] Preparation prior to the TPC was focused on strength exercises and weightlifting as well as several hikes of Scafell Pike and Snowdon in order to improve fitness and test equipment.

The prosthesis used was the Össur Cheetah Xplore (Figure 1). This is a lightweight waterproof prosthetic limb, made of carbon fiber, weighing 646 g. It had an

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References

1. Modahl CM, Mrinalini, Frietze S, Mackessy SP. Adaptive evolution of distinct prey-specific toxin genes in rear-fanged snake venom. *Proc Biol Sci*. 2018;285(1884):20181003.
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5. Carranza S, Arnold EN, Pleguezuelos JM. Phylogeny, biogeography, and evolution of two Mediterranean snakes, *Malpolon monspessulanus* and *Hemorrhois hippocrepis* (Squamata, Colubridae), using mtDNA sequences. *Mol Phylogenet Evol*. 2006;40(2):532–46.
6. Gonzalez D. Bissverletzungen durch *Malpolon monspessulanus* (Reptilia: Serpentes: Colubridae). *Salamandra*. 1979;15:266–8.
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The prosthesis used was the Össur Cheetah Xplore (Figure 1). This is a lightweight waterproof prosthetic limb, made of carbon fiber, weighing 646 g. It had an

Figure 1. Image to illustrate the Össur Cheetah Xplore prosthesis, with illustrated component parts.

operating temperature range of −10 and +40°C. Although a "running-blade" was available for this prosthesis, the full-length "foot" was chosen because it increased stability and therefore was more suitable for uneven surfaces. In addition, it enabled shoes and crampons to be worn. The heel component was specifically designed to aid shock absorption, offering further protection to the stump from compression forces.

To minimize the risk of mechanical failure, the prosthesis did not have a moving "ankle joint." Unfortunately, this meant that while walking on level ground, the amputee had to adopt a shorter stride and undertake more pronounced flexion of the knee and hip. This increased considerably when walking up or down a steep gradient and often proved tiring and uncomfortable.

The residual limb was attached to the prosthesis by pin socket. This had the benefit of being quick release but had the disadvantage of putting increased pressure on the point of the stump where the pin is placed, increasing the potential to cause stump soreness and skin breakdown. Although a suction socket spreads pressure evenly across the whole stump, it takes longer to position than a pin socket and is more likely to loosen and slip with fluctuations in stump size.

The liner provided the stump with a degree of protection. However, perspiration can accumulate and lead to the prosthesis slipping. This can compromise stability and increase the risk of skin damage.

The subject used 2 types of liner: a sports liner and a silicone day-liner. The latter provided good cushioning, but the impermeable nature of the material created a buildup of heat and moisture that caused slippage of the stump inside the socket and an increase in the risk of skin damage. The sports liner had laser drilled perforations that allowed egress of warm air and water. However, to allow for these perforations the fit was tighter, and the subject found that although he was stopping often to remove the day-liner to dry the stump, he also had to stop to remove the sports liner frequently to relieve the discomfort of compression.

Due to the need to regularly remove the prosthesis, the subject found that shorts were best worn over the lower limbs. Despite low ambient temperatures, this was not an issue on the TPC. This may be explained by the increased risk of hyperthermia experienced by amputees, since these individuals have a reduced body surface area and a much greater energy requirement than others.

As the temperature cooled, the residual limb reduced in size, and similarly as it warmed, it swelled. These size fluctuations were mitigated by taking spare liners and wearing them in duplicate or triplicate inside the socket.

With ice and snow on the higher parts of the mountains, walking poles were essential to improve stability and mitigate the loss of proprioception in the amputated limb. This was important as most of the walking was undertaken in the dark, and river crossings were common. The poles also enabled the offloading of bodyweight from the lower limbs and therefore helped reduce fatigue.

In conclusion, we identified 3 factors—physical fitness, choice of prosthesis, and stump care—that successfully enabled this amputee to complete the TPC. Future researchers may wish to focus their attention on these factors in order to ensure that amputees can further enjoy the mountains.

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References

1. GOV.UK. UK service personnel amputations: financial year 2019/2020. Available at: https://www.gov.uk/government/statistics/uk-service-personnel-amputations-financial-year-20192020. Accessed February 3, 2022.
2. Williams S, ed. *The National Three Peaks: Taking Up the Challenge*. 2nd ed. Northampton, UK: Discovery Walking Guides, 2012.
3. Seymour R, ed. *Prosthetics and Orthotics: Lower Limb and Spinal*. Philadelphia, PA: Lippincott, Williams and Wilkins, 2002.

Book Review

Mountain Emergency Medicine, 1st edition
Hermann Brugger, Ken Zafren, Luigi Festi, Peter Paal, Giacomo Strapazzon
Palm Beach Gardens, FL:
Edra Publishers, 2022
672 pages; hardcover $191 USD

Mountain Emergency Medicine (MEM) is ambitious and wide-ranging. The primary audience seems to be mountaineer physicians interested in mountain rescue, including those not trained in emergency medicine.

MEM is many things. It is an update and expansion of the International Commission for Alpine Rescue Medical Commission 2001 Consensus Guidelines on Mountain Emergency Medicine and Risk Reduction. It is a reference for the International Society of Mountain Medicine/International Commission for Alpine Rescue/International Climbing and Mountaineering Federation Diploma in Mountain Medicine courses. It is a comprehensive review of the current status of mountain emergency medicine. It provides some basic advice about adult education for training programs. It tells us how to design a very high-quality mountain rescue medical system. It relates heroic and instructive rescues in the Alps and the history of mountain rescue. It tells us what equipment we should carry for high-quality medical care during mountain rescue, although it does not teach us how to use this equipment.

MEM's primary focus is on field care, but 3 chapters are devoted to in-hospital care. These read like a core curriculum on trauma management for emergency medicine residencies. Except for diagrams showing the operative management of liver injuries, for the most part, it lacks detailed explanations or graphics of how to perform the procedures it recommends.

MEM is Euro-centric, Alps-centric, and mountaineering-expedition centric. The chapter Envenomation by Bites and Stings has to do not with mountains but with getting to mountains in low-income areas, where bites and stings are common and advanced medical care is hard to come by. It features an extended discussion of treating venomous snakebite via pressure band immobilization, but no mention that pressure bandages are not recommended, and many say absolutely contraindicated, for North American pit viper bites. One chapter states: "Because there is a risk of neurovascular injury, joint reductions (excluding the hip) should be attempted in the field only by experienced physicians." But in North America, we have long had wilderness EMT training, for which reduction of shoulder dislocations is a standard skill. Although there is a chapter on forensic medicine for deaths in the mountains, there is nothing on improvisation if you are in wild mountains with limited gear.

The 48 chapters read like independent highly-annotated review articles, with significant duplication. There are 3 separate reviews of scene safety and primary and secondary surveys, 3 of hypothermia management, 2 of helicopter operations, 2 of anaphylaxis, and 2 of Hannibal's crossing of the Alps in 218 BC. This independence also leads to conflicting recommendations. One chapter says: "The possibility of hypersalivation and laryngospasm and the increased numbers of victims needing intubation especially limit the use of ketamine in mountain or high altitude medicine." Another says: "Ketamine is a safe and effective sedative analgesic for remote environments." In 2 chapters, traction splints are recommended for femur fractures, but another says: "Traction can reduce pain and spasm by decompressing the broken bone fragments and increasing arterial blood flow, but the rescuer must first exclude hip or pelvic fractures, supracondylar fracture of the distal femur, knee fractures or fractures of the ankle or foot, which are strict contraindications. Due to these contraindications and to their bulkiness, these splints have largely been abandoned in mountain rescue."

There are errors of fact, such as: "Pre-hospital medical care began in urban areas in the 1980s, with the establishment of physician-staffed ambulances in Europe and paramedic-staffed ambulances in North America." Emergency medical services in North America began in 1967 with the Freedom House paramedic program in Pittsburgh, Pennsylvania.

MEM states: "In mountain areas, at least one helicopter with a mountain-rescue-competent crew should be dedicated to HEMS [Helicopter Emergency Medical Services] within a region.... The appropriate financial model of the organisation will depend on local conditions, but the model should not compromise safety or the basic principle that the service is for everyone according to medical and rescue need, regardless of nationality, insurance, or other influences." One hopes this does not mean that an underresourced country should reallocate scarce resources to provide such services primarily for visiting mountaineers. But many of MEM's authors work

in a collection of systems that *do* provide this sort of service in the Alps: an expensive, well-resourced system in a relatively-small mountain area. Therefore, you can get to a mountain casualty fast, and provide high-level emergency medical care, so that neurologically-intact survival is possible even after conditions such as cardiac arrest, including traumatic arrest. Such responses and results are the standard in the Alps, something that most other mountain ranges in North America and elsewhere can, at present, only aspire to.

Regardless of the rough spots, MEM provides a wealth of information; more importantly, it promotes intercontinental information exchange, and this North American mountain/cave rescue physician found portions of it fascinating. Especially in the mountains, we must often make our decisions based not on prospective, randomized, double-blind trials, but on anecdotes, case series, and expert opinion. This book provides many such expert opinions. Anyone involved in mountain emergency medicine or mountain emergency medical services—anywhere in the world—can learn quite a bit from it.

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WILDERNESS IMAGE

Welcome to the Hotel Termitaria: A Safe Place for Snakes

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There are 16 species of *Philodryas* snakes widely distributed in South America biomes.[1] *Philodryas* spp are non-front-fanged and have grooved posterior maxillary teeth and Duvernoy's venom glands.[2] Although bites by most species have not been well documented, a few species have caused medically significant envenomation. For example, there is evidence of mild erythema, pain, and widespread ecchymoses after *P olfersii* and *P patagoniensis* envenoming.[2,3] The experimental biological activities of some *Philodryas* venoms are similar to that of several pit vipers (eg, *Bothrops* spp).[3] For that reason, the effects of bites by *Philodryas* spp have occasionally been misdiagnosed by medical staff as *Bothrops*. Some patients presenting to Brazilian hospitals with confirmed *Philodryas* bites are incorrectly treated with antibothropic serum.[4] Currently, there is no specific antivenom medication for *Philodryas* envenomation.

Figure 1. Adult specimen of *Philodryas nattereri* inside a termitarium photographed in February in the National Park of Brasilia, Brazil (15°44'20.93"S, 47°55'33.74"O). Photo: M. de-Carvalho

Figure 2. Details of *Philodryas nattereri* in alert using a termitarium as shelter, photographed in February in the National Park of Brasilia, Brazil (15°44'20.93"S, 47°55'33.74"O). Photo: M. de-Carvalho

These images were taken while trekking 2 d after a fire event, on a sunny day in February in the National Park of Brasilia, Brazil (15°44'20.93"S, 47°55'33.74"O), a park highly frequented by tourists. At 1300, we observed an alert Paraguayan green racer *Philodryas nattereri* (Figure 1) with its body, except for the head, inside a termitarium (Figure 2). In the Brazilian savanna biome, temperatures vary greatly within a single day (differences of up to 50°C have been recorded), and interestingly, fire events are part of the ecological dynamics. Behavioral information about neotropical snakes is scarce, but we know that species that live in regions with direct sunlight and little vegetation cover need some physiological and/or behavioral adaptations to survive in hostile conditions. Termitaria can be a safe place for neotropical snakes, offering camouflage and protection from the heat.

References

1. Nogueira CC, Argôlo AJ, Arzamendia V, Azevedo JA, Barbo FE, Bérnils RS, et al. Atlas of Brazilian snakes: verified point-locality

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maps to mitigate the Wallacean shortfall in a megadiverse snake fauna. *S Am J Herpetol*. 2019;14(sp1):1–274.

2. Weinstein S. Non-front-fanged colubroid snakes. In: Brent J, Burkhart K, Dargan P, et al. eds. *Critical Care Toxicology: Diagnosis and Management of the Critically Poisoned Patient*. 2nd ed. Switzerland, AG: Springer Nature; 2017:2453–92.
3. Barbosa VDN, Amaral JMDS, Alves ÁAA, França FGR. A new case of envenomation by *neotropical opisthoglyphous snake Philodryas olfersii* (Lichtenstein, 1823) in Recife, State of Pernambuco, Brazil. *Rev Soc Bras Med Trop*. 2020;53: e20200151.
4. Correia JM, Santana Neto PDL, Pinho MSS, Silva JAD, Amorim MLP, Escobar JAC. Poisoning due to *Philodryas olfersii* (Lichtenstein, 1823) attended at Restauração Hospital in Recife, State of Pernambuco, Brazil: case report. *Rev Soc Bras Med Trop*. 2010;43(3):336–8.

WILDERNESS & ENVIRONMENTAL MEDICINE 2022; 33(2): 261–2

WILDERNESS IMAGE

The Bengal Tiger

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The Bengal tiger (*Panthera tigris tigris*) is one of the big cat species, found in the jungles of India, Nepal, Bhutan, Burma, Bangladesh, and the adjoining countries of Indian subcontinent. These muscular and gorgeous looking mammals are ferocious killers with powerful forequarters, with a length of 2.2 m to 3.0 m when fully grown and

A pair of Bengal tigers (*Panthera tigris tigris*) at Kanha National Park, Madhya Pradesh, India. Photo by Subho Bandyopadhyay.

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weigh more than 300 kg.[1] Tigers have a lifespan of 8 to 10 y in the wild; however, the life span increases up to 20 y in captivity. In 2010 there were merely 3200 wild tigers around the world, which was the lowest estimate of the century.[2] During the 2010 St Petersburg declaration on tiger conservation, the 13 countries where the last remaining tiger species are found made a commitment to double the population by 2022.[2] Nepal achieved this target in 2018 with an estimated 235 wild tigers, which was 121 in 2009.[3] There are stringent laws protecting these tigers; however, there are reports of poaching.[4] This animal is the target of poachers, who kill it for lucrative trade where the animal parts and hides are used as a souvenir item or a cure in indigenous medicine.[4] These terrestrial animals are apex predators and hunt other wild animals in a wide territory; however, when weak and frail, they target domesticated animals inside human settlements and sometimes also humans.[5] Therefore, they are infamously called "man-eaters" by the people who live near the wildlife conservation areas. The above picture was taken on February 2021, at Kanha National Park, Madhya Pradesh, India, 22.3345° N, 80.6115° E with a Nikon D610 camera using a 150–600 mm f/5–6.3 lens.

References

1. Kanchan T, Shekhawat RS, Shetty BSK, Jayaram L, Meshram VP. Fatal captive tiger attack – A case report with review of literature. *J Forensic Leg Med*. 2021;78:102100.
2. The St. Petersburg Declaration on Tiger Conservation. Global tiger initiative. Available at: https://www.iucn.org/sites/dev/files/import/downloads/st_petersburg_declaration_english.pdf. Accessed February 13, 2022.
3. World Wide Fund For Nature. Nepal set to become first country to double wild tiger population. Available at: https://wwf.panda.org/wwf_news/press_releases/?335210/Nepal-set-to-become-first-country-to-double–wild-tiger-population. Accessed February 13, 2022.
4. Kapoor C. Tiger poaching multiplies in India during lockdown. Anadolu Agency. Available at: https://www.aa.com.tr/en/asia-pacific/tiger-poaching-multiplies-in-india-during-lockdown/1924833. Accessed February 13, 2022.
5. Atreya A, Timalsina A, Nepal S. Human sufferings in human-tiger conflict: Nepalese perspective. *Asia Pac J Public Health*. 2021;33(5):689.

ERRATUM

Corrigendum to Wilderness Medical Society Clinical Practice Guidelines on Anaphylaxis {*Wilderness & Environmental Medicine* Volume 33, Issue 1, March 2022, Pages 75-91}

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An error appeared in the above-referenced article on page 84, under the Epinephrine section, Dosage subsection, in the third paragraph below Table 8.

The original text (error underlined) was:

"Alternatively, 0.1 mg of epinephrine may be added to 10 mL of normal saline, producing a concentration of 0.1 mg·mL^{-1}…"

The corrected text (corrected text underlined) is:

"Alternatively, 1 mg of epinephrine may be added to 10 mL of normal saline, producing a concentration of 0.1 mg·mL^{-1} ..."

The computations found in the paper are correct.

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