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EDITOR'S NOTE

Traditions and Transitions in Science Journal Editing

This will be my last missive as editor-in-chief of this journal. Transitions are challenging, but they also provide opportunity to reflect on what works and what might benefit from further consideration. I have generally chosen to focus the opening editorials not on the specific contents of the journal issue, but on current events and practice topics. The goal, with variable degrees of success, was to use this space to encourage thoughts on best practice regarding research publication. I will focus this piece on some of the less codified practices that have been followed during my tenure.

Requests for multiple "first author" credits are occasionally received, but they have not been accepted. The most extreme example was a recent submission that included a request for all six co-authors to be acknowledged as "first authors." The fundamental problem is that such requests go against convention and are probably not meaningful in any case. The relative weight of first, second, senior, and corresponding author credit is generally accepted, even if the actual contribution of each individual is unknown. There is no mechanism for acknowledging different patterns of credit in the standard search engines, and unusual claims will often carry little or no weight. Evaluating merit is challenging, and certainly beyond the reasonable expectations of editors, which puts it back into the hands of the author panel to work out. Part of the struggle of professional development is learning and earning one's way through various authorship positions.

This journal operates in a single-blind manner, with reviewers having the option to identify themselves if desired. I respect those who choose to identify themselves as a matter of course, but I am also happy to leave the choice to reviewers. There can be a range of motivations to opt for anonymity, including anxiety over future professional conflicts or interactions made personal. My primary concern has been that all reviews are respectful and constructive, effectively written as though the reviewer would be known in a fully open design. There are questions, though, as to whether the presence of author and institution names might bias the review process, in either a positive or negative manner. There are challenges in both assessment and implementation that make these difficult questions to address, but it is certainly worth consideration of the available research to decide whether the relative merits and pitfalls of any approach make changes worth testing or implementing for a niche journal such as WEM.

Norms in scientific publishing include documentation of research ethics approval and, where relevant, clinical trials registration. While these elements are undoubtedly desirable, decisions have to be made when submissions are received that do not comply with these norms. The simplest position is to call these absolute requirements, but this can bring its own bias. Some investigators, particularly those working outside of the western world, may follow credible but different research standards. Blanket disqualification may be counterproductive in restricting potential content and in discouraging scholarship. The journal practice has been to consider noncompliant reports on a case-by-case basis, with feedback provided through the review process intended to aid standardization of future efforts. The options and implications deserve ongoing consideration.

Questions arise on a regular basis as to how much curation is required for a healthy journal. Those with small submission numbers may benefit most from planned content. Efforts to curate likely become less important when a critical mass of unsolicited submissions becomes the norm. WEM approaches 300 original submission each year, and even with an overall accept rate less than 40% in recent years this provides a substantial base. It will remain important to look for knowledge gaps that researchers and authors can be encouraged to address, but this cannot compromise review standards. Essentially, the fact that an article or review may be encouraged or invited should not have any bearing on the evaluation of the submitted work. Substandard submissions, regardless of the interest in the topic, should be rejected if sufficient improvement cannot be achieved through reasonable revision. The journal practice has been to encourage almost all submissions, but expressly with no promises regarding the ultimate disposition. Plans and intent are unimportant. The final product must pass or fail on its own merits.

The question of arbitrary rejection rates also comes up intermittently. Some may feel that specific article types, for example, case reports, should be arbitrarily capped.

The fatal flaw in this, though, is the lack of knowledge of what will come in next. There is no way to compare the quality of what is in hand with what may or may not be submitted in the future. The only rational approach is a critical and objective evaluation of each submission in real time. The bar for acceptance should inexorably rise as the authority of a journal grows (usually reflected in a rising number and quality of submissions), but there is no comfortable way to arbitrarily apply caps.

Journals approach final disposition decisions differently. Some offer diffuse authority, with section or associate editors able to make final decisions. While this approach can reduce the workload of the editor-in-chief, it also makes it more difficult to maintain a uniform set of standards. While great weight should be given to the recommendations of proven subject matter experts, a critical top-level evaluation of all manuscripts, reviews, and recommendations can be very important to ensure continuity in the final product.

Editorial boards are important to concentrate and capitalize on skill, expertise, and institutional memory. Arbitrary limits on duration of service are counterproductive to the great service that can be provided by the panels. The only factor that should be considered for term of service is ongoing effort. Members should indeed step down, with or without encouragement, if interest and contributions wane, but those with ongoing commitment and high value service should continue without restriction.

Research journals should stand as credible repositories of objective scientific endeavor. They are expected to reflect evolving social and practice standards that can affect research efforts and analyzes. There is no simple solution to avoiding minefields, but the best protection is likely to remain in objectivity. It is the process of research that is important, not the outcome. If the process is clear, meaningful, and appropriate, and the interpretations objective and valid, the direction of the outcome should not be a factor in decision-making. The goal for a credible journal is to publish the work worthy of being published, regardless of the directions of the findings.

As my tenure draws to a close, I am pleased to announce that William D. Binder, MD has been appointed as the new editor-in-chief of WEM. Dr. Binder holds a bachelor of arts degree in European history from the University of Pennsylvania, a master of arts degree in the history of science from Harvard University, and a medical degree from George Washington University. He completed board certifications in internal medicine and emergency medicine. He holds an academic appointment as an associate professor of emergency medicine at Brown University and has served as editor-in-chief of the *Rhode Island Medical Journal* since 2018. Welcome aboard.

Neal W. Pollock, PhD
Emeritus Editor-in-Chief

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ORIGINAL RESEARCH

Gender Distribution Associated With the Journal *Wilderness & Environmental Medicine*

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Introduction—Publication and peer review are fundamental to career advancement in science and academic medicine. Studies demonstrate that women are underrepresented in science publishing. We evaluated the gender distribution of contributors to *Wilderness & Environmental Medicine* (*WEM*) from 2010 through 2019.

Methods—We extracted author data from ScienceDirect, reviewer data from the *WEM* Editorial Manager database, and editorial board data from journal records. Gender (female and male) was classified using automated probability-based assessment with Genderize.io software.

Results—A total of 2297 unique authors were published over the 10-y span, generating 3613 authorships, of which gender was classified for 96% (n=3480). Women represented 26% (n=572) of all authors, which breaks down to 22% of all, 19% of first, 28% of second, and 18% of last authorships. Women represented 20% of peer reviewers (508/2517), 20% of reviewers-in-training (19/72), and 16% of editorial board members (7/45). The proportion of female authors, first authors, and reviewers increased over time. Women received fewer invitations per reviewer than men (mean 2.1 [95% CI 2.0-2.3] vs 2.4 [95% CI 2.3-2.5]; P=0.004), accepted reviews at similar rates (mean 73 vs 71%; P=0.214), and returned reviews 1.4 d later (mean 10.4 [CI 9.5-11.3] vs 9.0 d [95% CI 8.5-9.6]; P=0.005).

Conclusions—While female representation increased over the study period, women comprise a minority of *WEM* authors, peer reviewers, and editorial board members. Gender equity could be improved by identifying and eliminating barriers to participation, addressing any potential bias in review processes, implementing strategies to increase female-authored submissions, and increasing mentorship and training.

Keywords: authorship, bias, publication, science, women, peer review

Introduction

Publication and peer review are fundamental to professional service and to career advancement in science and academic medicine. Publication is an important criterion for tenure and promotion.[1] Excellence in peer reviewing can lead to achievement awards and invitations to join editorial boards. Journal editors are often recruited from editorial boards. Active engagement in these activities confers rank, status, and influence, and factor into many measures of academic success.

Studies have shown that women are underrepresented across all roles in science publishing. Although the proportion of first and/or senior female authors among several prominent medical journals has increased from 6% in 1970 to 29% in 2004, women still comprised a minority of authors.[2] A similar disparity has been observed among specialty journals.[3-6]

Women are also underrepresented as peer reviewers and editors of medical journals,[3,5-9] and receive fewer peer review invitations.[10] The National Academy of Sciences,

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the *Lancet* journals, and other specialty journals have all called for improved representation of women on editorial boards, but disparities remain.[11-13]

Gender disparities can be detrimental in several ways. Underrepresentation can result in the perpetuation of gender bias. In addition, a lack of visible role models may discourage early career women.[14] Beyond the positive effect on women's careers, gender diversity in scientific organizations can improve the breadth, quality, and perspective in science,[15] and lack of diversity can stifle innovation.[16,17] Some work suggests that having more female authors increases the number of female study participants,[18] and lack of inclusion of female participants in sport and environmental science studies is a documented concern.[19] Identifying and addressing gender gaps is key for both individual advancement and the advancement of science and medicine.

Our goal was to evaluate the gender distribution of authors, peer reviewers, and editorial board members associated with the Wilderness Medical Society's (WMS) peer-reviewed journal, *Wilderness & Environmental Medicine* (*WEM*), in order to provide an empirical reference for discussions on gender equity and a baseline for future efforts to address this issue.

Methods

This work was a retrospective review of *WEM* contributors and supporters. Author and reviewer names were published in the journal (the latter in an annual recognition list) and were therefore publicly available. As such, this effort was not subject to research ethics oversight.

Author names were extracted as public domain information from a complete list of publications and authors appearing in *WEM* from 2010 through 2019, accessed through Science Direct (https://www.sciencedirect.com). Author names were extracted from lists using the Python 3.9.1 string split method (https://www.python.org; version release December 7, 2020). Individual author names were extracted from author lists for each article, using commas as the delimiter. We then identified first and last names using the first and last white spaces within each individual author name as delimiters. If any additional author names remained, we designated them as middle names. We reviewed the results manually to identify modifiers that could not be analyzed, for example, titles such as "Capt." or suffixes such as "Junior," which the white space delimiter method erroneously identified as first or last names. We updated these names manually to exclude unnecessary modifiers.

We entered the first names of authors and reviewers into Genderize.io (http://genderdize.io) to determine the probability of gender identity.[20] The software classified gender as male, female, or unknown, along with the probability of correct classification. There were insufficient data to classify nonbinary or nongender conforming individuals. We manually reviewed names classified as unknown and those with a gender probability estimate of $P<0.90$ and categorized them accordingly if the self-identified gender pronouns of the individual were known or if preferred pronouns could be determined through institutional profiles, LinkedIn, or ResearchGate. We classified gender as unknown if we were unable to determine preferred pronouns.

The total number of authors and authorships and the total first, second, and last authorships were collated by gender and article type. Authors with sole credit on an article were counted only as first authors. Articles were categorized as original research full, original research brief, review, case report, clinical practice guidelines, concepts, lessons from history, wilderness instructor, wilderness essay, editorial, letter to the editor, editor's notes, clinical image, wilderness image, or book review. Errata and meeting abstracts without full papers were excluded.

The names of all individuals reviewing manuscripts from 2010 through 2019 were accessed from the *WEM* Editorial Manager database, the system that tracks the submission and peer review processes for the journal. Reviewer first names were classified in the same way as the author names. Metrics for aggregate female and male groups over the 10-y study period included the number of reviewer invitations received; the number of reviews declined, accepted, and completed; the time to return completed reviews; and status as editorial board members or reviewers-in-training.

Data are reported as counts, percentages, and means, with 95% confidence intervals (CI). We used two-tailed Cochrane- Armitage trend tests (SAS v9.4, SAS Institute, Cary, NC) to evaluate gender patterns in authorship and reviewers over time. We compared gender differences in mean rates of invitation to review and time to complete reviews using unpaired t-tests, and proportions of accepted invitations and completed invitations using Chi-square tests (VassarStats; http://vassarstats.net). The significance for all statistical tests was accepted at $P<0.05$.

Results

Over the 10-y time span, 2297 unique authors were published in *WEM*, which totaled 3613 authorships. Of these, we were able to classify gender in 3480 (96%)

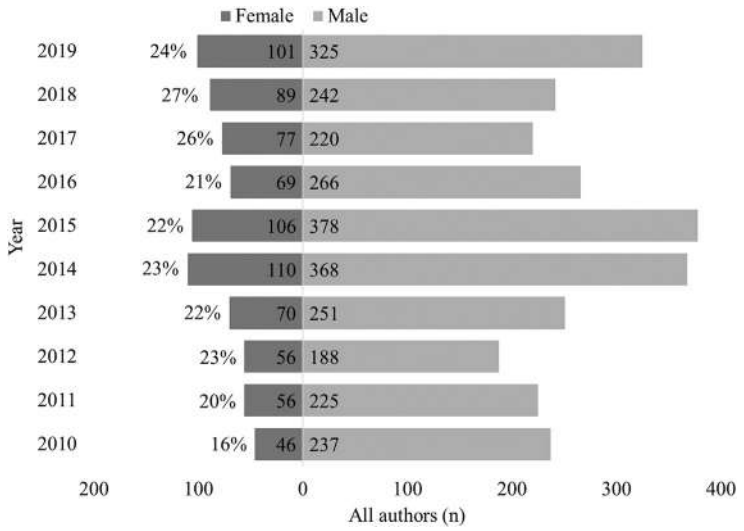

Figure 1. Total number of *WEM* authors categorized by gender between 2010 and 2019. Absolute counts are within bars. The annual percentage of women represented is located on the left of the female bars. The unknown gender cases are not shown.

cases. Gender remained unclassified in 133 (4%) cases. Of the unique authors, we classified 95% (2182), including 26% as female (n=572) and 74% as male (n=1610). For authorships with gender classified, women constituted 22% (780/3480) of all authors (ranging from 16-27% annually; Figure 1). Of these, 19% (179/966) were first authors (ranging from 12-23% annually; Figure 2), 28% (161/571) were second authors (ranging from 13-39% annually; Figure 3), and 18% (135/734) were last authors (ranging from 10-31% annually; Figure 4). The percentage of all female authors increased over time (P=0.0045), ranging from 16 to 27% annually, as did the proportion of first female authors (P=0.0428), ranging from 12 to 23% annually. The proportion of women as second authors and last authors did not change over the study period (P=0.0542 and P=0.6446, respectively).

The gender distribution of first authors by publication type is summarized in Table 1. Female first authorship was highest for concepts articles and brief research reports and lowest for book reviews and editorials.

During the study period, the database contained 2469 reviewers. Each of these were classified as female or male, with no unknown classifications. Table 2 summarizes reviewer characteristics. Figure 5 shows gender distribution of reviewers over time. The proportion of female reviewers increased over the 10-y study period (P<0.0001), with the annual range varying from 9 to 22% (Figure 5). The mean rate of invitations per reviewer was lower for women (mean difference=0.3 invitations, P=0.004), but there were no differences in the proportions accepted (P=0.214) or completed (P=0.597). Women took approximately 1.4 d longer to return reviews (P=0.005).

The *WEM* editorial board had a total of 45 members serving varying terms over the study period, 16% (n=7) of whom were women and 84% (n=38) who were men. The editorial board at the end of 2020 as listed on the masthead had 23 positions, which included 20 members, of which 20% (n=4) were women and 80% (n=16) were men. Three of the men held two separate positions each. There were 5 editors emeritus listed on the journal masthead, all men.

Discussion

The data presented here provide a 10-y snapshot of gender distribution associated with *WEM* journal activities. Women make up a minority of authors, peer reviewers, and editorial board members. The number of female authors doubled from 2010 to 2019, and was greater than the increase in number of male authors.

The percentage of female authors in 2019 (24%) was slightly lower than the percentage of female WMS members in 2020 (28%).[21] WMS membership is an imperfect benchmark, however, because it is not a prerequisite for publishing in *WEM*. Data are lacking on the number of women practicing wilderness medicine and/or conducting wilderness medicine research. It is also not clear whether women or men publish wilderness medicine research more or less often in journals other than *WEM*.

It is encouraging that the categories of articles where women have the highest representation include research

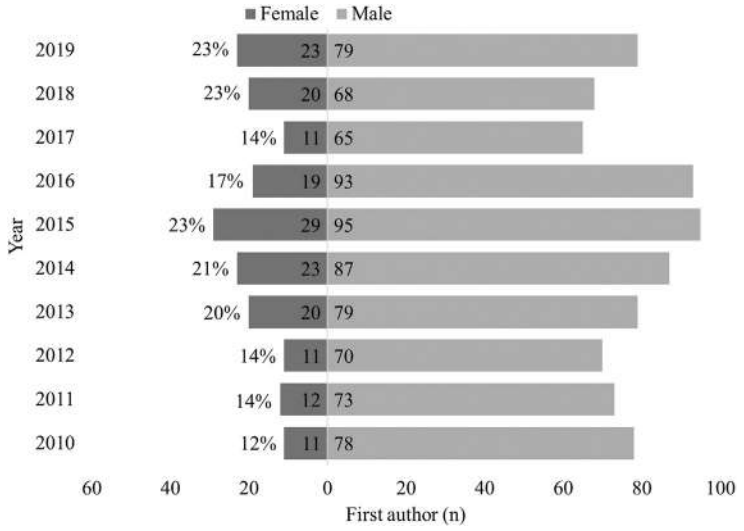

Figure 2. First authors of *WEM* publications categorized by gender between 2010 and 2019. Absolute counts are within bars. The annual percentage of women represented is located on the left of the female bars. The unknown gender cases are not shown.

and concepts articles, publications that actively advance the field of wilderness medicine. Women are underrepresented as editorial authors. However, invited editorials are relatively rare in *WEM*, providing only 2% of all first authorships. The vast majority of all submissions received by the journal are unsolicited. Efforts to seek a broad array of voices and increasing the number of invited works could be one way to include more women in the journal.

We found that the category with the fewest female authors was first authors of letters to the editor, which had approximately half the number of female first authors as did the category of original research. The reasons for this are unclear. We did not break down this category by types of letters (eg, research, comment, or response). It may be that women are less likely to submit letters in response to the work of others as is seen in letters to lay press,[22] and they may be more likely to decline to respond to letters than male authors. Because there are small numbers of senior women in wilderness medicine, as evidenced by low numbers of female senior authors, it is possible that women who have senior positions in

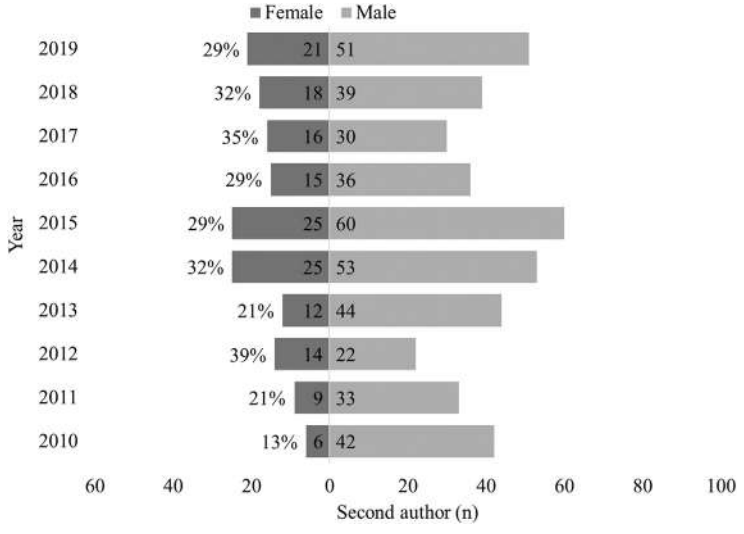

Figure 3. Second authors of *WEM* publications categorized by gender between 2010 and 2019. Absolute counts are within bars. The annual percentage of women represented is located on the left of the female bars. The unknown gender cases are not shown.

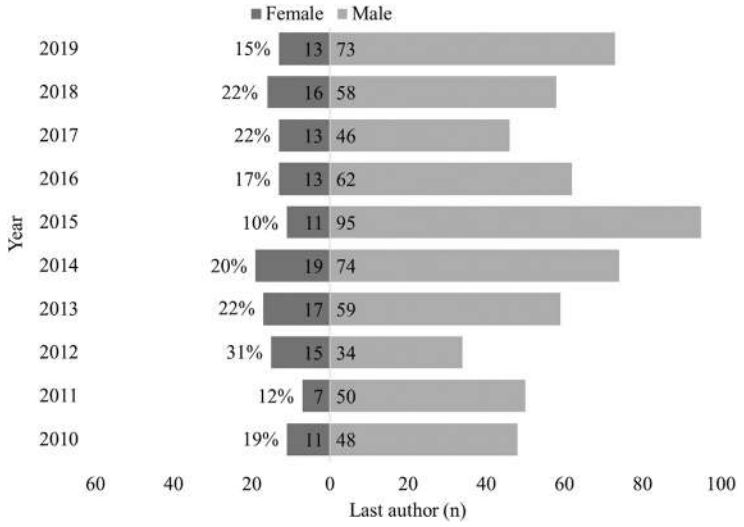

Figure 4. Last authors of *WEM* publications categorized by gender between 2010 and 2019. Absolute counts are within bars. The annual percentage of women represented is located on the left of the female bars. The unknown gender cases are not shown.

wilderness medicine may have too many requests and demands on their time to take on lower priority publications such as letters to the editor.

One noteworthy inequity is the low rate of female first authorship in clinical practice guidelines (15%). These guidelines tend to be high-profile documents, and underrepresentation in this type of work can have substantial implications for recognition, professional exposure, and opportunity. Future working groups for these projects should make an effort to include female experts.

Although female reviewers remain in the minority, female representation increased over the study period. There were no other meaningful differences in reviewer metrics. Women received fewer invitations to review, but the mean difference of 0.3 per reviewer is not practically important. Similarly, although women took longer to return reviews, the mean difference of 1.4 d has minimal practical importance, and the average of 10.4 d falls within the required deadline to return reviews. We did not evaluate the content or quality of individual reviews as part of the current work.

The composition of the *WEM* editorial board showed the greatest disparity, with women holding 17% of the positions over the period studied. Several studies of peer-reviewed journals have shown similar patterns. In a recent study of 410 leading medical journals across specialties, women comprised 21% of all editors-in-chief.[9] A similar review of the editorial board composition for the 60 leading medical journals found that 18% of editorial board members were women.[23] The lowest female representation for medical specialty editorial review boards was found in critical care (7%), and the highest was seen in internal medicine (37%).[23] Emergency and family medicine are the most commonly represented medical specialties in the WMS. Among journals from those fields, women make up 16 to 17% of emergency medicine journal editorial board members and 35% of family medicine journal editorial boards.[24-26]

Table 1. Gender distribution of first authorship by publication type in *WEM*, 2010–2019

Article Type	*Female, n (%)*	*Male, n (%)*	*Total known, n*	*Unknown, n*
Original Research	48 (24)	150 (76)	198	14
Brief Research	31 (25)	94 (75)	125	1
Reviews	7 (20)	28 (80)	35	0
Case Reports	33 (24)	106 (76)	139	1
Clinical Practice Guidelines	5 (15)	28 (85)	33	0
Concepts	8 (29)	20 (71)	28	0
Lessons from History	1 (7)	13 (93)	14	0
Wilderness Instructor	5 (24)	16 (76)	21	0
Wilderness Essays	4 (24)	13 (76)	17	0
Editorials	1 (5)	20 (95)	21	0
Letters to the Editor	23 (11)	184 (89)	207	1
Wilderness Images	7 (16)	36 (84)	43	0
Clinical Images	3 (11)	25 (89)	28	0
Book Reviews	1 (4)	22 (96)	23	0
Editor's Notes	2 (6)	32 (94)	34	0
Total	179 (19)	787 (81)	966	17

Table 2. WEM reviewer characteristics (2010–2019)

	Female	*Male*	*Total*
Reviewers, n (%)	508 (20)	2009 (80)	2517
Reviewers in training,[a] n (%)	19 (20)	53 (80)	72
Invitations to review	1074 (18)	4812 (82)	5886
Invitations per reviewer, mean (95% CI)	2.1 (2.0-2.3)[b]	2.4 (2.3-2.5)[b]	2.3 (2.2-2.4)
Accepted invitations	777 (73)[c]	3387 (71)[c]	4164
Completed reviews	744 (69)[c]	3291 (69)[c]	4031
Days to complete, mean (95% CI)	10.4 (9.5-11.6)[b]	9.0 (8.6-9.6)[b]	9.3 (8.9-9.7)

[a]Data from 2016 (when program began) through 2019.
[b]$P<0.05$.
[c]Difference is not significant.

Although determination of gender parity targets may not be straightforward, other journals have demonstrated that concerted efforts can improve gender balance. The *Lancet* journals committed to gender parity in 2018 following an internal review that showed an approximate 30% female representation on the editorial boards. The editorial boards of 4 journals in the group—*The Lancet Diabetes & Endocrinology, The Lancet HIV, The Lancet Infectious Disease,* and *The Lancet Oncology*—achieved 50% or more female membership as part of the #Lancetwomen project by early 2019.[12]

The root causes of the imbalance in participation in academic science are multifaceted, with origins as early as childhood or middle school.[27,28] Numerous strategies are needed to promote gender equity. A critical effort should be directed at establishing or strengthening mentorship and training pipelines.[29] The *WEM* reviewer-in-training program was established to encourage physicians interested in wilderness medicine and scientific publication by providing them with direct mentorship to help them develop their reviewing and writing abilities. Participation in this program approximates journal authorship and reviewer gender patterns, but additional targeted promotions could be used as part of an effort to attract underrepresented groups.

Work in other fields of medicine suggests that low representation of women is not solely due to a lack of qualified women, but rather that it is also due to institutional and noninstitutional barriers for female researchers.[2,30] Targeted efforts to remove barriers to gender parity are warranted. For example, journal procedures and materials should be evaluated to minimize the possibility for overt or unconscious bias. Some journals have shifted from the more common single-blind review process (the authors alone are blinded) to a double-blind review (both the authors and reviewers are blinded), and even a

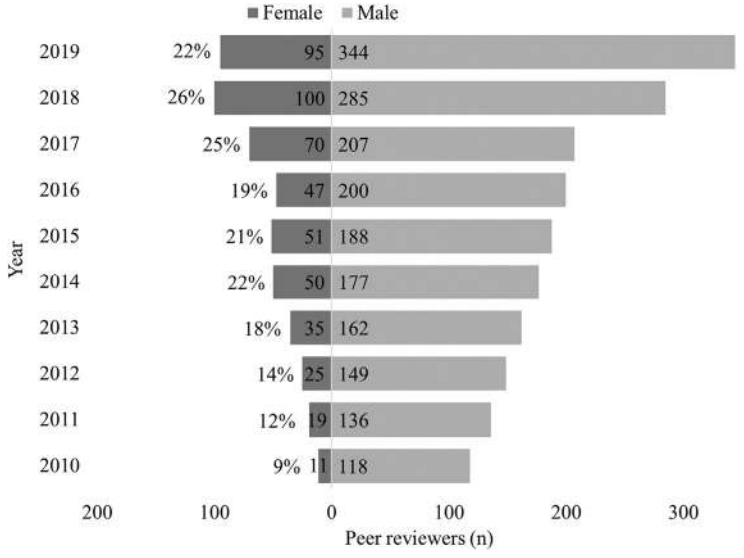

Figure 5. Peer reviewers of *WEM* categorized by gender between 2010 and 2019. Absolute counts are within bars. The annual percentage of women represented is located on the left of the female bars.

triple-blind process (the authors, reviewers, and editors are blinded). However, such changes have had mixed effects.[31,32] Other journals have used double-blinding as a strategy to achieve gender ratio parity in submissions and acceptances.[33] Information on the gender distribution of *WEM* submitters was not available for this study, but we encourage the consideration of strategies to promote equity. Improving the diversity of the reviewer pool may also help to address potential bias.

Limitations

This work has several limitations. It was restricted to the assignment of male and female gender groups; we did not attempt to identify nonbinary identifying individuals owing to the nature of the automated tool we employed. It is also possible that some of the gender classifications were incorrect. The automated tool that we used relied on statistical likelihoods based on self-reporting in scraped social media websites and combined localized data from global sources, rendering some individual names (eg, Jan and Kim) potentially more likely to be misclassified. Prospective efforts should collect this demographic information directly from contributors because self-identification is most likely to reflect individuals' gender identities. We did not evaluate individual manuscript submissions or reviews, making it impossible to comment on any potential quality differences or handling/disposition biases. We were also unable to confirm the relative contributions of any author, which can vary regardless of the authorship order. We only evaluated the authorship of accepted and published papers, not those that were withdrawn or rejected. Finally, we evaluated gender distribution but recognize that there are other underrepresented groups that may face publication barriers in wilderness medicine that we have not addressed in this study.

Conclusions

Our data are intended to promote discussion and to work toward the goal of gender equity in wilderness medicine. Although women's representation increased in some areas over the study period, women continue to comprise a minority of *WEM* authors, peer reviewers, and editorial board members. Although women's participation in *WEM* activities was broadly consistent with WMS membership gender distribution, there is marked underrepresentation compared with medicine and society as a whole.

Gender equity could be improved by identifying and eliminating barriers to participation, addressing any potential bias in review processes, implementing strategies to increase female-authored submissions, and increasing mentorship and training. Improvements in gender equity will require effort across all levels of the journal and the WMS in addition to monitoring to measure progress. The result of these efforts can strengthen the field of wilderness medicine and its influence as a medical specialty.

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Author Contributions: Study concept and design (LK, NWP, SS); data acquisition (AB, NWP, ABB, NEP, LK); data analysis (NWP, LK, SS, NEP, ABB); drafting, critical revision, and approval of the final manuscript (all authors).

Disclosures: Linda E. Keyes is past president of the WMS, Neal W. Pollock was editor-in-chief of WEM at the time of writing, and Alicia Byrne is managing editor of WEM. No authors were involved in the process of peer review or the editorial process of this manuscript.

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ORIGINAL RESEARCH

Gender Equity in Membership, Leadership, and Award Recognition in the Wilderness Medical Society

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Introduction—Despite near gender parity for women entering medical careers, women remain underrepresented in medical societies. This study evaluated the gender distribution associated with Wilderness Medical Society (WMS) activities.

Methods—A retrospective review was performed on the gender breakdown of the following WMS members: a single-day 2020 snapshot, conference attendees 2012 through 2020, conference presenters from winter 2017 through winter 2021, and leadership and awards data from 1984 through 2021. Genderize.io was used to generate probability-based gender categorizations (male/female) based on first names or pronoun associations.

Results—Gender was assigned in 91% (4043/4461) of 2020 WMS members, 92% (6179/6720) of 2012-2020 conference attendees, and 100% of remaining categories. Women represented 28% (1143/4043) of members, 27% (1679/6179) of conference attendees, 31% (143/465) of all conference presenters, 20% (62/303) of mainstage presenters, 23% (17/75) of all board members, 38% (14/37) of committee chairs, and 10% (2/20) of board presidents. Women received 18% (42/228) of recognition awards and 31% (15/48) of research grants issued.

Conclusions—Although women comprise a minority of WMS participants, gender distribution was similar across categories for membership, conference presenters, total board positions, and research grant awards. Relative underrepresentation was seen in the highest leadership levels, in recognition awards, and in mainstage presenters. Ongoing auditing may help to identify and address sources of bias and/or barriers to participation. Although it is only one of many components of equity, identifying successes and future opportunities for gender balance can strengthen the base of the WMS, promote growth, and ensure a strong leadership pipeline.

Keywords: bias, leadership, sexism, female, medical societies, awards

Introduction

Women make up approximately half of all medical students in the United States. However, female physicians constitute only 38% of full-time medical school faculty, 21% of full professors, 15% of department chairs, and 16% of deans.[1] A review of the 43 largest and most influential medical societies from 2008-2017 found that the medical society presidential leadership position was held predominantly by men, with only 17% of the president positions filled by women.[2] The same study found that women were particularly underrepresented among society presidents compared with active female physicians, and that 10 specialty societies had no female presidents over a 10-y time period.[2] Despite a growing number of female biomedical faculty, women continue to be less likely than men to advance in academic careers, to serve in leadership positions, or to receive awards in academic medical institutions and across biomedical professional societies.[1,3] A closer look at prize winners in

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the biomedical sciences suggests that women are underrepresented in the most prestigious and higher monetary awards in the top US biomedical societies, and that when women do receive prizes, they are over-represented in less prestigious awards such as service, advocacy, and education.[4]

Gender inequities in medical societies have individual and societal consequences. Participation and recognition in medical societies can impact career trajectory and influence promotion, mentorship, and leadership opportunities.[2,5] The benefits in innovation and productivity from having more women involved in leadership, research, and decision-making have been well documented.[5,6] Within the field of wilderness medicine, trips with gender-balanced leadership were associated with fewer participant injuries.[7]

Identifying imbalances in gender representation is one of the first steps to addressing inequities. Many societies are starting to promote awareness of explicit and implicit bias with "gender report cards" to track gender representation at multiple levels.[8] By assessing, reporting, and responding to gender inequities, academic societies provide transparency and can progress toward gender equity.[9] In the Wilderness Medical Society (WMS) values statement, the society states that it recognizes the importance and benefits of a diverse and inclusive society and makes a commitment to fostering an environment of acceptance that is equitable to all. With these values in mind, our goal was to evaluate the gender distribution of WMS membership, leadership, and award issuance.

Methods

We conducted a retrospective review to categorize the gender of WMS members, conference attendees, conference presenters, board members, and award winners. We primarily used publicly available information, and the WMS administrative staff provided the first names of members and meeting attendees with no other personally identifying information or additional data. This effort was not subject to research ethics oversight.

The WMS database did not allow us to capture the names of members by year. We captured a snapshot of the members' first names on a single day and used the gender distribution of conference attendees for conferences in 2012-2020 as a proxy for membership to document gender distribution over time. According to a communication from WMS staff (February 2022), only a small minority of conference attendees are non-members. Conference attendee data was not available before 2012.

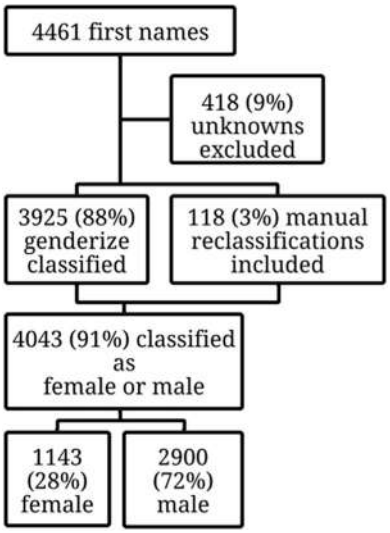

Figure 1. Gender distribution of WMS membership, August 17, 2020.

Members and conference attendees were classified by first name using Genderize.io software (http://genderdize.io).[10] First names were classified as male, female, or unknown, along with a computed probability of correct classification. The study authors reviewed all names classified as unknown as well as names with a gender probability estimate of <0.90. We manually categorized these names if the self-identified gender of the individuals was known based on unique first names. Some names were unclassified owing to the inclusion of extraneous data in the field (eg, titles, double names, or initials). These were also manually reviewed and categorized. We were unable to classify nonbinary or nongender-conforming identities with Genderize.io software without access to individually identifying data such as preferred pronouns.

We obtained the following names directly from the WMS: all WMS board members since the inception of the society in 1983, all recognition award recipients and grant recipients from award inception, conference speakers for 10 conferences from winter 2017 through winter 2021, the most current committee chairs as of April 2021, and conference chairs from 2018 through 2021. Personal knowledge of individuals by the authors was used in concert with verification of pronoun usage on professional or institutional websites. All individuals were classified as male, female, or unknown. Each speaker was given presentation credit for every presentation, whether presenting alone or in a group. We also evaluated separately the number and percent of female and male panelists. Panels were defined as discussion sessions with ≥3 advertised speakers, distinct from workshops with multiple instructors. Terms of service

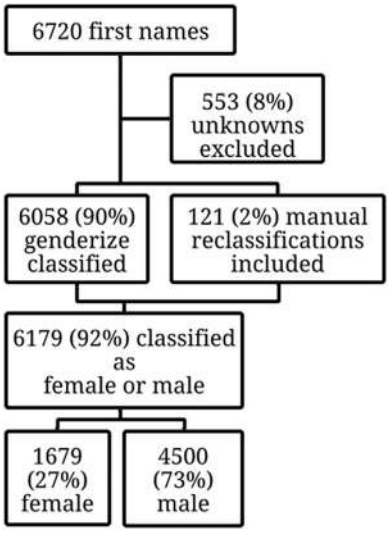

Figure 2. Gender distribution of WMS conference attendees, 2012-2020.

were captured for individuals holding the office of president.

Descriptive statistics were calculated in Excel. Chi square goodness of fit tests were used to compare gender distribution of awards and grants from 2012 through 2020, (the subgroups with enough people to make statistically valid comparisons) compared with the expected benchmark distribution of the average distribution of conference attendees over the same time period.

Results

Our membership snapshot captured a total of 4461 individual WMS member first names on August 17, 2020. Manual review of the Genderize.io output led to name reclassification in <3% of cases (n=118); 418 (9%) unknowns were excluded. Unknown names were reclassified to both female and male. Outcomes of member name classifications are shown in Figure 1.

Gender classification of all conference attendees over the 9-y period included 6720 names. Manual review of the Genderize.io output led to name reclassification in <2% of cases (n=121); 553 (8%) were excluded as unknowns. The outcomes of conference attendee classifications are shown in Figure 2 and are illustrated by year in Figure 3. The higher number of conference attendees in 2020 corresponded with a virtual conference format employed that year.

Women provided 31% (143/465) of all conference presentations, including small group sessions and workshops that were part of the main conference, but excluding separate pre-conference sessions and Diploma in Mountain Medicine classes and workshops (range 18-45% per event, Figure 4). Women accounted for 20% (62/303) of mainstage presentations (range 13-33% per event) (Figure 5) in the 10 WMS conferences held from winter 2017 through winter 2021. Out of all female presenters, 14% (20/143) were speakers on panels and 11% (16/143) were accounted for by 5 panels, of which 4 were women-only panels on the topic of women in wilderness medicine. Among the 5 conferences with panels, 26% (20/77) of female presenters at those conferences were accounted for by panel presentations.

Women constituted 23% (17/75) of all board members and 10% (2/20) of presidents over the 38-y history of WMS. Women comprised 27% (3/11) of WMS board members in 2019 and 2020 and 36% (4/11) in 2020 and 2021.

The WMS organizational structure includes committees that function under the board of directors (https://www.wms.org/about/board). Women constituted 38% (14/37) of all committee chairs from 2020 to 2021, including 14% (1/7) standing committee chairs, 36% (14/22) non-standing committee chairs, and 63% (5/8) special interest committee chairs or co-chairs.

The WMS began to issue recognition awards in 1994 (Table 1). Since then, the percentage of female recipients in each of the 10 award categories has ranged from 0-35% and overall, women received 18% (42/228) of all awards (Table 1). In the time period for which we have conference attendee data, women accounted for 24% (27/112) of awardees. These percentages did not differ statistically when compared with the gender distribution of conference attendees (X^2 [df=1, n=112]=0.34, P=0.55).

WMS began to issue research funding awards in 2008 (Table 2). Women received 31% (15/48) of the total research grants awarded (Table 2). In the time period for which we have conference attendee data, women received 35% (13/ 37) of the research grants awarded, which was similar to the gender distribution of conference attendees (X^2[df= 1, n=37]=86, P=0.35). To evaluate whether one or more individuals receiving multiple grants might influence percentages, we also counted the total number of individuals who won grants. The Hultgren grant has been awarded 12 times to 10 individuals (2 women, 8 men; with 1 woman and 1 man each receiving the award twice). No other grant has been awarded more than once to a single individual.

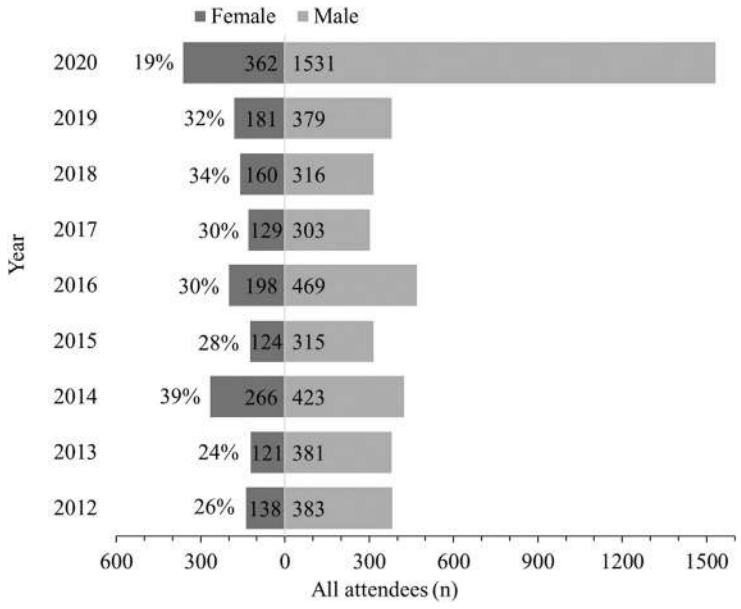

Figure 3. Gender distribution of WMS conference attendees, 2012-2020. Absolute counts are within bars, with the percentage of women represented to the left of the female bars. The unknown gender cases are not shown.

Discussion

We report the available historic and existing gender proportions in the WMS to identify gender disparities and opportunities for the next steps. Our key finding is that women are a minority across all WMS roles, although the gender distribution of speakers, board members, and award recipients generally reflects the gender distribution of the membership and conference attendees, with some notable exceptions (described herein).

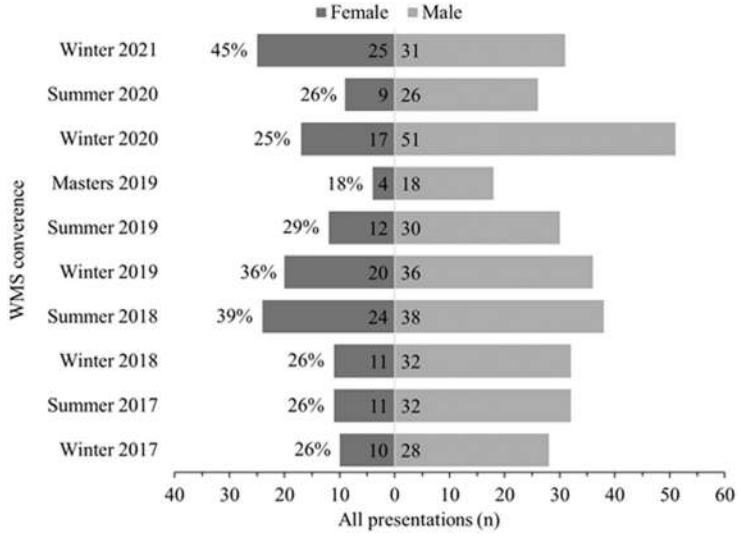

Figure 4. Gender distribution of all WMS conference presenters, 2017-2021. Absolute counts are within bars, with the percentage of presentations made by women represented to the left of the female bars. The unknown gender cases are not shown.

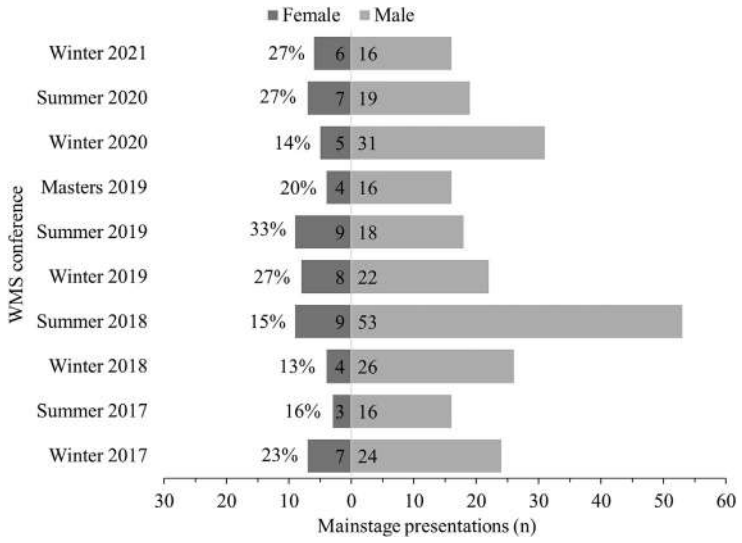

Figure 5. Gender distribution of WMS mainstage conference presentations, 2017-2021. Absolute counts are within bars, with the percentage of presentations made by women represented annually to the left of the female bars. The unknown gender cases are not shown.

In our 2020 membership snapshot, the proportion of female membership, approximately one-third, was similar to the proportion of female conference attendees. Women comprised a smaller minority in leadership, mainstage speakers, and multiple award categories. The proportion of women holding committee chair positions declined with ascending rank in the organization structural hierarchy. Similar to trends identified in other specialty societies, the situation is most imbalanced at the highest levels of leadership.[2]

The total percentage of female conference speakers reflects the percentage of female conference attendees. However, the percentage of female main stage speakers was lower across multiple conferences. The lowest percentage of female main stage presenters occurred in the fairly recent conferences in the winters of 2018 and 2020, at 13% and 14%, respectively. Further analysis showed that all-female panels boosted female percentages. The proportion of female mainstage presenters changed little over the 5-y period evaluated, with half of the conferences featuring male presenters 4 or more times as often as female speakers.

The recognition awards with the greatest number of female recipients were for outstanding research presentations and service awards. This stands in contrast with the awards with the lowest number of female recipients, both of which are better described as leadership awards. This pattern supports prior work of others that found women more often won prizes awarded for reasons such as education, support, teaching, and public service compared to research or leadership awards.[4,11] Of the 2 award categories with the lowest representation of women winners, the proportions were 0 and 7%. Other authors have noted that "low stakes" awards tend to be more equitable, but more prestigious awards tend to go to men across scientific and medical societies.[12-14]

We were not able to assess why so few women have been recognized in some categories. Without the ability to show the gender composition of society membership through the time period of award history, we cannot assess relative representation for awards whose inception date occurred before the time period for which we had membership or conference attendee data. The proportion of female recipients of research presentations and grants, which started more recently than the recognition awards, shows better gender balance and approximates the gender distribution of WMS members. Despite possible changes in the gender balance of membership compared with earlier years, the process by which recognition and research awards are granted is worth several considerations described below.

Unlike many of the recognition awards, the proportion of female WMS grant winners (31%) was similar to that of the membership at large. The percentage of female WMS grant awardees is less than the proportion of female US scientific grant winners, but greater than the proportion of Canadian female grant winners over a recent 5-y period.[15] The WMS research grants and the research presentation awards are intended to be determined by a merit-based process with published award scoring criteria. This is in contrast to self and/or peer nominations for recognition awards, which may be at

Table 1. Gender distribution of WMS recognition award recipients, from award inception through 2020

Award	*Inception y*	*Female n (%)*	*Male n (%)*	*Total n*	*Description*
Founders	1994	2 (7)	27 (93)	29	Given in recognition of outstanding contributions to the principles and objectives of wilderness medicine as envisioned by the Society's founders.
Education	1994	6 (22)	21 (78)	27	Given in recognition of outstanding contributions in education to students, members, or the public in the field of wilderness medicine.
Research	1994	4 (15)	23 (85)	27	Given in recognition of outstanding research pertinent to the field of wilderness medicine.
Dian Simpkins Service	1994	8 (29)	20 (71)	28	Given in recognition of outstanding service to the function and operation of the Society.
Blair Erb World Congress International	1995	0 (0)	10 (100)	10	Given to individuals and organizations representing countries, groups, academic societies, operational societies, and centers with outstanding contributions in wilderness medicine worldwide.
Warren D. Bowman	2000	7 (35)	13 (65)	20	Given to an associate member or an allied health professional for outstanding contributions in support services for wilderness medicine.
Paul S. Auerbach	2000	3 (14)	18 (86)	21	Given to a physician or PhD in recognition of sustained significant clinical or service contribution to wilderness medicine and/or scientific achievement in wilderness medicine in combination with service to the Society.
WMS Ice Axe	2008	3 (23)	10 (77)	13	Honors an individual with a distinguished record of public service in wilderness medicine who is also a strong advocate of the WMS and outdoor health and safety. Accomplishments may be in clinical practice, teaching, exploration, the arts, or research.
WEM Excellence in Peer Review	2010	8 (18)	37 (82)	45	Given in recognition of excellence in journal review activities.
Outstanding Research Presentation	2016	4 (31)	9 (69)	13	Given in recognition of the best research abstracts in the field of wilderness medicine.
Total		42 (18)	186 (82)	228	

higher risk of bias for several reasons. One potential contributing factor to a lower representation of women is that they have been found to be less likely to self-nominate or be nominated by male colleagues, owing to a multitude of reasons that range from differences in how men and women evaluate their own performance to perceived risk of backlash.[16] Another reason may be unintentional or implicit bias in nomination letters and in consideration of eponymous awards with male names.[17] An additional source of bias may be the perpetuation of a cycle in which underrepresented groups remain underrecognized, while those holding society leadership positions gain organizational exposure and increase the likelihood that they will achieve recognition.[9] One way to minimize unintentional bias in the nomination and decision processes could include using explicitly predefined evaluation criteria, as is currently done for research presentations and grant awards, or to ensure a gender-blind selection process.[14,18]

Our data show that gender distribution for award and grant winners and conference attendees is similar over a similar time period. An important question remains: By what standard should we evaluate gender ratios? The 2019 Association of American Medical Colleges workforce data indicates that female/male gender balance in medical schools in the United States is currently near parity, but gender distribution varies by medical specialty.[19] Gender imbalance in the WMS may reflect the

Table 2. Gender distribution of WMS research grant award recipients, from award inception through 2020

Award	*Inception y*	*Female n (%)*	*Male n (%)*	*Total n*	*Description*
Houston	2008	4 (31)	9 (69)	13	Given to medical students. $5000
Hultgren	2008	3 (25)	9 (75)	12	Given WMS members at any stage in their career in support of research that advances the field of wilderness medicine. $10,000
Researcher-in-Training	2008	5 (31)	11 (69)	16	Given to residents and fellows of an accredited graduate medical education program or doctoral candidates working towards a PhD. $5000
Hackett-Auerbach	2014	3 (43)	4 (57)	7	Given to young investigators (physician or non-physician, who is either a resident, fellow, or less than 5 y out of training) in support of research that improves wilderness medicine practice. $10,000
Total		15 (31)	33 (69)	48	

gender distribution of the medical specialties that are likely to participate in wilderness medicine. Emergency medicine has the highest representation within the WMS, followed by family medicine and prehospital providers, but the available data on WMS members' specialties are insufficient for statistical comparisons. The gender distribution of the WMS 2020 membership snapshot is roughly similar to that of emergency medicine, which comprises 36% female residents and 28% practicing female emergency physicians. It is also similar to the distribution for prehospital providers, where emergency medical technicians and paramedics in the United States are 35 and 23% women, respectively.[20] The Association of American Medical Colleges reports that women make up 41% of family medicine physicians,[19] substantially higher than the proportion of female WMS members.

Wilderness medicine is in the company of many specialties that struggle to achieve gender equity. A niche field like wilderness medicine has specific challenges. For example, we do not know when factors that influence interest in wilderness medicine have the greatest impact. It is possible that women and men develop their interest in wilderness activities before medical school. Although outdoor industry data show that women comprise 46% of outdoor recreation participants, and that the percent of women involved in outdoor recreation increased every year from 2017 through 2019,[21] women involved in the WMS, using conference attendance as a proxy, has remained stable at around 30% over a similar time frame. This discrepancy suggests that women's interest in wilderness medicine is not due to an inherent difference in men and women's interest in outdoor activities. Other, as yet unidentified, gender differences may exist that impact exposure to wilderness medicine and contribute to fewer women being involved in the field. Likewise, gender balance may be influenced by a confluence of factors, including implicit bias, lack of diversity in leadership, and the belief that disparities do not exist and therefore need not be prioritized by the organization.[22] For wilderness medicine, the existing gender imbalance itself may perpetuate a reluctance for female students to pursue the field, as has been seen in other specialties.[23,24]

Minority status for women can create continued problems. At the member end, the underrepresentation of female physician members in specialty societies, as compared with their numbers in their respective fields, may reduce engagement and opportunity. Underrepresentation at the highest levels makes it harder for women to identify role models, perpetuates the status quo, and may result in unintended bias across society activities. Areas with extremely low proportions of women participants are particularly concerning as they can indicate hidden attitudes that exclude women.[9]

Striving for the goal of gender equity is beneficial to medical societies and their members.[25] Professional societies with women in visible leadership roles have been shown to have greater gender equity throughout the society.[12,26] Improved gender balance in leadership can generate a positive feedback cycle for women early in their careers by means of role modeling and mentorship, which can have an important influence on career guidance, research productivity, and personal development.[27] Evidence suggests that early career providers will remain loyal to medical societies that strive to adapt to their needs.[28] Efforts to improve diversity and inclusion will have a positive impact not only for members who are women, but can strengthen the organization as a whole.[29]

Gender equity in the WMS could be addressed multiple ways. Outreach efforts can ensure that an adequate

pipeline for women in the WMS is developed or expanded to encourage broad participation in science, research, publication, and teaching. Creating opportunities to attract and engage junior members can build the membership pool, which is critical to promoting long-term parity. Websites can be reviewed and conference and course programs developed to avoid unintended bias and ensure optimal promotion and reach. We appreciate the complexity of addressing equity and the challenges that exist in making progress in diversity and inclusion. Previous work has recommended that such efforts include a transparent process focused on metrics and outcomes that operates under the assumption that there will always be room for improvement.[19] Society membership surveys that assess perceptions, collect suggestions, and evaluate the effectiveness of efforts to improve inclusiveness are warranted. These should be part of ongoing data collection and reporting to support self-appraisal and identification of areas for improvement in gender equity.

Limitations

There were several limitations to this work. We evaluated different time periods across several measures. We sampled a 1-d snapshot of membership data, conference speakers over 5 y, conference attendance over 9 y, and board and award counts over the life of the award and/or organization. We used conference attendees as a proxy for membership; gender distribution of conference attendees may differ from that of members. We did not evaluate the number of unique conference speakers in gender proportion calculations, such as instances when one woman gave multiple presentations. We did not assess the unique weight of individual contributions, with equal units of credit given for each presenter listed on the conference schedule. The review of final selected speakers and award recipients did not include data on speaker proposals, speaker invitations, or award nominees. The automated tool we used for gender classification only classifies names as "female" or "male" based on statistical likelihoods drawn from self-reporting, which did not address representation of other gender groups. In addition, the tool derives statistical likelihoods based on localized data from global sources, such that some names may be misclassified on the basis of localization (eg, "Jan" may be more likely to be male in Europe, but female in North America). Data on self-identification should be collected directly from community members to best represent individuals' gender identities. Future studies would benefit from consistent data availability across similar time periods.

Conclusions

Our findings add to a larger collective effort to evaluate and advance gender balance in science and medicine. We hope that these data will help WMS efforts to enact its values statement in policy. Although it is only one of the many components of equity, identifying successes and future opportunities for gender balance can strengthen the WMS base, promote growth, and ensure a strong leadership pipeline.

Author Contributions: Study concept and design (SMS, LEK, NWP); data acquisition (SMS, NWP, NEP, ABB, AB, LK); data analysis (SMS, LEK, NWP, NEP, ABB); drafting and critical revision of the manuscript (SMS, LEK, NWP, NEP, ABB); approval of the final manuscript (all authors).

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WILDERNESS & ENVIRONMENTAL MEDICINE 2022; 33(3): 284–9

ORIGINAL RESEARCH

Eye Injuries Caused by Wooden Projectiles in Finland

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Introduction—Eye injuries can cause decreased vision or even blindness, and predispose to future complications. Wood as an independent cause of eye injuries has infrequently been the focus of the studies. The aim of this study is to report the current population-based epidemiology, treatment, use of resources and outcomes of eye injuries caused by sticks, branches, and other wooden projectiles in Finland.

Methods—The study included all patients injured by wooden projectiles with ocular or orbital traumas over a 1-y period. Patients were treated at the Helsinki University eye hospital, which covers a population of 1.5 million. The follow-up time was 3 mo.

Results—Wooden projectiles caused 67 eye injuries and compromised 6% of all eye traumas during 1 y. Of the patients, males predominated (76%) and 22% were children under 17 y. Injury was most likely in spring (36%) and in males aged 51 to 67 y. The most common activity to cause injury was playing (27%), but in relation to time spent in each activity, the highest risk for eye injury was in gardening. Diagnoses were mild superficial trauma (54%), blunt ocular trauma (37%), eyelid wound (4%), orbital fracture (3%), and open globe trauma (1%). Permanent disability was estimated for 10% and a need for lifelong follow-up was estimated for 37%. Eleven patients needed major surgeries.

Conclusions—Wooden projectiles often cause serious eye injuries, permanent disability, and a need for lifelong follow-up. Caution is required to protect the eyes when playing with sticks and during gardening, forest work, and woodwork.

Keywords: ophthalmology, prevention, visual acuity, gardening, forest, play

Introduction

Wood as an independent cause of eye injury has rarely been the sole focus of studies. However, we know that among children sticks cause 7 to 27 % of eye traumas in Finland, 12% in Brazil, and up to 27% in Nigeria.[1-3] In Denmark, 33% of children's penetrating eye traumas, 4% in adults in Finland, and 6% in Canada have arisen from wooden items.[4-6] Among geriatric patients, wood strike was the most common reason for penetrating eye trauma in Turkey.[7]

Wooden material causing eye and intraorbital injuries have varied from branches and sticks to pencils, bamboo sticks, and corn stalks in previous studies.[4,8-10] As an organic material, untreated wood entails a risk for serious infections. Case reports are published on intraorbital, intraocular, and surface infections from uncommon bacteria and fungi.[10-12] On the other hand, in a few larger studies, no particular type of organism predominated and no mycobacteria or fungi were found.[8,9]

The purpose of this study was to provide an overview of the types of eye injuries wood causes.

Methods

The study includes all eye trauma patients injured by wooden items, for example, sticks and branches, who were taken into care at the emergency clinic of Helsinki University eye hospital (HUEH) over a 1-y period from May 1, 2011, to April 30, 2012. The HUEH is the sole tertiary and secondary eye care hospital in the area, covering a population base of 1.5 million. Patients injured by wooden dust, cosmetic wooden items, and matchsticks were excluded from the study. The study

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protocol was approved by the local ethics committee of the Helsinki-Uusimaa hospital district and followed the tenets of the Declaration of Helsinki.

Patients were first prospectively identified in the emergency clinic and requested to fill out the questionnaire. Secondly, to obtain full coverage of the data the hospital records were accessed and ICD-10 diagnoses indicating eye injury were searched from hospital records to find missed patients. The case history of all patients was examined and the accuracy of the injury details were confirmed. From all patients (n=1151), patients injured by wooden projectiles were selected for this substudy.

A patient questionnaire inquired about the circumstances and causes of the accident, use of protective eyewear, influence of alcohol, and whether the injury was intentional. Informed consent was obtained from patients or their caregivers. In the absence of the questionnaire (n=28), the same information was gathered from the hospital records. Additional information, including the involved eye, age, sex, possible amblyopia, detailed clinical findings structurized by anatomic site and finding type, diagnoses, treatments, use of resources, sick leave days, and activity restrictions were recorded for all patients from hospital records. The follow-up time was 3 mo. The record from the last visit included the final visual acuity (VA), intraocular pressure (IOP), and significant symptoms and clinical findings.

Severity of the eye trauma was evaluated by estimating the need for lifelong follow-up, by performed surgery and estimated future surgery, and by permanent disability due to abnormal VA (<0.5 Snellen equivalent) or other functional symptoms.

Eye traumas were divided into 5 primary diagnosis groups: "blunt ocular trauma," "wound" referring to wound in eyelid or periorbital area, "orbital fracture," "open globe trauma" or group "other" referring to mild superficial trauma in the eye or periorbital area. Clinically, the most significant ocular trauma or the one needing most health care resources was chosen as the primary diagnosis. Possible secondary and tertiary diagnoses were recorded. In cases of binocular eye injury, the more seriously injured eye was selected. The energy of the trauma was evaluated as high-energy, if tools or falling was involved.

Resource use was estimated by the number of outpatient visits, duration of hospitalization and medication, number of operations performed, and need for sick leave or activity restriction. If sick leave or sports restriction was not recorded, the need for these was estimated based on clinical findings and international recommendations.[13-16] Where averages were determined, results were noted as mean±SD (range).

Activity during the accident was categorized into gardening, forest work, play, outdoor recreation, woodwork, or in different sports. Woodwork referred to working with wood as a hobby or at work. Forest work was chosen when the trauma took place during silviculture work, eg, harvesting wood and planting. Data on alcohol use and relation to work or assault was collected.

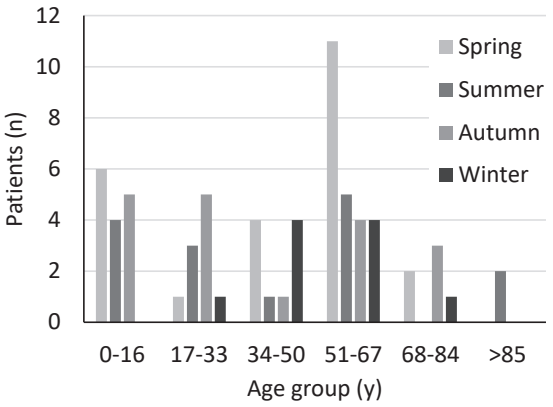

Figure 1. Age and seasonal variation of patients injured by wooden projectiles.

The incidence rates of eye injuries in each activity were calculated by dividing the number of accidents by the total population time spent in each activity in the HUEH area. The time spent in each activity was obtained from a Finnish time use study on forest activities,[17] and from a Finnish time use survey from Statistical Finland PX-web statistical database. Confidence intervals of 95% were calculated by exact method and used for statistical analysis of gardening, forest work, woodwork, outdoor recreation, cycling, skiing and orienteering. Data were available for people over 10 y of age.

Because some activities are seasonal in Finland, the year was divided into 4 seasons: spring (March, April, May), summer (June, July August), autumn (September, October, November) and winter (December, January, February). Epidemiological data were analyzed, distributions presented, and percentages calculated from the reported results.

Results

Wooden projectiles caused 67 eye traumas, which is 6% of all eye traumas treated at HUEH in a 1-y period. Of the patients, 76% (n=51) were males and 22% (n=15) were children under the age of 17 y. The incidence was 4.4 /100,000 population.[18] An eye injury was most likely in males aged between 51 and 67 y (n=24) (Figure 1). Two patients were lost to follow-up.

The injury was equally common in the left and right eye. No binocular traumas or traumas in an amblyopic eye were identified.

Table 1. Primary diagnoses, permanent disability, and need for lifelong follow-up caused by wooden projectiles in relation to activity. Eleven patients had significant secondary diagnoses

	All	*BOT*	*Wound*	*Fracture*	*OGT*	*Other*	*Permanent disability*	*Need for lifelong follow-up*
Play	18 (27%)[a]	7	2	–	–	9	–	7 (39%)[b]
Gardening	12 (18%)[a]	4	–	–	1	7	1 (8%)[b]	5 (42%)[b]
Forest work	11 (16%)[a]	6	1	–	–	4	1 (9%)[b]	5 (45%)[b]
Outdoor recreation	8 (12%)[a]	1	–	–	–	7	1 (13%)[b]	1 (13%)[b]
Woodwork	6 (9%)[a]	5	–	–	–	1	1 (17%)[b]	5 (83%)[b]
Sport	3 (4%)[a]	–	–	2	–	1	1 (33%)[b]	–
Unknown/Other	9 (13%)[a]	2	–	–	–	7	2 (22%)[b]	2 (22%)[b]
Total	67	25	3	2	1	36	7 (10%)	25 (37%)
Work-related	4 (6%)[a]	3	–	–	–	1	–	3
High-energy	15 (22%)[a]	9	1	1	1	3	5	10

BOT, blunt ocular trauma; OGT, open globe trauma; other, mild superficial trauma in the eye or periorbital area.
[a]Percentage calculated from the total number of eye injuries (n=67).
[b]Percentage calculated from the number of activities.

More injuries occurred during spring (36%) and autumn (27%) (Figure 1). Accidents took place at home (55%, 93% outside the house), at outdoor sites (12%), at school or day care (10%) and at work sites (8%). Data were not available for 16 patients.

There were no known intentional traumas. Alcohol was involved in 3 injuries of males aged 25-26 y. Protective eyewear was used by 1 patient while working with a table saw.

ACTIVITIES

The most common activities were playing (27%, n=18), gardening (18%, n=12) and forest work (16%, n=11) (Table 1). The activity could not be determined in 9 cases. Children were injured during play (n=14) and gardening (n=1). At play, the accidents took place when someone threw (n=4), a child swung (n=4) or someone hacked (n=2) a stick, while climbing in trees (n=2) or while kickboarding (n=1). In 1 patient, a keratitis scar remained in the cornea. Bacterial, fungal and viral cultures were negative.

While gardening, an 87-y-old male fell and was diagnosed with open globe trauma and orbital fracture. Eventually, the eye was eviscerated. Other gardening traumas were caused by a hit from a branch.

In forest work, 3 patients were using an axe, 1 a billhook, and 1 a saw. In outdoor recreation, 1 trauma was caused by stumbling in the woods and others were hits from branches. During the woodwork working with table or circular saw (n=3), axe (n=1), poking a window tab (n=1), and building a fence for horses (n=1) caused eye injuries. In sport, injuries were caused by a crash on a bike and in orienteering and skiing by a hit from a branch.

High energy was involved in 15 injuries (22%) (Table 1). All were adults, with males predominating (n=13, 87%). Tools were used in 11 cases and falling was a mechanism in 4.

When comparing the number of eye traumas in relation to time used for activity, the risk was highest in gardening, followed by forest work and woodwork (Table 2).

DIAGNOSES, TREATMENT AND USE OF RESOURCES

The most common primary diagnoses were superficial bulbar or periorbital trauma (n=36, 54%) and blunt ocular trauma (n=25, 37%) (Table 1). Clinically significant secondary diagnoses were reported for 16% of patients (n=11).

Major surgeries were needed for 10 patients (15%). One patient, probably in need of orbital surgery, was lost to follow-up. High energy was involved in 4 cases. Five patients were predicted to need surgery in the future. All injuries involved tools or falling.

The number of outpatient visits was 167 (2.5±2.4 [1−12] / 67 patients), hospitalization days 30 (3.3±3.1 [1−9 d] / 9 patients), and sick-leave days 405 (10.4±13.6 [1−54 d] / 40 patients) for patients aged over 16 y. Medication was needed for a total of 983 d (16.4±2,2 [3−90]) for 60 patients, 2 for elevated IOP.

THREE-MONTH FOLLOW-UP, PERMANENT DISABILITY, NEED FOR LIFELONG FOLLOW-UP

VA was lowered (0.5 Snellen equivalent or less) in 4 patients. Three months after the accident, 2 patients were medicated for elevated IOP.

Table 2. Risk for eye injury caused by wooden projectiles in different activities in relation to time spent in each activity. The time period was 1 y

Activity	*IR*[a]	*(95% CI)*
Gardening	10.70	(5.53–18.69)
Forest work	8.84	(4.41–15.81)
Woodwork	4.94	(1.81–10.76)
Outdoor recreation	2.40	(1.04–4.73)
Orienteering[b]	1.76	(0.04–9.80)
Cycling[b]	0.89	(0.02–4.97)
Skiing[b]	0.72	(0.02–3.98)

CI, confidence interval.
[a]Per 10,000,000.
[b]Included 1 patient.

Permanent disability was predicted for 7 patients (10%) because of lowered VA (n=3) due to retinal ablation, cataract, and subluxation of artificial lens, diplopia (n=2), evisceration (n=1), and glare due to mydriasis (n=1). Activities were various. High energy was involved in 5 cases. Tools were used in 2 cases, in forest work and woodwork. No children under the age of 17 y had a permanent disability (Table 1).

The need for lifelong follow-up was predicted for 25 patients (37%) because of elevated glaucoma risk (n=24) and evisceration (n=1). The most common activities were playing, gardening, forest work, and woodwork. High energy was involved in 10 cases. Tools were used in 7 cases, in forest work and woodwork-caused injuries. Six patients were children under the age of 17 y.

Discussion

This study presents a wide variation of eye injuries caused by wooden projectiles. We present a comprehensive population-based longitudinal study over a 1-y period from southern Finland. In this study, we analyzed the outcome of wooden projectile-caused eye injuries in relation to cause in urban and rural areas of southern Finland.

Interestingly, we found that spring was the most common season for wooden projectile eye injuries. Longer daylight in spring in Finland increases the possibility and enthusiasm for outdoor activities and also increases the time spent in gardens.

In our study, an eye injury was most common in males aged 51 to 64 y. Patients were older than in previous studies.[8,9] In Finland, older men seem to be in the greatest danger; they may be more active participants in forest work and gardening.

Playing, gardening, and forest work were the most common activities. In previous study forest work, assault and falling were the most common activities causing intraorbital wooden foreign bodies.[9] Compared with our study, there were no assaults, but falling was involved in 4 cases.

In relation to time spent in each activity, gardening, forest work, and woodwork were estimated to include the biggest risk for eye injuries. The use of tools possibly explains the increased risk in woodwork and in forest work. In gardening, only 1 patient used a tool (wood chipper) and another fell. The short working distance to branches may increase the risk for eye injuries. Also, the use of protective eyewear is not routine. Since comparable data for statistical analysis was available for people over 10 y of age and 12 out of 18 patients injured during playing were younger than 10 y, playing was not analyzed.

Permanent disability and need for lifelong follow-up were caused by various activities, but not by playing. The need for lifelong follow-up was not related to high-energy traumas only and also involved children. In 2 cases of severe blunt ocular traumas, the activity could not be defined.

A special interest in previous studies has been in intraorbital wooden foreign bodies. The incidence for these is rare, studies focus on case reports, and in our study only 1 patient had an intraorbital wooden foreign body.[8-10] A challenge in wood-induced eye traumas is the difficulty in identifying wood in radiological imaging. This may delay diagnosis and treatment.[10,12,18-22] Also, in our study, the radiological finding was reported as "air in intraorbital space," but since wood was suspected the report was corrected.

In our study, only 1 case of keratitis was diagnosed. Several reports of infections caused by wooden materials exist.[10] In many cases, the diagnosis was delayed, with the wooden intraorbital or intraocular foreign body identified only after infection.[8,9,11,12] However, the incidence of wood-associated orbital or ocular infections or keratitis has not been reported. According to our study, bacterial infections are rare.

Playing is essential for children and playing with sticks is ubiquitous. Playing should not be restricted excessively, but care should be taken when playing with sticks. Fortunately, playing with sticks did not cause any permanent disabilities. Nevertheless, 7 children need lifelong follow-up because of an elevated risk for glaucoma.[23-24]

Contrary to expectation, despite the use of protective eyewear, 1 eye injury took place while working with a table saw. The use of eye protection would likely have prevented or diminished eye injuries in woodwork and forest work, activities in which tools are commonly used. In addition, some accidents occurred unexpectedly in activities where eye protection is not generally an issue.

More attention should thus be focused on eye injuries when working with tools or in forestry.

Hospitalization, outpatient visits, and medication induce costs for society as direct health care costs. Indirect costs such as loss of income due to sick-leave, home care, and travel costs remains the burden of the individual. Preventing eye morbidity, the economic burden used for eye injury treatment could be aimed for other purposes. Further studies are needed to estimate the real costs of eye injuries.

Limitations

A few limitations are noteworthy. Firstly, the number of patients is relatively small for statistical analysis. Secondly, the short follow-up may affect the evaluation of permanent disability. A longer follow-up would likely have a positive impact since VA may improve after treatment and diplopia may slightly diminish over time.[25] In our study, diplopia in 1 patient may decrease over time and operating traumatic cataract probably improves VA. However, obvious disabilities, such as eviscerated eye and glare due to traumatic dilatated pupil can be seen in the 3-mo follow-up.

Conclusions

Our study shows that wooden projectiles cause various eye injuries in a wide range of circumstances, resulting in permanent disability and need for lifelong follow-up for many patients, including children. Most of these injuries are preventable and more attention should be directed to use of eye protection, especially during gardening, forest work, and woodwork. Children should be guided in playing safely with sticks.

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Author Contributions: Study concept and design (AKH, AS, TL); data analysis (AKH, AH, PP, TL); drafting and critical revision of the manuscript (AKH, AH, PP, TL); approval of the manuscript (AKH, AH, PP, TL).

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ORIGINAL RESEARCH

Oxygen Consumption and Blood Pressure Are Not Influenced by Use of a Backpack Hip Strap

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Introduction—Several studies have explored the effect of backpack carriage on physiologic responses while walking, but few have focused specifically on the influence of the use of a hip strap on these responses. The aim of this study was to investigate the effect of a backpack hip strap on physiologic responses when walking at a moderate intensity while carrying a backpack with a standardized relative load of 30% of the wearer's body mass.

Methods—Twenty-three healthy, active participants carrying backpacks walked on a treadmill at a speed and grade that elicited 40-50% of their heart rate reserve. Participants completed 2 counterbalanced 30-min trials, one with the hip strap in the strapped condition and one with the hip strap unfastened. Metabolic, heart rate, blood pressure, and muscle oxygen saturation (SmO_2) responses were recorded during both trials. For each variable, 5-min intervals were averaged at baseline, 5, 10, 15, 20, 25, and 30 min. A repeated measures ANOVA test was used to evaluate the differences between the conditions at each time point. Data reported are the values from the final 5-min interval (30 min) and are reported as mean±SD.

Results—No differences were found between strapped and unstrapped trials for oxygen consumption (strapped 21.9±4.2 $mL \cdot kg^{-1} \cdot min^{-1}$; unstrapped 22.0±4.4 $mL \cdot kg^{-1} \cdot min^{-1}$, P=0.842), Δmean arterial pressure (strapped +5±17 Δmm Hg; unstrapped +12±14 Δmm Hg, P=0.128) or muscle oxygen saturation of the quadriceps (strapped 86±15%; unstrapped 90±12%, P=0.359) and calf (strapped 73±19%; unstrapped 81±12%, P=0.888).

Conclusions—These results suggest that wearing a hip strap does not influence physiologic responses up to 30 min of moderate intensity walking while carrying 30% of the wearer's mass.

Keywords: energy costs, physical work, physiology, near infrared spectroscopy

Introduction

Backpacks are designed to decrease the subjective and objective effort of moving while carrying moderate to heavy loads and are used by students, military personnel, and recreational hikers.[1,2] Previous research suggests that backpack loads exceeding 15% of body mass are likely to cause adverse effects on walking biomechanics.[3] In addition, the physiologic stress of carrying a backpack increases as the mass of the backpack increases.[4,5] To balance discomfort with the need to carry significant loads, a pack load of no greater than 30% of the wearer's body mass has been recommended for recreational hikers.[6]

Backpacks designed for heavier loads often have an attached hip strap, which helps secure the load to the body. This results in more mass being placed closer to the wearer's center of mass.[7] In addition, by reducing the load on the wearer's shoulders, a backpack hip strap also decreases the subjective discomfort of the wearer.[8] Despite the effects on comfort, relatively little research has been published examining the effect of a hip strap on energy expenditure while walking.

Several studies have considered the effects of walking with a backpack and the changes in physiologic response over the duration of a trial and at various different backpack loads.[9-11] Yet, only one study[12] examined the effect of a hip strap on physiologic responses to walking with a backpack. That study found that the use of a backpack hip strap

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resulted in a lower oxygen consumption and rate of perceived exertion compared with no hip strap. The results of that study suggest that the use of a hip strap reduces energy cost during backpack carriage.[12] However, that study employed a protocol that was only 10 min in duration, a self-selected light exercise intensity, and a standardized absolute backpack load of 24 kg for all participants. No research has been done to examine the effect of the use of a hip strap when performing a bout of exercise at a standardized relative moderate intensity, utilizing a recommended standardized relative pack load of 30% of body mass[6] and a duration in line with recommendations for cardiorespiratory exercise.[13] Therefore, the purpose of the current study was to investigate the effect of a backpack hip strap on energy expenditure and cardiovascular responses while walking for 30 min at a moderate intensity with a load equal to 30% of the wearer's body mass.

Methods

All volunteers reported no known injuries to the feet, ankles, knees, hips, and or spine within the year prior to testing. Participants self-reported partaking in regular exercise at least 3 times per week for a minimum of 30 min each session and had experience carrying heavy backpacks. Lastly, participants reported being free from known cardiovascular, metabolic, or neurological diseases or disorders. Prior to data collection, the experimental procedures and risks of the study were explained to the participants, after which they provided written informed consent. The institutional review board of Montclair State University approved the consent form and experimental protocol prior to data collection.

Each participant reported to the laboratory for one screening visit and two testing visits. During the screening visit, the participants filled out questionnaires regarding health history. Height was measured using a stadiometer (Detecto, Webb City, MO) and body mass was measured using the bioelectrical impedance scale (Tanita MC-780U Segmental, Tokyo, Japan), which also predicted body composition. Resting blood pressure and heart rate (HR) were measured using an automated blood pressure cuff (BP785N, Omron, Kyoto, Japan). Resting HR was then used to calculate 40-50% of the participants' heart rate reserve (HRR) using the Karvonen formula.[14] The target heart rate zone was 40-50% of HRR because it corresponds to the lower limit of moderate exercise intensity according to the American College of Sports Medicine.[13] Participants were then asked to perform a 10-min walk carrying a backpack (Commander + Pack Bag, ALPS OutdoorZ, New Haven, MO) containing 30% of their body mass. The backpack load of 30% of body mass was chosen because it has been identified as the recommended upper load limit for recreational hikers.[6] Throughout the initial 10-min treadmill test, a Polar E600/T31 (Polar, Kempele, Finland) HR monitor was used to monitor HR. Participants were positioned on a treadmill at a grade of 3%. The speed was slowly adjusted until the participant's HR was within 40-50% of their HRR for three consecutive min. The corresponding speed was recorded and used for the following two testing visits.

On a different day, the participants reported to the laboratory to perform one of two backpack treadmill tests. One test employed the use of the hip strap (strapped) and the other was without the use of a hip strap (unstrapped). The 30-min treadmill trials were counterbalanced and took place on different days, with between 2 and 10 d separating the trials. The time of day for the trials was not standardized between all subjects, but each subject reported for both of their trials at a similar time of day. Prior to the start of each trial, the participants were asked to refrain from physical activity for 24 h, avoid caffeine and alcohol consumption as well as illicit and over-the-counter drug use for 12 h, and fast for at least 4 h. Participants sat quietly for a 5-min baseline period before beginning the 30-min treadmill walking trial.

Cardiovascular measurements were made using a human non-invasive blood pressure (NIBP) continuous monitor (ADInstruments, Colorado Springs, CO). The NIBP allows for beat-by-beat finger systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and HR[15] using ADInstruments PowerLab with LabChart 8 software (ADInstruments, Colorado Springs, CO). The NIBP monitor was placed on the middle finger of the right hand. The right arm was placed in a sling hanging from the neck and rested against the participant's abdomen with the elbow at approximately a 90° angle to ensure that the arm and hand maintained the same position during both trials. Participants were then outfitted with an appropriately sized facemask, which was used to continuously monitor whole-body aerobic metabolism using the Vmax Encore metabolic cart (Yorba Linda, CA).

Muscle oxygen saturation (SmO_2) and total hemoglobin (THb) were measured on the participant's left side in the muscle of the forearm (FM), quadriceps (QM), and calf muscle (CM) via near-infrared spectroscopy (NIRS) using Moxy sensors (Moxy Monitor System, Hutchinson, MN). The FM sensor was placed at the widest part of the anterior portion of the lower arm and was used as a control site for these measurements. The QM sensor was placed midway between the greater trochanter and patella and in the anterior mid-line of the thigh. The CM sensor was placed on the lower leg over the belly of the gastrocnemius muscle. The QM and CM were measured to more directly monitor oxygen handling of the prime

movers between trials. All sensors were outfitted with light shields to prevent ambient light from influencing the signal and were gently wrapped to ensure stable positioning while still allowing for normal blood flow.

Once the participant completed the treadmill test, the backpack and equipment were removed and the subject was encouraged to perform a 5-min recovery walk. On another day, the subject reported back to the laboratory and followed the same protocol in the opposite hip strap condition.

During the three visits, each participant carried the same loaded backpack (Commander + Pack Bag, ALPS OutdoorZ) adjusted to weigh 30% of their body mass, including the mass of the backpack. Sand-filled sacks of predetermined mass were placed inside the backpack in order to achieve the proper mass load for each subject. The backpack was loaded such that the mass was positioned at approximately the level of the subject's waist. During the strapped trial, the middle of the hip strap was placed over the iliac crest of the wearer and tightened. The shoulder straps were used during both conditions and were self-tightened by the subject to their level of comfort.

Data from baseline and exercise were averaged (5 min of baseline and exercise at 0-5, 6-10, 11-15, 16-20, 21-25, and 26-30 min) for the following variables: oxygen consumption (VO_2), respiratory exchange ratio (RER), minute ventilation (V_E), HR, FM SmO_2 and THb, QM SmO_2 and THb, and CM SmO_2 and THb. Change scores from the last 2 min of the seated baseline were calculated for SBP, DBP, and MAP. Change scores are reported for these variables because although the NIBP system allows for noninvasive continuous measurements with accurate change scores, absolute values are generally believed to be less accurate using this technique.[16] A two-way repeated measure analysis of variance (ANOVA) test was used to determine differences across time and conditions (strapped vs unstrapped). When the ANOVA was significant ($P<0.05$), a Bonferroni post hoc analysis was run to determine where the difference existed.

An a priori power calculation was performed using an alpha of 0.05, a power of 0.80, and an estimated 10% difference in oxygen consumption between the strap and unstrapped conditions. The results revealed that 17 participants were needed for this study. All statistical analyses were performed using SPSS (IBM, version 25, Armonk, NY). All results are reported as mean±SD unless otherwise noted, and the α-level was set at $P<0.05$.

Results

Twenty-three participants (12 male, 11 female; age 24±4 y) completed the study. Anthropometric and resting measures from the participants were: body mass (72.7±5.4 kg), height (1.70±0.10 m), body fat (23±8%), resting blood pressure (SBP 113±10 mm Hg; DBP 68±9 mm Hg), and resting HR (67±16 beats·min^{-1}). The target HRR was 118±12-130±10 beats·min^{-1}. The backpack mass was 21.6±4.6 kg, treadmill speed was 1.2±0.2 m·s^{-1}, and grade for all subjects was 3%. Laboratory conditions were stable throughout the data collection trials (temperature 18.5-20°C; relative humidity 30-40%).

No main effect for strapped vs unstrapped conditions was found for any of the variables ($P>0.05$). There was a difference in most variables from baseline to the first 5 min of exercise, which was maintained throughout the study.

Metabolic data are presented in Table 1. A main effect for time was found ($P<0.001$) in the VO_2 response. All exercising VO_2 values were elevated compared with baseline ($P<0.001$), but there were no differences in VO_2 between any exercising time points ($P>0.05$). There was no main effect for condition ($P=0.842$) and no interaction ($P=0.467$). There was a main effect for time on RER. The first 5 min of exercise resulted in a decrease in RER compared with baseline and all other time points

Table 1. Metabolic data measures from baseline and at minutes 0-5, 6-10, 11-15, 16-20, 21-25, and 26-30 of treadmill walking during strapped and non-strapped trials

Variable	*Time (min)*	*Condition*	
		Strapped	*Unstrapped*
VO_2 (mL·kg^{-1}·min^{-1})	Baseline	4.8±1.2[a]	4.8±1.0[a]
	5	20.3±3.9	20.7±5.2
	10	21.2±4.0	21.1±4.7
	15	21.1±4.0	21.2±4.3
	20	21.5±4.0	22.6±4.2
	25	21.6±4.0	21.8±4.3
	30	21.9±4.2	22.0±4.4
RER (unitless)	Baseline	0.88±0.08	0.91±0.11
	5	0.84±0.06	0.84±0.05
	10	0.90±0.05	0.88±0.06
	15	0.89±0.06	0.89±0.06
	20	0.89±0.06	0.88±0.06
	25	0.88±0.07	0.88±0.06
	30	0.86±0.07	0.87±0.07
V_E (L·min^{-1})	Baseline	10.3±3.6[a]	10.6±2.8[a]
	5	33.0±8.8	33.8±10.9
	10	36.4±9.2	35.9±10.1
	15	36.2±8.9	35.9±7.6
	20	36.8±9.3	36.5±7.7
	25	36.7±9.3	37.1±8.2
	30	36.8±9.0	37.1±8.4

VO_2, volume of oxygen consumed; RER, respiratory exchange ratio; V_E, minute ventilation.
Data are displayed as mean±SD.
[a] $P<0.05$ from all other time points within condition.

Table 2. Cardiovascular measurements from baseline and at minutes 0-5, 6-10, 11-15, 16-20, 21-25, and 26-30 during the strapped and unstrapped trials

Variable	*Time (min)*	*Condition*	
		Strapped	*Unstrapped*
HR (beats·min^{-1})	Baseline[a]	78±14	79±14
	5	118±11	111±15
	10	126±14	123±17
	15	129±14	126±18
	20	132±15	127±18
	25	133±16	129±17
	30	136±17	135±19
ΔSBP (mm Hg)	5	28±38	297±28
	10	29±35	31±22
	15	29±30	31±22
	20	27±33	29±24
	25[b]	24±34	26±28
	30[b]	20±34	26±28
ΔDBP (mm Hg)	5	3±16	6±19
	10	4±15	8±19
	15	4±14	8±19
	20	3±15	7±19
	25	2±14	8±19
	30	1±14	8±18
ΔMAP (mm Hg)	5	9±19	11±19
	10	10±12	13±17
	15	10±16	13±17
	20	8±17	12±17
	25	6±17	11±18
	30	5±17	12±18

HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial. pressure.
Data are displayed as mean±SD.
[a]$P<0.05$ from all other time points.
[b]$P<0.05$ from 15 min.

($P<0.05$). No differences existed between conditions ($P=0.886$). There was an interaction between condition and time on RER ($P=0.048$). A main effect for time was observed for V_E such that all exercising V_E values were increased during exercise compared with baseline ($P<0.000$). There was no main effect of condition on V_E ($P=0.926$), but there was an interaction ($P=0.043$) between condition and time.

Cardiovascular data are presented in Table 2. There was a main effect of time on HR such that there was an increase in HR from baseline to 5 min ($P<0.000$), but HR was not different between conditions at any time point ($P=0.194$), with no interaction ($P=0.143$). There was a main effect of time such that ΔSBP was different between 5 and 25 min ($P=0.033$) and 5 and 30 min ($P=0.018$). There was no main effect for time on ΔDBP nor ΔMAP ($P=0.142$ and 0.128, respectively). Also, the ΔSBP, ΔDBP, and ΔMAP were not different between conditions at any time point ($P=0.708$, 0.374, and 0.389, respectively), with no interaction ($P=0.954$, 0.302, and 0.521, respectively).

Table 3. Muscle oxygen and total hemoglobin data from baseline and at minutes 0-5, 6-10, 11-15, 16-20, 21-25, and 26-30 for forearm, quadriceps, and calf muscles during the strapped and unstrapped trials

Variable	*Time (min)*	*Condition*	
		Strapped	*Unstrapped*
FM SmO_2 (%)	Baseline	55±16[a]	58±16[a]
	5	52±16	53±15
	10	57±19	53±16
	15	57±20	53±17
	20	57±21	51±17
	25	57±21	52±18
	30	58±20	54±18
FM THb (g·dL^{-1})	Baseline	12.7±0.4[a]	12.6±0.5[a]
	5	12.7±0.5	12.7±0.5
	10	12.7±0.5	12.7±0.5
	15	12.7±0.5	12.7±0.5
	20	12.6±0.5	12.6±0.5
	25	12.6±0.5	12.7±0.5
	30	12.6±0.5	13.4±3.9
QM SmO_2 (%)	Baseline	79±14[a]	78±14[a]
	5	76±14	73±14
	10	83±13	77±13
	15	85±13	82±12
	20	86±15	85±11
	25	86±14	85±11
	30	86±15	90±12
QM THb (g·dL^{-1})	Baseline	11.8±0.6[a]	11.7±0.5[a]
	5	11.7±0.5	11.6±0.6
	10	11.8±0.5	11.7±0.5
	15	11.9±0.4	11.8±0.5
	20	12.1±0.4	11.9±0.5
	25	12.0±0.4	11.9±0.4
	30	12.1±0.6	12.0±0.4
CM SmO_2 (%)	Baseline	74±15[a]	66±14[a]
	5	46±23	53.9±19
	10	56±22	57±23
	15	65±21	63±19
	20	70±22	67±17
	25	71±20	69±18
	30	73±19	81±12
CM THb (g·dL^{-1})	Baseline	12.1±0.6[a]	12.2±0.5[a]
	5	12.1±0.6	12.0±0.5
	10	12.1±0.6	12.0±0.5
	15	12.1±0.6	12.0±0.5
	20	12.1±0.6	12.0±0.5
	25	12.1±0.6	12.0±0.4
	30	12.1±0.6	12.0±0.4

FM, forearm; SmO_2, muscle oxygen; THb, total hemoglobin; QM, quadriceps muscle; CM, calf muscle.
Data are displayed as mean±SD.
[a]$P<0.05$ from all other timepoints within the same condition.

Table 3 contains SmO_2 and THb data. There was a main effect for time with FM SmO_2, which was increased from baseline to all exercise time points (P=0.030), but there was no difference in FM SmO_2 between conditions (P=0.243), with no interaction (P=0.139). Similarly, QM SmO_2 was elevated during exercise compared with baseline (P=0.007), but no changes were observed between conditions (P=0.359), and there was no interaction (P=0.734). Calf muscle SmO_2 also increased from baseline (P<0.000) but was not different between conditions (P=0.888), with no interaction (P=0.130). FM THb was similar at all time points (P=0.924) and was not different between conditions (P=0.426) nor was there any interaction (P=0.892). QM THb was increased from baseline at all exercise time points (P=0.007) but was not different between conditions (P=0.087) with no interaction (P=0.734). Similarly, CM THb was greater at all exercise time points compared with baseline (P=0.301) but was not different between conditions (P=0.563), with no interaction (P=0.595).

Discussion

The key findings of this study are that the use of a backpack hip strap did not have an impact on any of the measured physiologic variables when participants walked for 30 min at a constant moderate intensity, carrying a load of 30% body mass.

Several studies have examined the effect of backpacks on energy cost while walking.[9-11,17,18] However, those studies did not systematically examine the effect of hip strap use on energy expenditure. One previous study[12] examined the effect of a backpack hip strap and found that exercise VO_2 was greater when no hip strap was worn as compared with when a hip strap was used. In that study, exercise intensity was self-selected, the exercise interval lasted only 10 min, and the absolute carrying load was standardized at 24 kg for all subjects. When compared with that study, the present study's findings are more applicable to recreational hikers.

The exercise interval in the present investigation was 30 min versus 10 min in previous work.[12] The 30-min interval better reflects recommendations for daily cardiorespiratory exercise.[13] The present investigation also employed a standardized relative backpack load of 30% of the participant's body mass, which is the recommended upper limit for the backpack load in recreational hikers.[6] Future research should compare the effect of hip strap use during different durations, intensities, and loads on physiological variables.

The researchers in the previous study[12] used an all-purpose lightweight individual carrying equipment military backpack with a load distribution over the midthoracic region. The present study used an ALPS Commander backpack with the load distribution at the waist. The difference in load distribution may have influenced the differing results because external load has been shown to affect energy costs and loaded carriage capacity.[16] Loads that are closer to the wearer's center of mass, as was the case in the present investigation, have shown to decrease postural instability, which leads to a reduction in energy costs.[19] Other research[20] found that carrying a load closer to the lower back, as was the case in the current study, reduced the amount of energy expended when compared with having the load placed closer to the upper back. Future research should incorporate the effect of load placement while also considering the effect of a hip strap on energy expenditure.

It has been established that SBP increases as workload increases.[21-24] Blood pressure recovery rise was also shown to be greater following exercise when a backpack loaded with 20% versus 10% body mass was carried.[2] The present study did not find a difference in SBP between the strapped and unstrapped conditions when carrying 30% of body mass. This may have occurred because the physical mass of the backpack remained unchanged despite the fact that the hip strap reduced the vertical load from the shoulders to the hips. Blood pressure may have remained the same between the 2 conditions because the mass of the backpack did not change. Also, cardiovascular response may also have remained similar because the mass remained the same.

Previous studies have examined muscle oxygenation and backpack carriage, specifically shoulder muscle oxygen.[25,26] Those studies found that backpacks reduce muscle oxygenation in the shoulder and upper extremities. The present study measured the SmO_2 of the prime movers while walking, with the forearm serving as a control. No difference was found at any of the sites between the strapped and unstrapped conditions. There was no difference in total VO_2 or THb between the 2 conditions, indicating that neither was influenced by use of a hip strap. We did not assign a non-backpack trial for comparison. Our results suggest a hip strap does not influence muscle oxygenation compared with carrying a backpack without using a hip strap.

Limitations

The limitations of this study include the use of a single backpack load, exercise duration, and exercise intensity. Testing multiple backpack loads, durations, and exercise intensities might better determine the effect that the use of a hip strap exerts on a variety of physiologic variables.

Another limitation is placing the subject's arm in a sling to collect accurate blood pressure data while walking. This created a fixed and unnatural position that likely influenced walking biomechanics. Lastly, only college-age, physically active participants were examined in this study, making it difficult to generalize our findings to other populations.

Conclusions

Many backpacks used for hiking or carrying moderate to heavy loads have been designed with hip straps, which may lead people to believe that this design feature is essential. Our findings indicate that a backpack hip strap may not have an effect on the energy cost or several other measures of physiological stress when walking at a moderate intensity carrying a moderate to heavy load. Thus, people may choose a backpack with a hip strap based upon perception of a benefit that may not exist. To further clarify a hip strap's efficacy, future studies should compare the metabolic cost and cardiovascular strain when a hip strap is used under different loads, exercise intensities, durations, and load placements.

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ORIGINAL RESEARCH

Intranasal Fentanyl for On-the-Hill Analgesia by Ski Patrol

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Introduction—Intranasal fentanyl offers a means for safe and effective pain management in austere environments. Prehospital analgesia traditionally involves intravenous or intramuscular medication. However, for wilderness rescuers, these methods are often impractical.

Methods—We conducted a retrospective review of health records to evaluate the safety and efficacy of intranasal fentanyl administered by EMT-Basic certified ski patrollers. Our primary aim was to measure the reduction in initial pain scores to subsequent measurements at 5, 10, and 15 min using the pain numeric rating scale (0–10). Clinically significant reduction in severe pain has been established as ≥1.8 points. We used paired t-tests and multilevel modeling to measure statistical significance and potential interactions and reviewed patient charts for adverse events, including respiratory depression or the use of naloxone.

Results—We compiled the results from the winter seasons for 2007 through 2012 and 2016 through 2020. A total of 247 patients were included. The initial pain score was 8.6±1.5 (mean±SD). The decrease in pain scores from 0 to 5, 10, and 15 min, respectively, was −1.8, −2.4, and −2.9 (P<0.0001), which demonstrated a clinically and statistically significant decrease in pain scores. There were no adverse events.

Conclusions—Traditional standard of care analgesics are invasive, elongate scene times, and increase the risk of environmental exposure and provider needlestick. Intranasal fentanyl offers a safe, noninvasive, and rapid analgesia that is well-suited for austere winter environments, such as those encountered at ski resorts. This study demonstrates the safety and efficacy of the administration of intranasal fentanyl by EMT-Basic certified providers.

Keywords: alpine ski accidents, winter rescue, prehospital, EMS, pain management

Introduction

The undertreatment of acute pain continues to be a pervasive problem in the prehospital setting.[1–4] Adequate pain control can decrease the risk of subsequently developing posttraumatic stress disorder.[5] Barriers to timely and effective prehospital analgesia include lack of certified personnel and restrictive protocols.[6–10] For rescuers like ski patrollers, these barriers are further compounded by the unique difficulties of a winter environment. The transport of an injured patient by ski patrol often involves a long and uncomfortable sled ride, with transport times ranging from 10 min to more than an hour for more prolonged evacuations. On-the-hill analgesia can rapidly reduce the patient's pain and mitigate worsening pain with movement and positioning during wilderness transport. Traditionally, the standard of care for analgesia in the prehospital setting has been the use of intravenous (IV) or intramuscular (IM) medications.[8] Intranasal administration of medications has become increasingly used because of its noninvasive nature, decreased time to administration, and reduced risk of needlestick injury.[4,11,12] In the winter wilderness setting, the invasive nature of IM/IV access necessitates exposing the patient—increasing risk for hypothermia

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and risk of unpredictable drug efficacy due to potentially decreased extremity perfusion.[4]

Fentanyl is a lipophilic, potent opioid analgesic and is thus ideally suited for intranasal (IN) administration. Intranasal fentanyl has an onset of 2-7 min and a duration of just under an hour, making it highly comparable to IV opioids.[13,14] Numerous studies have demonstrated the safety and equivalent efficacy of IN fentanyl as compared with IM/IV morphine,[4,13,15–18] IV fentanyl,[14,19] and subcutaneous (SQ) fentanyl.[20] Intranasal fentanyl has been successfully implemented for pain management for a variety of patients in whom IV access is difficult or not otherwise indicated, such as pediatric patients in the emergency department,[13,21] breakthrough cancer pain,[22] postoperative and minor burn patients.[23]

Intranasal fentanyl presents a noninvasive alternative for prehospital analgesia. The United States National Scope of Practice Model limits the administration of pain medications by EMS providers, depending on their level of certification, but states may expand the scope of practice associated with certification levels at their discretion.[8] International EMS organizations in New Zealand[24] and Germany[25] introduced a protocol that enabled their paramedic-level providers (previously unable to give narcotic medications) to provide IN fentanyl guided by online medical direction. Both studies showed a mean reduction in pain of 3 and 4.6, respectively, and found no serious adverse events. The equivalent safety and efficacy of SQ and IN fentanyl administration by EMT-B providers has been demonstrated in a study of a Quebec EMS system in which only a small subset of patients experienced minor adverse events, such as hypotension, nausea, and mild sedation. No serious adverse events occurred, and no naloxone reversal was used.[20]

A clinical practice guideline of wilderness analgesics gave IN fentanyl a strong recommendation as a potentially safe and effective analgesic in the austere setting but lacked studies specifically targeting the wilderness setting.[4] In these more austere settings, pain management is limited by local protocols and access to qualified personnel. In the United States, only a small subset of professional ski patrols are EMS-affiliated and have protocols that allow for the advanced practice administration of any opioid analgesia.[26] For EMS-affiliated ski patrols, administration of opioid analgesics is further limited to personnel with paramedic-level certifications or higher, comprising an even smaller subset of patrollers.[7]

We present data on the use of IN fentanyl in ski patrol or wilderness settings. Intranasal fentanyl eliminates many barriers to achieving on-the-hill analgesia presented by environmental and austere factors. It is also available in needleless, prefilled syringes,[27] increasing administration efficiency, decreasing dosing errors, and eliminating needlestick risk.

To address the gap in pain management protocols, in 2007, the Taos Ski Patrol applied for a New Mexico EMS special skills protocol that enabled patrollers with the minimum certification of EMT-B to undergo specific training to provide eligible patients with on-the-hill IN fentanyl analgesia under the direction of a physician. In this study, we evaluated the reduction in pain scores and adverse events in patients who received IN fentanyl at Taos Ski Valley in the 13 y since the protocol's adoption. We evaluated the safety and efficacy of the Taos special skills protocol.

Methods

This retrospective health records review evaluated acute pain management at Taos Ski Valley, NM. We reviewed patient charts from the 2007−2012 and 2016−2020 seasons. Data from the 2013−2015 season were not included because they were misplaced when the clinic moved to a new location. Eligible subjects included those seen and evaluated by ski patrol personnel for acute, painful orthopedic injuries and who received IN fentanyl as outlined by Taos Ski Patrol's special skills protocol (Figure 1). Results were excluded if no pain scores were recorded. The study was approved and deemed exempt by the University of Vermont institutional review board (11/8/19, STUDY00000583).

The special skills protocol was approved by the New Mexico EMS special-use advisory board in 2007 and updated in 2010. In the protocol, ski patrollers with a minimum certification of EMT-B were required to participate in an initial 3-h training on narcotic pharmacology, pharmacokinetics, dosing, administration, and FDEA regulations. When evaluating a patient, the ski patroller verbally elicited the patient's subjective pain score using the 0 to 10 numerical rating scale (NRS-11), which has been validated by multiple studies.[28-30] If the patient had severe pain, defined as >7, the patroller requested physician online medical control and verified the rationale, the patient's sex, age, weight, medical allergies, and narcotic history, and then requested permission to administer a standardized dose. Literature recommendations for IN fentanyl dosages range from 1 to 2 $\mu g \cdot kg^{-1}$.[31] Standardized dose ranges were established to increase efficiency at the scene and to minimize dosing errors and variability caused by user technique and atomizer dead space (Table 1).

If approved by medical control, the patroller called for fentanyl, which was kept in a locked box in patrol

Indication: Relief of severe pain (>7/10) caused by traumatic injury in an alert and oriented patient.
Contraindications: Opiate allergy, significant blunt chest trauma, the possibility of closed head injury or diminished level of consciousness.

1. Determine indication for intranasal medication and lack of contraindications.
2. Request online medical control.
   a. Verify chief complaint, the patient's sex, age, weight, medical allergies, narcotic history.
   b. Request permission to administer a standardized dose, using closed loop communication.
3. Ensure naloxone is available.
4. Using a 3 mL syringe, with plastic anti-stick safety needle, draw up the prescribed dosage of fentanyl (50 mcg·mL^{-1}).
5. Remove the needle and attach the atomizer onto the syringe for administration.
6. Inspect the patient's nostrils for blood or mucous discharge which may limit mucosal absorption.
7. Verify patient and dosage information with a secondary patroller at the scene.
8. Lean patient's head back slightly, or lay supine.
   a. Administer 0.5 mL of fentanyl into alternating nares.
   b. Utilize short firm pushes to create a fine spray.
9. Monitor the patient for allergic and adverse reactions.

Figure 1. Taos Ski Patrol intranasal fentanyl administration protocol.

headquarters on the mountain, in accordance with FDEA narcotic protocol. The patroller then drew up fentanyl (50 μg·mL^{-1}) from a vial and delivered the dose using a mucosal atomizer device (Wolfe Tory Medical, Salt Lake City, UT) in fractions of 0.5 mL in alternating nares because of volume limitations of intranasal administration.[32] Before administration, the patroller confirmed the dosage in a second closed-loop communication with another trained patroller at the scene. Repeat doses were possible under online control. A protocol remained in place for paramedic-level patrollers to give additional IM morphine if needed.

The responding ski patroller elicited the initial pain score (at 0 min) and subsequent pain scores (at 5, 10, and 15 min), with minimal interruption to transportation. The ski patroller also recorded patient characteristics, dosage information, and the occurrence of any adverse events (such as respiratory depression, nausea, vomiting, or the use of the naloxone reversal agent). The data were recorded on a standardized paper records maintained by the ski patrol organization.

The study team collected and reviewed the patients' pain scores, basic characteristics, and adverse events. Due to missing timepoint data, the analyses were performed using multilevel modeling to estimate the least square means, with the patient as a random effect, and time nested within patient. The data are presented as least square mean±SD. Based on prior validated studies, we determined that the clinically meaningful reduction in severe pain was >1.8 points.[33-35] Complete case analyses were also conducted using paired t-tests for each follow-up timepoint compared with time at 0 min. Multilevel modeling was used to evaluate for the differences in pain scores associated with several variables, such as sex, age, weight-based dose, and initial pain score. Statistical significance of the interactions was evaluated using F-tests. Statistical significance was determined by $P \leq 0.05$.

Table 1. Standardized dosage regimen for Taos Ski Patrol

Patient weight (kg)	*Fentanyl dose (μg)*
≥68	100
45-67	75
23-44	50
≤22	<50

Results

We compiled the results from the winter seasons of 2007 through 2012 and 2016 through 2020. A total of 247 patients were included; 4 patients were excluded due to lack of documented pain scores. We were unable to locate data from 2012 to 2016, and data were incomplete for 28 patients, for whom medication dosage or pain scores at one or more timepoints were missing, so we used multilevel modeling to estimate least square mean±SD. Before the special skills protocol was instituted at Taos, IM morphine was used infrequently (between, 5−7 times per year). Since the protocol was adopted in 2007, an average of 30 injured skiers received on-the-hill analgesia each year. Patient age was 33±18 y, ranging from 6 to 74 y, with 59% of patients identifying as male. The most common injuries involved the lower leg, shoulders, and obvious deformities and/or dislocations. Detailed patient demographics are summarized in Table 2. The initial pain score was 8.6±1.5. Using multilevel modeling, the decreases in pain scores from 0 min were −1.8, −2.4, and −2.9, respectively, for

Table 2. Patient characteristics and demographics, n (%)

Characteristic	*Pooled*[a]	*Female*	*Male*
Total	247	99 (41)	141 (59)
Demographics			
Age (y) mean±SD	33±1	34±2	33±1
(range)	(6–74)	(7–74)	(6–74)
<18	52 (21)	23 (26)	23 (19)
18–29	70 (29)	21 (24)	37(30)
30–39	39 (16)	11 (12)	23 (19)
>40	83 (34)	34 (38)	39 (32)
Mechanism of injury			
Fall (unspecified)	73 (59)	25 (56)	45 (62)
Twisting fall	14 (11)	6 (13)	8 (11)
Fall on rocks	4 (3)	1 (2)	2 (3)
Fall from jumping	6 (5)	0 (0)	6 (8)
Object strike	10 (8)	6 (13)	4 (5)
Collision	4 (3)	2 (4)	1 (1)
High speed	9 (7)	2 (4)	7 (10)
Fall from lift	2 (2)	2 (4)	0 (0)
Fall walking	1 (1)	1 (2)	0 (0)
Injury			
Shoulder	67 (31)	20 (22)	46 (39)
Clavicle	13 (6)	3 (3)	10 (8)
Trunk	6 (3)	4 (4)	2 (2)
Hip/Pelvis	12 (6)	5 (5)	7 (6)
Elbow	5 (2)	4 (4)	1 (1)
Wrist	14 (6)	6 (7)	6 (5)
Forearm	7 (3)	2 (2)	4 (3)
Humerus	14 (6)	6 (7)	8 (7)
Thumb	1 (<1)	0 (0)	1 (1)
Arm unspecified	4 (2)	1 (1)	2 (2)
Knee	15 (7)	14 (15)	1 (1)
Femur	11 (5)	4 (4)	7 (6)
Lower leg	38 (17)	20 (22)	17 (14)
Ankle	5 (2)	2 (2)	3 (3)
Foot	1 (<1)	0 (0)	1 (1)
Leg unspecified	5 (2)	1 (1)	3 (3)
Obvious deformity	34 (16)	5 (5)	27 (23)
Initial pain score			
<8	51 (21)	20 (23)	27 (23)
8	55 (23)	17 (20)	33 (29)
9	37 (15)	13 (15)	15 (13)
10	97 (40)	36 (42)	40 (35)
Weight-based dose			
Under ideal	15 (7)	4 (5)	7 (7)
Ideal	193 (89)	68 (86)	96 (92)
Over ideal	10 (5)	7 (9)	1 (1)
Rescue dose			
1 dose	213 (89)	79 (80)	104 (76)
2+ doses	25 (11)	10 (10)	16 (12)
IN fentanyl	17 (7)	8 (8)	11 (8)
IM morphine	8 (3)	2 (2)	5 (4)

[a]Pooled data include all patients, including 7 for whom sex was not recorded.

each additional time point at 5, 10, and 15 min (a linear trend across time, $P<0.0001$). The time at 0 min represented the time of initial pain score at time of first IN fentanyl administration (Figure 2). Using a paired t-test, we found both a clinically significant decrease in pain scores from 0 min of >1.8 and statistical significance of $P<0.0001$, at all time intervals from 0 min. There were no adverse events such as respiratory depression or use of naloxone.

Table 3 contains the variables of sex, age, initial pain score, and weight-based dose, which were evaluated for significance of interactions. Only the baseline pain score showed a statistically significant interaction. Patients with a higher initial pain score had a statistically greater decrease in pain ($P<0.0001$). There was no difference in pain reduction between age groups ($P<0.93$) or sex ($P<0.25$). When evaluating the standardized dose of fentanyl administered, some patients received less or more than the ideal weight-based dose. Few patients received higher (>2 $\mu g \cdot kg^{-1}$) or lower (<1 $\mu g \cdot kg^{-1}$) doses per weight (n=10 and n=15, respectively). No statistical difference in pain scores was found with respect to weight-based dose ($P<0.32$). No adverse events occurred for any patients, including those receiving the higher than ideal dose. We found that female patients and younger patients were more likely to receive non-ideal weight-based doses. Seventy percent of the patients who received non-ideal doses were less than 21 y old. All but one of the 15 patients receiving a higher than ideal dose was female.

Seventeen patients (7%) received additional fentanyl doses and 8 patients (3%) received additional IM morphine. No non-opioid medications were given on the hill. When examining the response of patients who received a single dose, the decrease in pain from 0 min was statistically significant at all time intervals ($P<0.001$). For those who received a repeat rescue dose of either IN fentanyl or IM morphine, there was no significant decrease in pain from 0 to 5 min ($P=0.20$), as measured from administration of the initial dose. However, the decrease in pain from 0 to 10 min and from 0 to 15 min was significant ($P=0.02$ and $P=0.003$). When comparing pain scores for single vs repeat doses using the multilevel model, the initial 0-min pain scores were similar in both samples. At both 5 and 10 min, the sample of patients receiving a repeat dose were more likely to have a smaller decrease in pain scores than those receiving a single dose. However, at 15 min, the decrease in pain scores was statistically similar in both samples. There were no significant differences in patient demographics between samples.

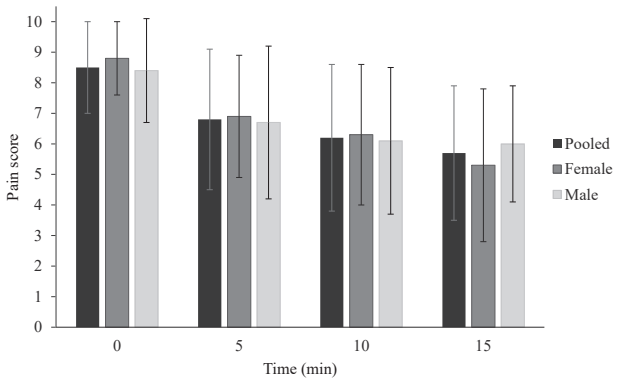

Figure 2. Pain score by time as estimated by least square mean. The error bars represent the standard deviation.

Discussion

Our study found that patients who received on-the-hill IN fentanyl had a statistically significant and clinically meaningful decrease in pain scores with no adverse events. Before the special skills protocol was adopted at Taos Ski Valley, IM morphine had been used as on-the-hill analgesia, albeit rarely. Intranasal fentanyl was found to be a safe and efficacious alternative that markedly increased the usage of on-the-hill analgesia. We found that IN fentanyl offers a safe, effective, noninvasive approach to rapid analgesia when administered by EMT-B certified providers in the ski patrol setting.

The analysis of potentially interacting variables found no statistically significant decrease in pain scores for age, sex, or weight-based ideal dose. Additionally, patients who presented with higher initial pain scores were more likely to have larger decreases in their reported pain. This finding has been similarly noted in the literature.[34,36] A study of postoperative pain in patients in a Colombian hospital found that patients who endorsed severe pain required a larger decrease in NRS-11 pain scores to note a meaningful decrease in pain relief when compared with patients who reported moderate pain.[34]

Repeat IN fentanyl doses and additional IM morphine were seldom administered. Patients who received rescue doses had smaller decreases in pain at 5 min than patients receiving a single dose despite the fact that they presented with similar initial pain scores. However, after the rescue doses were administered, they experienced pain relief equivalent to the pain relief reported by the patients who received a single dose. No adverse effects were found for any patient, including those who received higher than the ideal weight-based or repeat doses. We observed that 14 of 15 patients who received the higher than ideal dose were female, which may relate to standardized dosing in patients who had lower body weight.

Challenges remain in achieving adequate analgesia using IN fentanyl. It is volume-limited with an ideal volume of 0.15 mL per naris to prevent nasal runoff.[32,37,38] However, our study and several other studies[20,39] successfully used larger volumes of 0.5 mL per naris in several aliquots. In one study, doses greater than 50 μg were further divided, which may have helped decrease nasal runoff.[20] In addition, vasoconstriction caused by exposure to a cold environment leads to decreased mucosal absorption and slower onset of action.[40] These barriers highlight the possibility of under-dosing even those patients who receive an ideal weight-based dose.

To improve nasal delivery and absorption, several studies have shown the efficacy and safety of higher concentrations of fentanyl (available in concentrations of 300 to 1000 $\mu g \cdot mL^{-1}$)[37,41] and other more potent opioids such as sufentanil.[42–44] These formulations offer an alternative means of overcoming the volume limitations of IN administration. As the concentration increases, smaller dosing errors may increase the risk for serious adverse effects due to their potency. Using a lower concentration of fentanyl (50 $\mu g \cdot mL^{-1}$) with an emphasis on repeat dosing, as outlined in the Taos protocol, allows for titrating as well as standardizing IN and IV medications.

The need for and success of progressive protocols that enable providers with less advanced certification to provide pain management has been demonstrated in a diverse range of rural and prehospital settings.[6,8,20,24–26,31,45] Local protocols for non-EMS affiliated organizations often tightly restrict the ability of paramedics to provide an advanced level of care and pain management. Though standardized and evidence-based protocols that enable paramedics to provide an advanced level of care would help decrease barriers to prehospital analgesia, paramedics comprise only a small minority of ski patrollers, wilderness rescuers, and rural EMS providers.[6,8,31] The study of pain management by providers with less advanced training than the paramedic level thus far has been limited.[20] Our results have demonstrated the safety and efficacy of IN fentanyl with a clinically and statistically significant decrease in pain scores at all time intervals measured. This study is part of a growing body of evidence for innovative prehospital analgesia protocols.

LIMITATIONS

As we previously mentioned, we were unable to locate the data for 2013 through 2015. In the years that were included, missing data for patients such as pain scores, fentanyl dosage, etc, necessitated the use of multilevel modeling and led to the exclusion of several patients. As a

Table 3. Multilevel model for longitudinal pain score data with calculated least square mean±SD. Significance of variable interaction by time evaluated using F-test

Variable	*0 min*	*5 min*	*10 min*	*15 min*	*Interaction* P *value*
Pooled	8.6±1.5	6.8±2.3	6.2±2.4	5.7±2.2	<0.0001
Sex					0.25
Female	8.8±1.2	6.9±2.0	6.3±2.3	5.3±2.5	
Male	8.4±1.7	6.7±2.5	6.1±2.4	6.0±1.9	
Age					0.93
<18 y	9.1±1.2	7.1±2.1	6.6±2.2	6.4±1.9	
18-29 y	8.5±1.5	7.1±2.1	6.2±2.5	5.6±2.5	
30-39 y	8.4±1.5	6.5±2.6	6.0±2.2	5.7±2.4	
40+ y	8.4±1.8	6.5±2.3	6.0±2.4	5.7±1.9	
Initial pain score					<0.0001
<8	6.2±1.2	5.1±1.8	4.8±1.5	4.5±1.6	
8	8.0±0.1	6.6±1.9	5.6±2.3	6.0±2.0	
9	8.9±0.2	7.0±1.8	6.4±2.2	4.4±2.3	
10	10.0±0.1	7.7±2.4	7.2±2.3	7.0±2.0	
Weight-based dose					0.32
Under ideal	9.3±1.1	7.6±2.1	7.4±2.0	5.1±2.2	
Ideal	8.4±1.6	6.6±2.2	6.0±2.3	5.7±2.2	
Over ideal	9.6±0.7	8.4±2.0	7.4±2.9	6.0±3.2	
Number of doses					0.005
1 dose	8.5±1.5	6.6±2.3	6.0±2.4	5.7±2.4	
2+ doses	8.8±1.8	8.2±1.6	7.4±1.5	6.4±1.8	
Paired t-test	0.54	0.002	<0.001	0.69	

health records review, this study lacks the rigor of a randomized, blinded, placebo-controlled study. Several factors may have impacted the study's generalizability. For example, the time before intitial administration (0 min) can be affected by the time it takes for the rescuers to arrive, the role of splinting or other non-medication treatments for pain mitigation, and the possible effect of cold temperatures on reported pain scores. Also, because similar pain scores were not available for patients who did not receive IN fentanyl, there is a lack of an innate control group.

Conclusions

This study of the Taos protocol demonstrates that IN fentanyl administration by EMT-B certified providers could help further bridge the gap in pain management and provide safe and effective analgesia for other ski patrols, and potentially be applied to broader rural and austere settings. Intranasal administration of fentanyl is non-invasive, needleless, and available in prefilled syringes, making it well-suited for the winter wilderness setting. It offers a compelling alternative for safe and effective pain management in the austere setting. A national survey of ski patrols and other rescue groups is warranted to identify other opportunities for this mode of pain management and to also identify barriers toward broader implementation of IN fentanyl protocols.

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ORIGINAL RESEARCH

Accessory Climbing Routes Associated With More Rescue Operations Than the Main Climbing Route: A Retrospective 12-Year Report of Yushan National Park

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Introduction—This study compared the casualties and types of rescues conducted on the main climbing route (MCR) and accessory climbing routes (ACRs) in Yushan National Park (YSNP) between 2008 and 2019.

Methods—We collected the following information for all documented mountain rescue operations conducted on the MCRs and ACRs in YSNP between 2008 and 2019: accident location, casualty type, victim number, and type of rescue. The victims were categorized as to injury, illness, mortality, or no medical problem (NMP) groups according to their condition at the time of rescue.

Results—Two-hundred forty-four rescue operations involving 329 victims were conducted during the 12-y study period. Among them, 105 (32%) did not require medical treatment, 102 (31%) were injured, 82 (25%) were ill, and 40 (12%) were deceased. Of the 82 individuals with illness, 69 (84%) had acute altitude sickness. The accident and mortality rates on the ACRs were significantly higher than those on the MCR ($P<0.001$; χ^2). The ACR incidents involved significantly higher percentages of helicopter-based rescues and victims in the NMP group ($P<0.001$).

Conclusions—Acute altitude sickness accounted for most of the rescues. ACRs had higher injury and mortality rates and required more helicopter-based rescues for patients who did not have medical problems. This study may serve as a reference to reduce casualties and overuse of helicopters by educating tourists on the appropriate use of maps and the evaluation of trails in relation to weather conditions.

Keywords: search and rescue, Taiwan, helicopter, acute altitude illness, emergency medical services

Introduction

Participation in outdoor recreational activities has increased in popularity in Taiwan in recent years.[1,2] A 2018 national survey of recreation and the environment reported that approximately 45% of adults in Taiwan participated in some type of recreational activity in the mountains in the preceding year.

At a height of 3952 m, Jade Mountain is the highest peak in east Asia and is a common site for recreation. When engaging in outdoor recreational activities, individuals can risk activity-related injuries or illnesses that may require rescue. Rescue operations in Taiwan involve several organizations, including government and nongovernment organizations operating under the delegated authority of the fire administration. These operations are facilitated by ground-based rescue teams that collaborate closely with helicopter-based medical services.

Rapid evacuation and treatment can drastically improve the outcomes of mountain rescue operations.[3,4] However, rapid rescues may be affected by the type of activity and environmental factors (eg, terrain and geological structures).[5] Reviewing and critically appraising historical rescue operations can help to more efficiently allocate future resources, optimize triage, and streamline protocols for rescue.[5–11] The most recent study of mountain rescues in Yushan National Park (YSNP) was published in 2009

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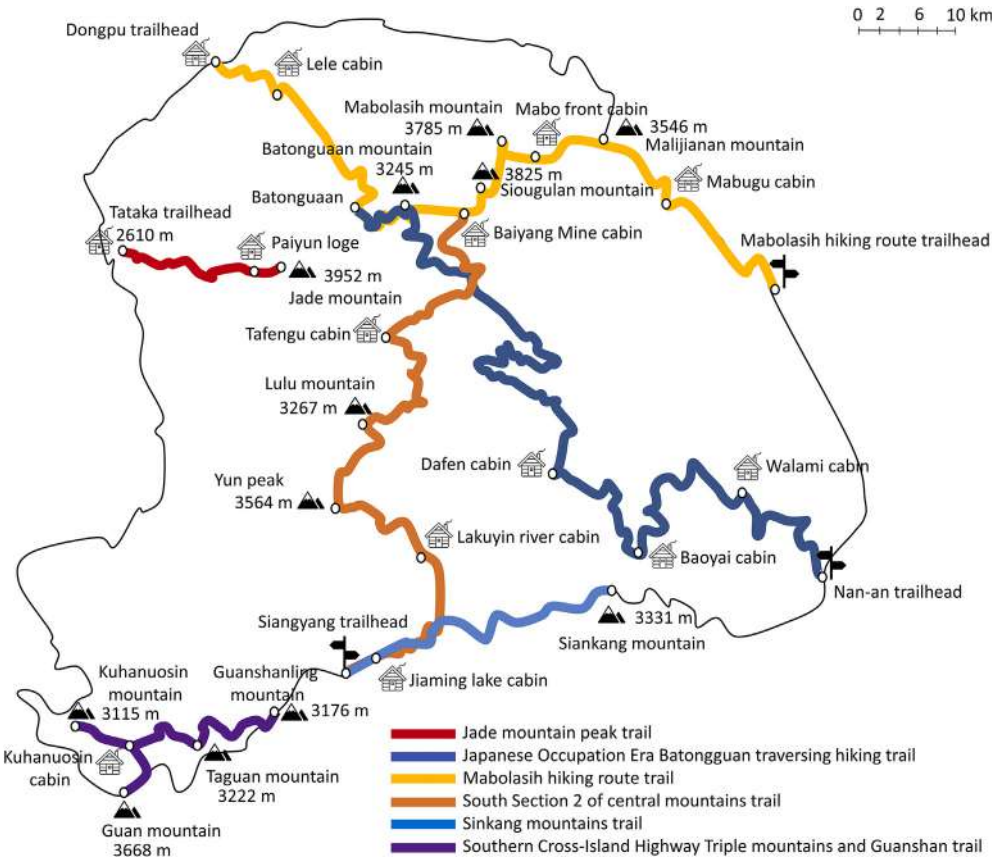


Figure 1. Trail map of Yushan National Park. The main climbing route is a route to Jade Mountain (red route); the other routes are accessory climbing routes.

and concerned only victims who required medical treatment, excluding victims who called for help after becoming lost or trapped by weather conditions.[6]

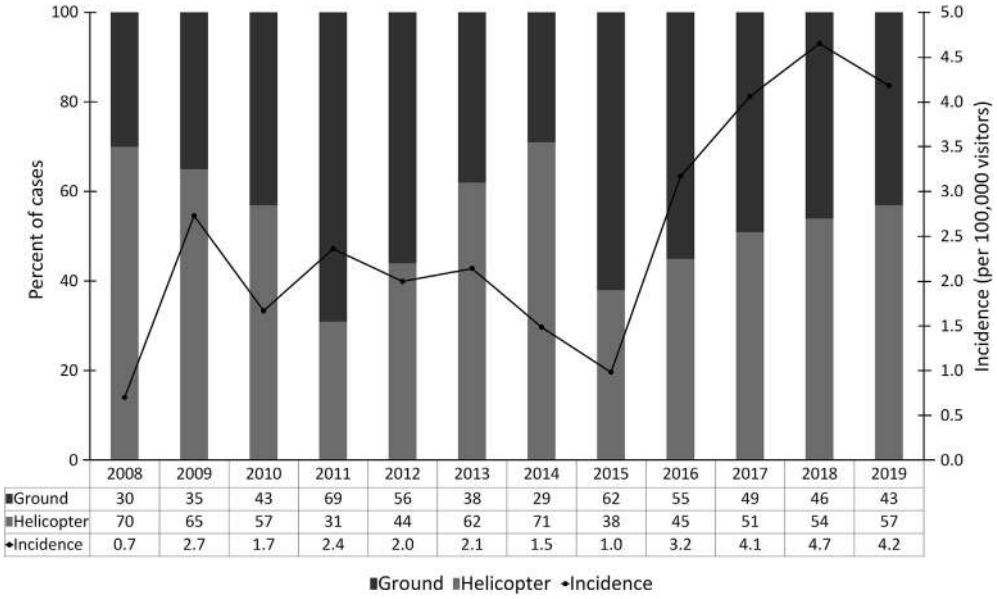
Our study compared the types of casualties and rescues conducted on both the main climbing route (MCR) to Jade Mountain and the accessory climbing routes (ACRs) in YSNP.

Methods

This study was approved by the institutional review board of China Medical University Hospital (CMUH110-REC2-116).

The national park is located in Taiwan's central mountain range and, with an area of 1031 km^2, comprises 10% of the total area of Taiwan. The park contains regions with altitudes ranging from 300 to 3952 m above sea level. Two-thirds of the park's area has an altitude of >2000 m above sea level, and >30 of its peaks have an altitude of >3000 m above sea level. YSNP is becoming increasingly popular as a site for adventure recreation, and it has many climbing routes (Figure 1). The MCR is a route to Jade Mountain (red route on Figure 1); the other routes are termed ACRs. The most common type of climbing on both the MCR and ACRs is hiking uphill on trails. However, the routes have distinct environmental characteristics. The MCR is an adequately maintained trail with an elevation of 1342 m (from 2610 to 3952 m above sea level) and was the route used by most of the trekkers in YSNP in the study period. By contrast, the ACRs have high forest density and frequent landslides.

This study involved retrospective collection of documented mountain rescue operations conducted in YSNP between 2008 and 2019. Incident data were gathered from standardized report forms generated by medical and rescue personnel at the scene of each incident. We excluded patients seeking medical services at mountain lodges without interventions from the mountain rescue teams. The data collected for each incident were the ages of the victims, the incident location and date, the type of rescue (ground- or helicopter-based), and the descriptions



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Ground	30	35	43	69	56	38	29	62	55	49	46	43
Helicopter	70	65	57	31	44	62	71	38	45	51	54	57
Incidence	0.7	2.7	1.7	2.4	2.0	2.1	1.5	1.0	3.2	4.1	4.7	4.2

Figure 2. Incidence of rescue operations and proportions of helicopter-based rescue operations by year. The incidence of rescue operations began to increase in 2015.

of the incident and associated fatalities, injuries, or illnesses. The victims were categorized into groups according to injury, illness, mortality, or no medical problem (NMP) at the time of rescue. Patients in the injury group were involved in accidents in which they sustained physical trauma, patients in the illness group were involved in accidents in which casualties occurred that required medical attention but were nontraumatic, those in the mortality group were involved in accidents in which a victim died before the rescuers arrived, and those in the NMP group were rescued without requiring medical support.

The primary outcome of our study was to analyze the types of casualties and means of rescue on the MCR and ACRs in YSNP between 2008 and 2019. The secondary study outcome was to investigate the evolution of mountain rescue medical care in an increasingly popular area known for outdoor recreation by analyzing rescues in YSNP.

Descriptive statistics were used to analyze variables in each category: the differences between categorical variables and odds ratios were analyzed using a χ^2 test. Statistical significance was set at $P<0.05$, and SAS version 9.4 (SAS Institute, Inc., Cary, NC, USA) was used for the analyses.

Results

This study analyzed 244 rescue operations involving 329 victims over the course of 12 y between 2008 and 2019. The proportion of helicopter rescue interventions was highest in 2008 (70%) and lowest in 2011 (31%; Figure 2), and the incidence of rescue operations increased in 2015.

Table 1 lists the distribution of each type of casualty and rescue, as well as the location of the each rescue. Among the 329 victims, 105 (32%) did not require medical treatment, 102 (31%) were injured, 82 (25%) were ill, and 40 (12%) were deceased. The most common nonfatal injuries were lacerations or contusions, multiple trauma due to falling, and sprains or strains. Of the 82 victims in the illness group, 69 (84%) had acute altitude illness. Of these, 60 had acute mountain sickness, 2 had high altitude cerebral edema, and 7 had high altitude pulmonary edema. Other common illness cause were gastrointestinal, genitourinary, and cardiorespiratory distress. The most common cause of mortality was trauma. Of the total 40 deaths, 27 victims died from trauma, 21 fell off cliffs and 6 were involved in air crashes. Most of the rescue operations (74%) were conducted on the ACRs.

Over the study period, 13,341,262 people visited YSNP. Among them, 423,560 and 102,441 trekkers used the MCR and ACRs, respectively. The MCR was used by 81% of the trekkers in YSNP during the study period. The accident and mortality rates of the ACRs were significantly higher than those of the MCR (odds ratio [OR]=11.71, 95% CI: 9.15−14.97, $P<0.001$ and OR=19.50, 95% CI: 8.63-44.08, $P<0.001$, respectively).

Table 1. The incidence of medical events and types of rescue associated with rescue operations on different routes in Yushan National Park from 2008 to 2019

Variable	*Total, n (%)*	*Incidence (per 10^5 visitors)*	*MCR, n (%)*	*ACR, n (%)*	P-*value*	*OR (95% CI)*
Total trekkers	526,001		423,560	102,441		
Types of casualties						
Sum	329 (100)	2.47	86 (0.02)	243 (0.24)	<0.001	11.71 (9.15–14.97)
Medical problems						
Illness	82 (25)	0.61	31 (0.01)	51 (0.05)	<0.001	6.81 (4.35–10.63)
Acute altitude illness	69 (21)	0.52	25 (0.01)	44 (0.04)	<0.001	7.28 (4.46–11.89)
AMS	60 (18)	0.45	21 (0.01)	39 (0.04)	<0.001	7.68 (4.52–13.06)
HACE	2 (0.6)	0.01	1 (0.00)	1 (0.00)	0.351	4.13 (0.26–66.10)
HAPE	7 (2)	0.05	3 (0.00)	4 (0.00)	0.030	5.51 (1.23–24.63)
Gastrointestinal distress	4 (1)	0.03	0 (0.00)	4 (0.00)	0.001	–
Genitourinary distress	4 (1)	0.03	1 (0.00)	3 (0.00)	0.025	12.40 (1.29–119.3)
Cardiorespiratory difficulties	3 (0.9)	0.02	3 (0.00)	0 (0.00)	1.000	–
Injury	102 (31)	0.76	38 (0.01)	64 (0.06)	<0.001	6.97 (4.66–10.41)
Lacerations/Contusions	35 (11)	0.26	11 (0.00)	24 (0.02)	<0.001	9.02 (4.42–18.42)
Polytrauma from falls	18 (5)	0.13	5 (0.00)	13 (0.01)	<0.001	10.75 (3.83–30.16)
Sprain/Strain	16 (5)	0.12	8 (0.00)	8 (0.01)	0.005	4.13 (1.55–11.02)
Fractures	15 (5)	0.11	2 (0.00)	13 (0.01)	<0.001	26.88 (6.07–119.1)
Death	40 (12)	0.30	7 (0.00)	33 (0.03)	<0.001	19.50 (8.63–44.08)
Trauma (air crashes, fall off a cliff)	27 (8)	0.20	4 (0.00)	23 (0.02)	<0.001	23.77 (8.22–68.75)
Non-trauma	13 (4)	0.10	3 (0.00)	10 (0.01)	<0.001	13.78 (3.79–50.08)
No medical problem	105 (32)					
Lost	69 (21)	0.52	10 (0.00)	59 (0.06)	<0.001	24.41 (12.49-47.71)
Weather	36 (11)	0.27	0 (0.00)	36 (0.04)	<0.001	–
Means of rescue						
Ground-based	110 (46)	0.82	47 (0.01)	63 (0.06)	<0.001	5.55 (3.80–8.09)
Helicopter-based	129 (54)	0.97	18 (0.00)	111 (0.11)	<0.001	25.52 (15.51–42.00)
Location					<0.001	11.71 (9.15–14.97)
MCR	86 (26)	0.64	86 (0.02)	–		
ACR	243 (74)	1.82	–	243 (0.24)		

MCR, main climbing route; ACR, accessory climbing route; OR, odds ratio; AMS, acute mountain sickness; HACE, high altitude cerebral edema; HAPE, high altitude pulmonary edema.

Table 2 lists the details of the rescue operations on the MCR and ACRs involving specific casualty types and rescue means. The rescues conducted on ACRs exhibited a significantly higher probability of involving victims in the NMP group (OR=3.36, 95% CI: 1.67–6.74, $P<0.001$) and victims who had gotten lost or trapped by weather conditions. Moreover, the rescue operations conducted on the ACRs used a helicopter-based means of rescue significantly more often than did those conducted on the MCR (OR=3.18, 95% CI: 1.78–5.66, $P<0.001$). In addition, they were significantly less likely to involve victims who required medical treatment (OR=0.21, 95% CI: 0.10–0.42, $P<0.001$) and used a ground-based means of rescue significantly less often than the rescues conducted on the MCR (OR=0.29, 95% CI: 0.17–0.48, $P<0.001$).

Discussion

During the study period, numerous rescue operations were conducted in YSNP. The incidence was higher than it was in the 2 decades preceding the study period (2.47 vs 1.18 victims/100,000 visitors), possibly because of the number of recreational hikers visiting the park increased.[6] The incidence of rescues was low in 2008 and 2015, which may be attributable to the closure of some of the ACRs because of natural disasters (specifically, typhoons Jangmi in 2008 and Soudelor in 2015). The average mortality rate during the study period was similar to that reported in the previous study (0.30 vs 0.24 deaths/100,000 visitors), and trauma remained the most common cause of death.[6] Most fatalities on the mountain occurred on the ACRs, probably because poor trail maintenance

Table 2. Probabilities of types of casualties and rescues associated with rescue operations on different routes

Variable	*MCR n (%)*	*ACR n (%)*	P-*value*	*OR (95% CI)*
Total victims	86	243		
Types of casualties				
Classification by medical treatment				
Yes (illness, injury, death)	76 (88)	148 (61)	<0.001	0.21 (0.10–0.42)
No (lost, weather)	10 (12)	95 (39)	<0.001	4.88 (2.40–9.90)
Medical problems				
Illness	31 (36)	51 (21)	0.005	0.47 (0.28–0.81)
Acute altitude illness	25 (29)	44 (18)	0.031	0.54 (0.31–0.95)
AMS	21 (24)	39 (16)	0.084	0.59 (0.32–1.08)
HACE	1 (1)	1 (0.4)	0.455	0.35 (0.02–5.68)
HAPE	3 (3)	4 (2)	0.383	0.46 (0.10–2.11)
Gastrointestinal distress	0 (0)	4 (2)	0.576	-
Genitourinary distress	1 (1)	3 (1)	1.000	1.06 (0.11-10.35)
Cardiorespiratory difficulties	3 (3)	0 (0)	0.017	-
Injury	38 (44)	64 (26)	0.002	0.45 (0.27–0.75)
Lacerations/Contusions	11 (13)	24 (10)	0.451	0.75 (0.35–1.60)
Polytrauma from falls	5 (6)	13 (5)	0.790	0.92 (0.32–2.65)
Sprain/Strain	8 (9)	8 (3)	0.038	0.33 (0.12–0.91)
Fractures	2 (2)	13 (5)	0.369	2.37 (0.52–10.74)
Death	7 (8)	33 (14)	0.184	1.77 (0.75–4.17)
Trauma (air crashes, falls from cliff)	4 (5)	23 (9)	0.162	2.14 (0.72–6.38)
Non-trauma	3 (3)	10 (4)	1.000	1.18 (0.32–4.42)
No medical problem				
Lost	10 (12)	59 (24)	0.013	2.44 (1.18–5.01)
Weather condition	0 (0.00)	36 (15)	<0.001	-
Type of rescue, mean				
Ground-based	47 (55)	63 (26)	<0.001	0.29 (0.17–0.48)
Helicopter-based	18 (21)	111 (46)	<0.001	3.18 (1.78–5.66)

MCR, main climbing route; ACR, accessory climbing route; OR, odds ratio; AMS, acute mountain sickness; HACE, high altitude cerebral edema; HAPE, high altitude pulmonary edema.

and frequent landslides increased the probability that visitors would fall off the cliffs.

Examination of the incident reports revealed that the 2 most common rescue categories were unrelated to the victims' physical condition (ie, spatial disorientation and weather conditions) and injury, which is similar to other results reported in epidemiological studies of recreational areas.[5,7,11] Acute altitude illness was the most common cause of illness rescue and was strongly associated with the MCR. The two key factors reported to favor the development of acute altitude illness were the hikers' altitude and the duration of their exposure to high altitudes.[12,13] The MCR spans 2610 to 3952 m above sea level. Because of convenient roads, the drive from sea level to the 2610 m entrance is only 70 km (approximately 3 h of driving), and some trekkers choose to drive to the trailhead and start hiking without an additional day of acclimatization. This rapid ascent may increase their susceptibility to acute altitude illness.

The rescue operations conducted on the ACRs involved victims who did not require medical treatment more often than did those conducted on the MCR. Callouts in response to spatial disorientation (ie, getting lost) were significantly more common on the ACRs than on the MCR, possibly because the ACRs are characterized by high forest density and because some areas are affected by landslides. The other common cause of rescues on the ACRs was an inability to continue along a route because of weather conditions. It's possible that some of the hikers were unprepared for weather or altitude changes, which may have increased their risk of requiring rescue.

In Taiwan, 80% of the hikers who climb Jade Mountain via the MCR were reported having participated in high altitude (>3000 m) mountaineering <5 times.[14] However, the inexperienced hikers who used the MCR were not involved in more mountain rescues. This may be owing to the fact that the MCR trail is maintained combined with the fact that the hikers using the ACRs were not sufficiently prepared for the conditions they encountered. YSNP is home to 19 mountain lodges. Paiyun Lodge, located on the MCR, is the only lodge

with medical facilities (as well as a doctor on weekends). The other 18 lodges are scattered throughout the ACRs and do not contain medical resources. Although hazardous physical environments can endanger mountain climbers and other visitors to the ACRs, other factors, such as inexperience or lack of preparation, which are in turn exacerbated by lower body temperatures, fatigue, and other medical conditions, can also pose problems.[15]

Rescue operations occur more commonly on the ACRs than on the MCR, and the rescue operations conducted on the ACRs require more resources than do those conducted on the MCR. Our study showed that rescue operations on the ACR exhibited a significantly higher probably of requiring a helicopter-based means of rescue. According to previous studies, the risk of accidents is greater for helicopter-based rescues than for ground-based rescues, and this enhanced risk must be taken into consideration whenever a rescue operation is requested.[16,17] The frequent use of helicopters to transport patients with minor injuries using the ACRs may increase risks for the rescue crews.[4]

The results of this study may serve as a reference for professionals seeking to reduce the number of casualties and overuse of helicopters by educating tourists on the appropriate use of maps and on how to evaluate the trails in relation to weather conditions. Moreover, to reduce accident rates, tourists wishing to enter the park should undergo more rigorous qualification procedures, especially those tourists planning to explore the ACRs. In addition, different trails in the same area were associated with different types of causalities. This finding should provide additional insight when evaluating and managing risk. Knowledge of the main risks of exploring an area may help improve the information available for visiting tourists. In addition, training programs for rescuers can also be targeted to the main problem areas of the route where they operate.

LIMITATIONS

Our study had several limitations. The greatest limitation of this study was its retrospective nature. The data were collected from reports generated for each incident, and the possibility of recall bias therefore could not be eliminated. Furthermore, the incident data were recorded by rescuers with varied medical and first aid training. Therefore, considerable variation was present in the details contained in the incident reports. Moreover, our study did not include victims who treated themselves or who sought medical services at mountain lodges as opposed to calling the mountain rescue teams. Thus, the overall accident rates were likely higher than reported in this study. Furthermore, additional studies are warranted to further refine triage and transport protocols to ensure that helicopter transport is offered only to patients for whom the potential benefits outweigh the risks. In addition, information that we did not have—including follow-up medical records and outcomes of the victims who were injured or ill, detailed records about the medical treatment provided at the scene, and information regarding the experience of the rescuers involved in each rescue—could be used to bolster our findings. Finally, we focused solely on YSNP and our sample size was, which limits the generalizability of our results. Additional large-scale studies that use data from various outdoor recreation sites are warranted.

Conclusions

Our study found that the overall accident and mortality rates were significantly higher on the ACRs than on the MCR. The percentages of the operations involving helicopter-based rescues and victims not requiring medical treatment were significantly higher on the ACRs than on the MCR. In other words, most of the rescues on the ACRs involved uninjured individuals requesting helicopter-based rescue after getting lost or trapped by weather conditions. The results of this study may serve as a reference in reducing the number of casualties and the overuse of helicopters by educating tourists who intend to use the ACRs about the appropriate use of maps and on how to evaluate the trails in relation to weather conditions. Our results also suggest the need to select rescue team members not only on the basis of their medical knowledge and familiarity with medical equipment, but also with consideration given to the most common medical diagnoses seen in individuals who engage in outdoor recreational activities. Overall, our analysis provides additional insight regarding the main risks associated with hiking and climbing on both MCR and ACRs in YSNP.

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ORIGINAL RESEARCH

Simulation-Based Drone Assisted Search Operations in a River

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Introduction—Drones can transmit live video and geographic coordinates during the planning stages for search and rescue operations and the operations themselves. There are few simulation studies in which drones provided rescue support. However, the literature does not contain any simulation studies involving the use of drones to locate lost "victims" represented by dummies in rivers. We developed a simulation model to compare the first visual contact times for drone-assisted search techniques (DAST) and classic search techniques (CST).

Methods—In this prospective experimental simulation study, we used both DAST and CST to perform a series of river searches for unconscious victims (represented by dummies). We calculated the first visual contact times, total scanned area, scanned area per minute, flight-walking distances, and flight-walking speeds and compared the results between both groups. The data are presented as mean±SD.

Results—We performed 20 search and rescue operations, 10 with the CST and 10 with the DAST. The time to reach the victim was 823±177 s using CST and 80±14 s using DAST. The area scanned by unit time was 3091±54 $m^2 \cdot min^{-1}$ using CST and 22,640±1622 $m^2 \cdot min^{-1}$ using DAST.

Conclusions—The drone-assisted search technique located a simulated victim drifting in a river faster than the classic search technique. The use of drones in search and rescue operations could improve the time to find victims.

Keywords: drowning, ground search, search and rescue, UAV

Introduction

According to World Health Organization data, drowning is the third leading cause of unintentional deaths worldwide, accounting for >236,000 deaths annually. The actual figures might be higher due to inadequate reporting.[1-6]

Ninety percent of these deaths occur in low- and moderate-income countries, and many occur in rivers.[1,2,5,6] Males and young people <25 y account for most of the drowning fatalities, and children <5 y are the highest risk group—however, the actual figures might be higher due to inadequate reporting.[6] The measures to protect against drownings vary depending on regional dynamics.[7] According to the World Health Organization data, factors leading to drowning deaths include a lack of protective barriers, adults failing to supervise children, inadequate swimming skills, the absence of warning signs in dangerous regions, alcohol consumption, water-borne transport, and natural disasters. Proper training of rescuers is one of the most important factors affecting mortality and morbidity in drowning cases.

There are several predictors of poor outcomes in drowning victims, such as the length of time the victim's head stays under water (submersion duration) and the time to restore oxygenation to the brain. According to the European Resuscitation Council and the American Heart Association, prolonged submersion times are associated with poor outcomes.[8,9] Finding victims as soon as

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possible is critical with regard to removing them from the water and administering medical intervention. Delays can lead to significant neurological or cardiopulmonary disabilities or death.

Different factors affect rescue efforts and the ability to find victims in river and lake drownings. It is often challenging to locate victims due to river currents, the incline of the watercourse, rugged terrain, and plant cover. Consequently, a substantial number of individuals involved in search and rescue operations may be involved in locating the victim.

Unmanned aerial vehicles—or drones—have increased in popularity and use over the past decade. They are currently employed in numerous ways both officially and by hobbyists, such as military operations, photography, distribution of aid packages during natural disasters, transportation of laboratory equipment, and distribution of medical equipment in search and rescue operations.[10-13] Drones are fast-moving, agile, capable of autonomous flight, and inexpensive. They can be used to obtain live images in challenging conditions, to transmit information to the coordination unit during operational planning, and to reach victims in search and rescue operations.[14]

Although there are experimental studies on search and rescue operations with drones, to our knowledge, no previous studies have considered the use of drones in the search for individuals at risk of drowning in rivers.[15,16] This study aimed to evaluate the practicality of using drones to locate simulated victims lost in rivers and compare the results with classic search techniques.

Methods

In this prospective experimental simulation study, search operations were conducted using dummies to simulate unconscious victims swept away in water at a temperature of 23°C on a sunny day in October 2020. The location was the Çoruh River in Bayburt, Turkey, 1480 m above sea level. The water flow rate was 2.4 km·h^{-1}. Both the drone-assisted search technique (DAST) and the classic search technique (CST) were used.

The primary endpoint of the study was to compare the times of the first visual contact with the victim by CST and DAST. Victim detection using CST involved a 2-member team searching along the river's edge and examining the watercourse. For the DAST searches, the drone pilot controlled the drone from the starting point and attempted to locate the dummy by examining live images transmitted to a tablet integrated into the drone's remote control system.

To determine the flow velocity of the river, we identified an area at the midpoint of the river 10 m wide using

Figure 1. To simulate the unconscious victim, boilersuits were filled with sawdust.

starting and ending points. A red plastic ball 10 cm in diameter was used as a floating instrument for calculating rivere plastic ball from the starting point and calculated how long it took to reach the endpoint. We repeated this process 4 times and the elapsed time was averaged. The water flow velocity was measured by calculating the distance covered in unit time and measured as 2.4 km·h^{-1} at the beginning of the simulation. River flow was not measured before each search.

We used dummies to simulate a typical unconscious victim drifting in the river. We prepared these dummies by filling boiler suits (coveralls) with dry sawdust. Each dummy was 180 cm tall and weighed approximately 40 kg (Figure 1). Ten dummies were prepared and assigned numbers. Wet dummies were not weighed after the study was performed.

The starting point was determined as 40°23'6.61"N latitude and 40°17'33.75"E longitude. A drone pilot, a local guide, a coordinator, and 4 different teams—1 throwing team (TT) and 3 search teams (STs) of 2 officials each (Figure 2)—were ready at the starting point. The TTs duty was to drop the dummies into the water. Each of the 3 STs consisted of 2 search and rescue officials who had received standardized training from the

Figure 2. Classic search technique; 2 search teams are searching for the dummy along the watercourse.

Figure 3. Picture of a dummy found by the drone.

Turkish Ministry of Health in basic search and rescue operations, including swift-water rescue, administering medical interventions at the scene, and learning various response techniques in natural disasters (avalanches, floods, earthquakes, etc). All the STs had cell phones with internet connections and could establish the global positioning system (GPS) location of the first visual contact point. The coordinator created a WhatsApp messenger group consisting of all the STs and the coordinator to facilitate communication and save the GPS data. The coordinator's task was to set the time for each search operation, alerting the search teams and the drone pilot to begin the search operations.

The study used a DJI Mavic 2 Pro (SZ DJI Technology Co., Ltd., Shenzhen, China) brand drone, which can transmit live video and 4K (3840x2160) video recordings, with a range of 8 km and speeds up to 72 $km{\cdot}h^{-1}$ (in sport mode). It was operated by a drone pilot licensed by the Turkish Civil Aviation General Directorate. The drone pilot monitored live images taken by the drone using an iPad Pro 11 tablet linked to the remote control. The drone also recorded the images onto a microSD card inside the drone. Three spare drone batteries were kept ready and charged during the study to avoid battery problems. Because the drone recorded its route and flight coordinates, it subsequently recorded the first visual contact points using a DJI Go 4 app on the iPad Pro 11.

For the first rescue operation, dummy-1 was dropped into the water by the TT. After 3 min, the coordinator alerted the drone pilot and ST-1 to search for the dummy simultaneously. ST-1 began its search operation following the river course direction on one side of the riverbank. The entire riverbed could be seen from one side of the river because of the sparse plant cover around the river and the acceptable transparency of the water. For this reason, a one-side search operation was enough to conduct the CST operations. The clock was started when the search commenced, and it was stopped when ST-1 established the first visual contact. The coordinator recorded the total search time at this time. ST-1 recorded the GPS information for the first visual contact point using WhatsApp's location-share function and shared it with the coordinator via the WhatsApp group. For the DAST operations, the drone pilot started the search simultaneously with ST-1. The coordinator started the clock, and the drone pilot elevated the drone to a height of 50 m. The camera angle was directed toward the watercourse, and the search began downstream (Figure 3). When the drone pilot made his first visual contact with the dummy, the coordinator recorded the time elapsed. The drone recorded the first visual contact location on the flight records. After all search operations ended, the coordinator saved the GPS data from the DJI Go 4 application. The drone then flew back to the starting point and waited for the next search operation. After CST and DAST operations finished, ST-1 retrieved dummy-1 from the river, returned to the starting point, and rested for their next search operation.

The second search operation started with dummy-2, which the TT dropped into the water. After 5 min, the coordinator alerted both the drone pilot and ST-2 to begin their search operation simultaneously, following the same procedure that was explained previously.

The same procedure was repeated 8 more times using new dummies each time and varying the waiting times before beginning each search according to the following schedule: 8, 10, 15, 20, 25, 30, 35, and 40 min. In total, 10 search operations were conducted using new dummies for each search. One of the STs took part in each search operation and the same drone was used for all search

Table 1. Simulation results for the classic search and the drone-assisted search techniques

			Classic search technique					*Drone-assisted search technique*				
Waiting time (min)	*Dummy number*	*Search team number*	*First visual contact (s)*	*Total scanned area (m^2)*	*Scanned area per min ($m^2 \cdot min^{-1}$)*	*Walking distance (m)*	*Walking speed ($m \cdot min^{-1}$)*	*First visual contact (s)*	*Total scanned area (m^2)*	*Scanned area per unit time ($m^2 \cdot min^{-1}$)*	*Flight distance (m)*	*Flight speed ($m \cdot min^{-1}$)*
3	1	ST-1	144	7413	3089	180	75	24	5959	14,897	157	393
5	2	ST-2	224	12,214	3271	364	97	34	7862	13,875	226	398
8	3	ST-3	405	19,708	2920	568	84	44	14,408	19,647	423	576
10	4	ST-1	491	25,525	3119	695	85	51	17,430	20,506	461	543
15	5	ST-2	774	39,984	3100	1048	81	64	25,479	23,887	684	641
20	6	ST-3	821	42,488	3105	1096	80	91	38,964	25,690	985	660
25	7	ST-1	886	50,907	3447	1378	93	99	45,214	27,402	1137	689
30	8	ST-2	1165	58,099	2992	1532	79	108	47,660	26,478	1238	685
35	9	ST-3	1358	67,913	3001	1811	80	129	58,423	27,174	1520	707
40	10	ST-1	1962	93,621	2863	2361	72	155	69,346	26,843	1809	700
Mean			823[a]	41,787[b]	3091[c]	615[d]	83[e]	80[a]	33,074[b]	22,640[c]	864[d]	599[e]
SD			177	8518	54	216	2	14	6972	1622	178	38
95% CI			423-1223	22,517-61,057	2969-3212	615-1592	77-88	49-111	17,303-48,846	18,971-26,309	462-1267	513-685

ST, search team.

Mann-Whitney *U* test was used for all comparisons.

[a,c,e] $P<0.001$;

[b] $P=0.496$;

[d] $P=0.406$.

The data specified with the same superscript were compared statistically among themselves.

Figure 4. View of the total search area and found points, on Google Earth Pro screen.

operations (Table 1). Each ST then rested until it was their turn to conduct another search. All search operations were completed on the same day.

For both the CST and DAST operations, we calculated the scanned area and flight/walking distance for each search using Google Earth Pro (Figures 4 and 5). We calculated first visual contact times, total scanned area, scanned area per min and walking and flight speed data. The data were analyzed using SPSS 23.0 software (IBM, USA) and are presented as mean±SD with 95% confidence intervals. Intergroup comparisons were made by applying nonparametric Mann-Whitney *U* tests. Confidence levels were chosen and statistical significance was set at $P<0.05$.

Figure 5. Method of calculating the area of the riverbed scanned from the starting point to the point of first visual contact (using Google Earth Pro).

Results

For the CST operations, the first visual contact time was calculated as 823±177 s. For the DAST operations, the first visual contact time was calculated as 80±14 s ($P<0.001$). For the classic search, the average river surface area scanned per minute was calculated as 3091±54 $m^2 \cdot min^{-1}$ as compared with 22,640±1622 $m^2 \cdot min^{-1}$ for the DAST searches ($P<0.001$). The data obtained from the study are shown in Table 1. Walking and flight speeds represent average values for each search separately.

Discussion

The principal finding from this study is that the simulated victim was located significantly faster in all drone-assisted search operations. Time is a crucial criterion, especially in submersion cases. According to the ERC 2021 resuscitation guideline, a shorter submersion duration is associated with better outcomes.[8] In addition, the American Heart Association's adult basic life support 2020 guideline emphasizes that people with <5 min of submersion time have better neurological outcomes than those who stay underwater longer.[9] Survival probability is extremely low in water warmer than 6°C if the submersion time is >30 min. In waters colder than 6°C, the probability of survival is extremely low if the submersion time is >90 min.[17] However, if the water is excessively cold, the resulting hypothermia may offer neuroprotection compared with average body temperature, and there may be a better chance of survival as the submersion time increases.[18]

First visual contact times were significantly shorter using DAST compared with CST ($P<0.001$). The time spent locating a victim is very crucial in search and rescue operations, which cannot proceed to the next stage without finding the victim. If the location of a victim is accessible, shortening the first visual contact time may reduce the time spent initiating rescue operations. In contrast, if accessing a victim is impossible or challenging, no relationship can be established between first contact and removal time.

The water flow speed in the present study was 2.4 $km{\cdot}h^{-1}$. Given that a river's speed of flow may vary at different locations in the river course, we measured water flow speed at the river center and the closest point from the surface, where a river has the highest velocity. River flow velocity could have been perceived as low, but the literature does not define an ideal water flow velocity for this kind of simulation study.

Rescuers play a critical role in river drowning cases. All rescuers risk their lives. There is a high prevalence of fatal and nonfatal drowning among untrained persons attempting to perform in-water rescues.[19] The search area can sometimes be huge in search operations, and accordingly, the search team may consist of many people. Drones can locate victims using fewer personnel and speed up the transition to the rescue phase of the operation. The use of drones means that fewer search and rescue personnel will need to work in risky areas.

The literature contains studies of different drone-assisted search simulations performed in a variety of scenarios, all of which generated their methodologies to approximate real-world experience as closely as possible.[15,16,20] In our study, we tried to simulate as close to reality as possible a search for a victim drifting in a river.

It may be more beneficial in actual search and rescue operations to apply a hybrid method with live images obtained from drones to locate the victim and the rescue performed by search and rescue teams. This technique is currently used in some search and rescue operations, but there is no detailed study examining this issue in the literature.

Study Limitations

In drone-assisted search operations, certain conditions can challenge the drones' technical capabilities, such as bad weather, plant cover in the search area, and the level of visibility. Different weather and terrain conditions (such as trees, rocks, and current velocity) can also affect the time it takes to locate the victim in classic search operations. For our study, we had favorable weather conditions and accessible terrain. Our study did not assess performance in high water flow conditions or with different numbers of search officials.

We used the WhatsApp messenger for communication and mobile data service quality was good in the study area. Radio communications are an alternative means of communication that can be used depending on regional requirements.

Search and rescue simulations present several inherent challenges, including selecting the proper dummy, and our choice of dummy could be considered the principal limitation of our study. We used dummies with blue apparel, and this color choice might have helped our searches. The color and design of the apparel on a dummy can increase the dummy's visibility. The dummies' composition may produce different reactions after contact with water. Thus, drifting or submerging characteristics may differ. We prepared these dummies by filling boiler suits with dry sawdust. The approximate weight of each dummy was 40 kg. However, we did not weigh the wet dummies to determine whether they reached actual adult human weight after contact with water. Therefore, we cannot comment on whether our dummies could simulate the mass of an unconscious victim drifting in the water.

Conclusions

The drone-assisted search technique located a simulated victim drifting in a river faster than the classic search technique. The use of drones in search and rescue operations could improve the time to find drowning victims, which may potentially affect survival.

Author contributions: Study concept and design (MC, SP, AG); acquisition of the data (MI, MY, MFB); analysis of the data (MC, MY, MFB); drafting of manuscript (MC, MI, MY, MFB); critical revision of the manuscript (MC, SP, MI, AG); approval of the final manuscript (all authors).

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CONCEPTS

Management of Live Insects in the External Auditory Canal: A Wilderness Perspective

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A live insect within the external auditory canal is an unpleasant possibility during wilderness recreation. To our knowledge, no study has attempted to quantify the risk of this event occurring in the wilderness. However, such events anecdotally seem to occur with some regularity in a variety of climates. Most cases are benign, but a small subset of patients can develop complications including infection, hearing loss, and vestibular complaints related to the foreign body. In the emergency department or clinic, removal of the insect is a simple procedure in most circumstances; however, the material and expertise required for backcountry removal of the insect are often limited. With this consideration in mind, we offer a conservative approach to backcountry insect removal based on a selective review of the published literature on this topic. Where published data are lacking, we make recommendations based on anecdotal experience of the authors dealing with this condition in austere environments and in the emergency department. We recommend insect removal only if the patient is acutely symptomatic and the insect is visualized and graspable with the instrument used for removal. In any other circumstance, intervention should be deferred until definitive care is reached because of risks of complications associated with removal, including infection, bleeding, and tympanic membrane damage.

Keywords: ear, foreign bodies, cockroach, vertigo

Introduction

Having an insect take up residence in one's external auditory canal is an unfortunate potential complication of sleeping outside. It can be a significant source of disability that results in shortened or aborted backcountry trips. There was a dramatic example in July 1957. At the Boy Scouts of America's National Jamboree in Valley Forge, Pennsylvania, 186 campers experienced Asiatic garden beetles crawling into their ear while they slept.[1] We discuss the current evidence behind the decision to intervene on a retained insect in the ear that does not spontaneously resolve, and the more commonly accepted clinical practices for management of this condition in the austere, low resource environment of the backcountry.

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Methods

A search query with the keywords "insects" and "external auditory canal" was entered into the PubMed database. This yielded 56 publications, including formal research, case reports, and case series. Each of these publications were manually searched for results sections with quantitative data related to the extrication of insects from the external auditory canal. These papers were prioritized for inclusion in the manuscript. Two additional publications not included in the PubMed search were also used from select wilderness medicine textbooks. The textbooks were chosen based on the authors' prior knowledge of their information on wilderness medical kits. After reading cited literature on the insecticidal activity of different reagents,[2] an additional PubMed search was undertaken with each of their reagents as a keyword

along with "ototoxicity." We combined all of these reports with our own experience in the wilderness and in the emergency department to generate our recommendations for insect removal.

EPIDEMIOLOGY

Foreign bodies in the ear are a common complaint in the emergency department setting, and of these, a significant proportion are the result of insects in the external auditory canal. In the adult population, it is estimated that up to 80% of presentations with the chief complaint of external ear foreign body are due to live insects.[3-5] In the pediatric population, due to children's proclivity to intentionally place objects in the external auditory canal, this is a lower but still significant 4 to 20%.[6,7] The most common insect causing such problems is the American cockroach, which is estimated as the culprit in 50% of insects in the ear.[1] Anecdotally, the majority of emergency department presentations for retained insects happen during routine activities near the home, but prolonged outdoor trips seem to increase the risk.

CLINICAL MANEFESTATIONS AND DIFFERENTIAL DIAGNOSIS

The decision to attempt removal of an insect in the wilderness should be systematic and thoughtful. The initial symptoms of a retained insect may be mild, with only 12 to 36% of patients experiencing otalgia, hypoacusis, or otorrhea; however, up to 20% can experience complications (discussed herein).[4,8]

In most patients, the clinical history and direct visualization alone are sufficient to diagnose an insect foreign body. However, it is important to consider a broad set of pathologies when presented with a less revealing presentation. A preliminary differential diagnosis for acute otalgia with otorrhea and hypoacusis includes otitis media with tympanic membrane perforation, cerumen impaction, cholesteatoma, otitis externa, otomycosis, and barotrauma in the right clinical setting. Because otoscopy is not feasible in the wilderness setting, it can be difficult to differentiate these entities if there are no distinguishing features on external inspection.

COMPLICATIONS OF INSECT RETENTION AND REMOVAL

The most common adverse event of removal of an ear foreign body outside of care by an otolaryngologist is damage to the external ear canal.[4] While complication rates after removal by an otolaryngologist are as low as 4%, that risk increases to 48% when the procedure is carried out by a nonotolaryngologist.[4] One study did estimate a complication rate of 26% when performed by otolaryngology, but the authors noted that they did not consider prior unsuccessful removal attempts by other medical or nonmedical persons.[9] The most common complication identified was a meatal laceration, occurring 15% of the time.[9] Less common were tympanic membrane perforation and otitis externa, occurring in 74% of removals.[9] There is no known data to suggest how complication rates in the wilderness compares to complication rates by otolaryngology in the emergency department. Complication rates of ear foreign body removal could further be stratified into graspable and nongraspable groups, with the graspable group having a higher success rate (64 vs 45%) and lower complication rate (14 vs 70%).[6] It is important to consider infectious sequela of these potential meatal lacerations when definitive medical care is not readily available. Acute otitis externa was documented in 3 to 7% of removals by nonotolaryngologists.[4,9] These relatively minor complications, when left untreated, can lead to more severe complications. Although rare, these include ossicle damage and potentially fatal conditions like mastoiditis, osteomyelitis, and cavernous sinus thrombosis.[10,11]

The risks of leaving an insect in the ear while completing the trip should also be considered. There is a theoretical risk of trauma caused by continued movement of the retained insect, as well as sequela of such trauma, including infection and bleeding. It is often difficult to distinguish between trauma caused by the insect prior to removal versus trauma occurring during the removal procedure itself. There are rare case reports of serious infections including skull base osteomyelitis and cavernous sinus thrombosis due to retention of an insect in the ear, but complications seem to have occurred 10 or more days after an unsuccessful removal attempt.[11] In general, it is thought that leaving the insect, even if there is sensation of animation, is safe if the patient is able to tolerate the symptoms.[12]

INDICATIONS FOR REMOVAL

Given the potential complications of removal, if the patient is asymptomatic, we recommend observation only until out of the wilderness. Treatment should then be performed in the hospital or office setting by a clinician, preferably an otolaryngologist.

If the patient is acutely symptomatic, consideration can be given to killing the insect using the methods described below. After killing the insect, the patient should be reassessed for continuation of distressing symptoms, including otalgia. If the patient continues to be symptomatic, then

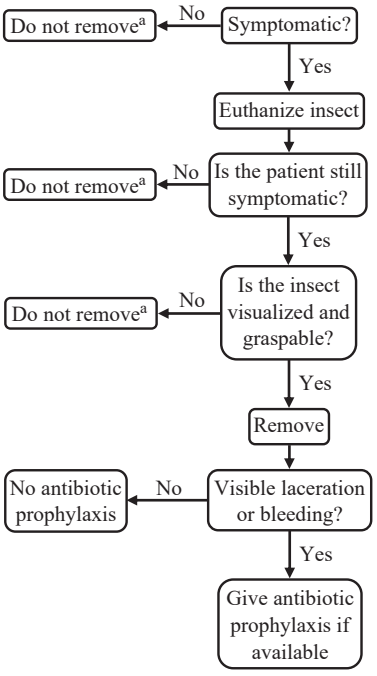

Figure 1. Decision tree for wilderness removal of intra-aural insect foreign body. [a]Once the trip has finished, seek removal by a medical professional.

risk of injury during removal should be weighed against the benefit of dislodging the insect.

REMOVAL TECHNIQUE

In the controlled hospital setting, a clinician has many tools at their disposal for the killing and removal of an insect; however, many of these tools are not common in the wilderness setting. Most adventurers will not carry an otoscope to aid in visualization of the insect. Of the items recommended by the Wilderness Medical Society to be carried in a wilderness medical kit, the items of potential utility in insect foreign body removal are as follows: tweezers, lidocaine, ethanol pads, and povidone/iodine swabs. Oral antibiotic pills (eg, amoxicillin-clavulanate, ciprofloxacin, or doxycycline), water, salt, vegetable oil, and soap are also helpful adjuncts in management.[13] Other common agents used for insect protection, including DEET and various other sprays, have not been studied in the context of insect removal from the external auditory canal, so we cannot recommend them.

The strategy for removal of an animate ear foreign body consists of 2 steps: killing/immobilizing the insect followed by removal. This stepwise approach is done to ensure the insect does not damage the external auditory canal during the removal (Figure 1).

Insecticides used for extermination of insects are generally split into 3 groups: anesthetics, antiseptics, and miscellaneous liquids (eg, water, saline, soapy water). In a study of the efficacy of different insecticides in vitro, all 3 groups can effectively kill insects (eg, roaches, bees, and beetles) with the exception of ticks, which did not die even after 3 min of submersion.[2] A faster time-to-kill is ideal, as it minimizes the time the insect has to react and cause further harm to the external auditory canal.

Of the 3 aforementioned categories, antiseptics seem to be the most efficacious, resulting in faster kill times than anesthetics or miscellaneous liquids in an in vitro setting.[2] The most likely antiseptics to be available for use in the backcountry are ethanol, povidone/iodine solution, and vegetable oil, which kill either via direct toxicity or suffocation. Of these, vegetable oil and ethanol appear to be the most efficient options, with mean times-to-kill of 28 and 30 s, respectively.[2,14] Povidone/Iodine is the next most potent at 58 s. Of note, chlorhexidine is often proposed as an effective killing agent; however, we recommend against its use due to the side effect of ototoxicity.[15] Of the miscellaneous liquids, soapy water was quickest at 67 s, followed by hypertonic saline at 84 s, saline at 158 s, and water at 180 s.[2] It is important to qualify these data as measured in a controlled laboratory setting, and significant departures from these killing times should be expected in the wilderness setting. In our experience, reapplication of the killing agent may be required if the patient continues to have animate foreign body sensation after the initial killing attempt.

Of the anesthetic options, lidocaine is most commonly used in the emergency department setting and the best studied in the literature. Many popular wilderness medical kits have a small amount of topical anesthetic available, and many wilderness-oriented health groups recommend bringing lidocaine on general expeditions.[13,16] While lidocaine and other similar topical anesthetics have been shown to be effective, the risk of vertigo should be considered.[17,18] The pathophysiology of vertigo is uncertain, but thought to be the result of lidocaine infiltration into the middle ear then through the round window into the inner ear, where it exacts its sodium-channel antagonism on receptors in the membranous labyrinth.[19] This risk would presumably be higher in a patient with a tympanic membrane perforation. Varying degrees of vertigo were reported in 4 of 9 subjects of a case series where lidocaine was injected over the promontory of the cochlea prior to eighth nerve monitoring.[18] Such a scenario simulates a tympanic membrane perforation and the patients had severe symptoms as a result: 6 to 9 h of incapacitating dizziness, staggering gait, and nausea with or without vomiting.[17,18] And although tympanic membrane perforation is diagnosed via otoscopy, vertigo is possible with

an intact membrane.[17,20] In the austere environment, such debilitation can be a great hazard, not only for the patient but also for the rest of the team, who are tasked with the care of a patient while they themselves are exposed to the elements. In the case series above, symptoms were resolved with antiemetic agents.[18]

The agent used for euthanization will likely be decided based on availability. However, if multiple options are available, we recommend vegetable oil as the first line based on reported killing ability and low risk profile.[2] Anecdotally, we have found success with the viscous vegetable oil compared to other liquids because vegetable oil allows for a small amount of movement of the patient's head during euthanasia without the oil quickly draining from their ear. Ethanol, povidone/iodine, hypertonic saline, soapy water, or water (ensuring the water is potable) is a viable alternative agent depending on available resources.[2,14] Because of the debilitating effects of vertigo, we recommend against the use of lidocaine and other topical anesthetics if the decision to remove a live insect is pursued. Once an agent has been chosen, it is important to warm the liquid to near body temperature prior to infusion, as cold-water irrigation can precipitate vertigo.

The second step of insect foreign body removal is the removal itself. Although no studies have been done to investigate whether euthanization of the insect reduces symptoms before removal, the authors' clinical experience has found this to be the case. Therefore, even if the patient is initially symptomatic, their symptoms should be reassessed post-insect euthanasia to determine whether removal should be considered. Because the instrument being used to remove an insect will likely be basic tweezers or forceps, it is important for the medical provider to be confident in their ability to remove the insect. As discussed above, a prerequisite for removal is that the insect be graspable, as non-graspable objects have higher failure and complication rates than graspable ones. Another factor to consider is the physical properties of the bug itself. A study observing the success rates of emergency department providers showed that the shape and hardness of the foreign body can greatly affect the difficulty of removal.[21] This study employs the terms of "soft, irregular" and "firm, rounded" to characterize the foreign body. Using mostly forceps or flushing, "soft, irregular" objects were successfully removed 86% of the time. In contrast, "firm, rounded" objects were only removed by the same methods in the emergency department 34% of the time.[21] In the wilderness, it is reasonable to assume success rates for removal would be even lower than in the emergency department when using similar removal methods.[9] A 67% success rate is seen when direct visualization alone is used for removal.[9] In addition, it is the authors' experience that even after removal of superficially-located insects, insect parts tend to remain in the external auditory canal. Because of that, the potential benefit of avoiding a clinic visit with wilderness removal is negated, as follow-up should occur to ensure complete removal. Negative consequences of removal discussed above should also be considered carefully before removal. If removal is deemed too difficult or the patient is no longer symptomatic, the dead insect should be left in place until removal can be performed by a trained provider in a definitive clinical setting.

If the decision is made to remove the insect, proper technique is important to maximize success rates.[21]

1) Visualization. Adequate visualization should be a requirement prior to removal of the insect. In the wilderness, perhaps the most beneficial light source will be a camper's headlamp. If the insect is visualized but retreats farther into the ear canal when stimulated with the light source, the removal should be aborted.
2) Preparation for irrigation. Once an available irrigation solution has been chosen as discussed, make sure the solution is as close to body temperature as is feasible. Then fill a container that will allow for a pressurized stream of solution during irrigation. We recommend a 60 mL syringe with a narrow tip if available. If a syringe is not on hand, creation of a small perforation in an improvised container (eg, a clean, compressible water bottle or plastic bag) may serve as a possible alternative.
3) Irrigation. Direct steady stream of irrigation solution behind the insect in the external auditory canal. Multiple washes can be used. Wait several minutes and reassess the insect's position and movement. In the ideal irrigation, the insect will become dislodged and become easier to remove.
4) After allowing time for euthanization and reassessing the patient's symptoms, attempt removal of the insect with the smallest available forceps under direct bright light visualization. During removal, take note of debris that remains in the external ear.

ALTERNATIVE REMOVAL TECHNIQUES

Various other techniques have been described both anecdotally and within the literature that could be feasible in a resource poor pre-hospital setting, including light assisted removal,[22] and cyanoacrylate (superglue)[23] added to cotton swabs. The authors have not seen such techniques employed in either the clinic or austere settings. If providers have experience with these techniques, they may be viable. However, partial or full occlusion of

the external auditory canal with adhesive material is a likely complication, especially in the anxious patient who is not completely still.

POST-REMOVAL CONSIDERATIONS

Once an insect has been successfully removed from the ear, further management of symptoms is important to maximize patient comfort and reduce risk of infection. Pain within the ear canal can be expected in the period after insect removal and is reasonable to treat with basic analgesics brought on the trip, including acetaminophen and ibuprofen. People with signs and symptoms of active infection, including fever, spreading erythema, and purulent discharge should be immediately evacuated if possible. Patients with comorbidities that predispose to malignant otitis externa (eg, diabetes, immunosuppression) should carry a lower threshold to begin evacuation. Additionally, intractable vertigo should also be evaluated as these patients can decline quickly and lose the ability to participate in their own extrication from the austere environment.

It is generally accepted that patients with evidence of external auditory canal trauma after removal should receive antibiotic ear drops, typically of the fluoroquinolone class.[24,25] If tympanic membrane rupture is suspected, only fluoroquinolone drops should be used to avoid middle ear ototoxicity caused by other antibiotic classes. However, the rate of infection after foreign body removal in patients who either have or have not received antibiotic drop prophylaxis is not well studied. Oral antibiotic prophylaxis after external auditory canal trauma, on the other hand, is not routine management and there is no proven efficacy of this practice. We therefore recommend using clinical judgement before administering oral antibiotics for minor ear trauma. Systemic antibiotics carry risks of their own, including allergic reactions and diarrheal disease. Consider basic wound care alone (eg, boiled water irrigation with careful monitoring for signs of infection) in cases of minor trauma.

While there is little data on the pathogenicity of skin infections in the wilderness, it is reasonable to assume that common skin flora (eg, staphylococcus and streptococcus species) are major contributors to otitis externa in the wilderness. We recommend treatment with amoxicillin/clavulanate, a cephalosporin of any class, doxycycline, or trimethoprim/sulfamethoxazole.[18] Pseudomonas infection is an additional concern specific to otitis externa, and is best treated with an oral fluoroquinolone like ciprofloxacin if ear drops are unavailable. Additional research is needed to identify wilderness-specific causes of otitis externa and skin and soft tissue infections in general, as etiology likely varies widely by environment.

Conclusions

Live insects within the external auditory canal represent a rare but potentially debilitating condition across a wide range of expedition environments. We recommend that euthanasia of insects, ideally using vegetable oil or ethanol, be attempted in symptomatic cases. Insect removal should not be attempted unless the patient continues to be symptomatic post-euthanasia and the benefit of removal is deemed to outweigh the risks (infection, middle ear trauma).

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CASE REPORT

Russula subnigricans Poisoning Causes Severe Rhabdomyolysis That Could be Misdiagnosed as Non-ST Segment Elevation Myocardial Infarction

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Mushroom poisoning and subsequently the number of patients visiting emergency rooms are increasing, as well as the proportion of fatal mushroom poisonings. Myocytic mushroom poisoning is one of the new clinical classifications. This report documents the course of a family with *Russula subnigricans* poisoning complicated by severe rhabdomyolysis, including a case that was misdiagnosed as myocardial infarction. A 64-y-old man visited our hospital with symptoms including substernal chest discomfort, nausea, vomiting, and myalgia, lasting for 12 h. His laboratory tests showed elevated serum high-sensitive troponin I. He was diagnosed with non-ST segment elevation myocardial infarction. After that, 2 family members who ate mushrooms together were transferred from a local emergency room with the diagnosis of rhabdomyolysis. Consequently, rhabdomyolysis due to mushroom poisoning was diagnosed. They were hospitalized in the intensive care unit. After admission, conservative management, including primary fluid resuscitation, was performed, and the patients were discharged without complications. *R subnigricans* poisoning was revealed after investigation and should be considered in mushroom poisoning with rhabdomyolysis. Early recognition and intensive supportive care are important for mushroom poisoning patients.

Keywords: mushroom toxicity, diagnostic error, cyclopropylacetyl-(R)-carnitine

Introduction

Picking and eating wild, uncultivated, or foraged mushrooms have become popular in recent years. More than 2000 species of mushrooms found worldwide are safe for human consumption; however, there are no easily recognizable differences between nonpoisonous and poisonous mushrooms, which is why amateur foragers occasionally confuse toxic mushrooms for edible ones.[1] Consequently, cases of mushroom poisoning and the concomitant number of patient visits to the emergency department are increasing.[2] One study showed that the majority of reported mushroom exposures (86%) had benign outcomes[2], however, the proportion of fatal mushroom poisoning seems to be increasing.[1] Since the 1990s, several toxic mushroom species have been reported to cause unique toxidromes following their ingestion.[3] New wild mushroom toxidromes include subacute myopathy with subsequent rhabdomyolysis following the ingestion of *Russula subnigricans* (blackening russula).[3] *R subnigricans* is a mushroom first found in Japan in 1955.[4] Since then, it has also been found in Taiwan, China, and has sometimes been reported in the southeastern United States. Here, we present a case of a family with *R subnigricans* poisoning complicated with severe rhabdomyolysis, including 1 patient who was misdiagnosed with myocardial infarction.

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Cases

Four people from 1 family, including 2 men and 2 women, had dinner including wild mushrooms that had been picked from the forest of Yangsan-si,

Table 1. Background date, vital sign, and laboratory findings of 4 patients with *Russula subnigricans* poisoning at the time of emergency department admission

	Normal range	*Patient 1*	*Patient 2*	*Patient 3*	*Patient 4*
Age, y		64	44	36	63
Sex		M	M	F	F
Blood pressure, mm Hg		124/79	155/30	123/82	160/100
Heart rate, beats·min^{-1}		94	82	85	76
Respiratory rate, breath·min^{-1}		18	14	14	16
Body temperature, °C		37	36	37	37
Oxygen saturation, %		98	98	98	96
Hemoglobin, g·dL^{-1}	13.5–17.5 M 11.5–15.5 F	14.8	16.7	12.4	13.4
Hematocrit, %	40.0–52.0 M 36.0–48.0 F	39.4	46.6	36.7	39.2
Leukocyte count, 10^3·uL^{-1}	4.0–11.0	11.3	10.4	12.0	4.9
Seg neutrophil, %	40–73	78	80	82	40
Platelet, 10^3·uL^{-1}	140–400	203	200	239	384
C-reactive protein, mg·dL^{-1}	0 – 0.5	0.09	0.05	0.13	0.24
Blood urea nitrogen, mg·dL^{-1}	6.6–23.6	12.9	13.9	9.3	18.2
Serum creatinine, mg·dL^{-1}	0.67–1.17 M 0.51–0.95 F	0.86	0.95	0.78	0.60
Sodium, mmol·L^{-1}	136–146	134	137	136	137
Potassium, mmol·L^{-1}	3.5–5.1	4.1	4.4	4.5	4.0
Chloride, mmol·L^{-1}	101–109	103	105	106	105
Aspartate aminotransferase, IU·L^{-1}	0–50	80	459	193	22
Alanine aminotransferase, IU·L^{-1}	0–50	36	174	55	21
Creatinine kinase, U·L^{-1}	0–171	7685	31371	9640	129
CK-MB, ng·mL^{-1}	0.5–3.1	250.4	>300	>300	2.0
Myoglobin, ng·mL^{-1}	12–80	>3811	>3811	3346	27
High sensitive troponin I, pg·mL^{-1}	0–19.8	63.8	62.2	8.8	<2.3
PT(INR), s	11.5–15.4 (0.8–1.2)	12.9 (1.0)	12.6 (0.9)	13.6 (1.0)	12.4 (0.9)
aPTT, s	28.3–43.8	31.5	35.2	35.4	35.5
D-dimer, ug·mL^{-1}	<0.5	<0.27	<0.27	<0.27	<0.27

CK-MB=creatinine kinase myocardial band.

Gyeongsangnam-do, Republic of Korea in August, late summer, 2019.

A 64-y-old man (Patient 1) visited the emergency department of Pusan National University Yangsan Hospital with symptoms including substernal chest discomfort, nausea, vomiting, and myalgia, lasting for 12 h. He had a medical history significant for hypertension, diabetes, and coronary artery disease. His vital signs were stable (Table 1). Electrocardiogram (ECG) showed sinus rhythm and right bundle branch block, and there was no difference from the ECG obtained 2 d prior in the outpatient department. His laboratory tests showed elevated serum high-sensitive troponin I (hs-TnI) and creatinine kinase myocardial band (CK-MB) (Table 1). His symptoms and findings were consistent with the diagnosis of non-ST-segment elevation myocardial infarction (NSTEMI), and a coronary angiography was planned.

After that, Patient 2 (son-in-law of Patient 1) and 3 (daughter of Patient 1) were transferred from a local emergency room (ER) with a diagnosis of rhabdomyolysis. They had eaten mushrooms 36 h before admission to the ER and complained of similar symptoms to Patient 1. Neither of them had a significant medical history. Their hemodynamic conditions were stable. Their laboratory tests revealed elevated creatinine kinase (CK) and myoglobin levels (Table 1). Rhabdomyolysis was diagnosed in both patients, and they were hospitalized in an intensive care unit.

When Patients 2 and 3 arrived at Pusan National University Yangsan Hospital, where Patient 1 was admitted, the additional history that he had also shared the meal containing foraged mushrooms was conveyed to his clinical team, and they then suspected he was also suffering toxicity from mushroom ingestion. Echocardiography and serial cardiac enzyme sampling were performed to differentiate the presenting symptoms from those of NSTEMI at 2 h after the emergency department visit of Patient 1. Echocardiography showed normal left ventricle size and contractility, and there was no definite

Figure 1. Leftover mushrooms from case.

regional wall motion abnormality. Cardiac enzymes were not significantly elevated from the baseline level (CK 7685 $U \cdot L^{-1}$, hs-TnI 75 $pg \cdot mL^{-1}$), CK-MB >300 $ng \cdot mL^{-1}$). Rhabdomyolysis due to mushroom poisoning was then diagnosed, and Patient 1 was hospitalized in an intensive care unit for close observation and treatment.

Patient 4 (wife of Patient 1) was initially admitted to the emergency department of another hospital for mushroom poisoning investigation. She had mushrooms for dinner with her family, and immediately after mushroom ingestion, she developed nausea, vomiting, and diarrhea. She was treated and, after her symptoms improved, discharged. Two days later, she visited the Pusan National University Yangsan Hospital emergency room, but she had no specific complaints. Her hemodynamic status was stable and laboratory test results were unremarkable. She was discharged from the emergency department.

For the analysis of toxic substances, a picture of mushroom leftovers (Figure 1) was sent to a mycologist via mobile phone, and specimens of the mushrooms along with blood and urine samples of all family members were sent to the Forensic Toxicology Department, National Forensic Service, Wonju-si, Gangwon-do, Korea. The mushrooms were identified as *R subnigricans* based on gross morphology, and cyclopropylacetyl-(R)-carnitine, an indicator component of *R subnigricans,*[5] was detected in mushroom leftovers and urine samples, but was below the detection limit in blood samples.

After admission, primary fluid resuscitation was performed to prevent renal failure and failure of other organs as a consequence of rhabdomyolysis. Serum CK and myoglobin levels further increased on the day after admission. However, 3 d after hospitalization, serum CK and myoglobin levels gradually declined (Figures 2 and 3), and most of the symptoms, including chest pain, myalgia, nausea, and vomiting, disappeared. The patients were discharged without any complications after hospitalization for 7 to 10 d.

Discussion

A new type of mushroom poisoning has been identified in recent years. Several case series of *R subnigricans* poisoning with rhabdomyolysis have been reported in China, Japan, and Korea.[6,7] The most severely ill patients presented with electrolyte disturbances (hyperkalemia, hypocalcemia), respiratory failure, acute renal failure, pulmonary edema, ventricular tachycardia, and circulatory shock. A possible cause of rhabdomyolysis after the ingestion of *R subnigricans* is cycloprop-2-ene carboxylic acid.[8] The mechanism of this toxin is the depletion of ATP within myocytes, which leads to an unregulated increase in intracellular calcium, resulting in myocyte disintegration.[8] In the case presented here, 3 people from 1 family developed severe rhabdomyolysis due to *R subnigricans* poisoning.

In this case, Patient 1 was admitted to the emergency room with chest and back pain. He was misdiagnosed with NSTEMI because of chest pain and elevated cardiac enzyme levels. However, additional medical history revealed that the same wild mushrooms were consumed by him and his family members who developed rhabdomyolysis. Furthermore, dynamic changes >50% in hs-TnI levels from presentation to a 3-h retest identifies patients at high risk for acute coronary syndrome,[9] but there was only a slight change between consecutive hs-TnI tests in Patient 1. Also, to improve on the cardiac specificity of CK for the diagnosis of acute myocardial infarction, measuring both total CK and CK-MB is recommended. A CK-MB to CK ratio of >6% is specific for myocardial injury, whereas a ratio of <6% in consistent with skeletal muscle damage or noncardiac causes.[10] In Patient 1, the CK-MB (250 $ng \cdot mL^{-1}$) to CK (7685 $U \cdot L^{-1}$) ratio was 3%, consequently myocardial infarction could be excluded. In addition, there was no regional wall motion abnormality on echocardiography and no abnormal ECG findings. Therefore, diagnosis was confirmed as rhabdomyolysis induced by mushroom poisoning rather than myocardial infarction. Cardiac troponin I (TnI) elevation is common among patients with rhabdomyolysis,[11] but the underlying mechanism of its elevation is unclear. The possible reasons for micro injury to the myocardium as a cause of elevated TnI concentration in cases with rhabdomyolysis include the presence of free radicals or circulating cytokines,

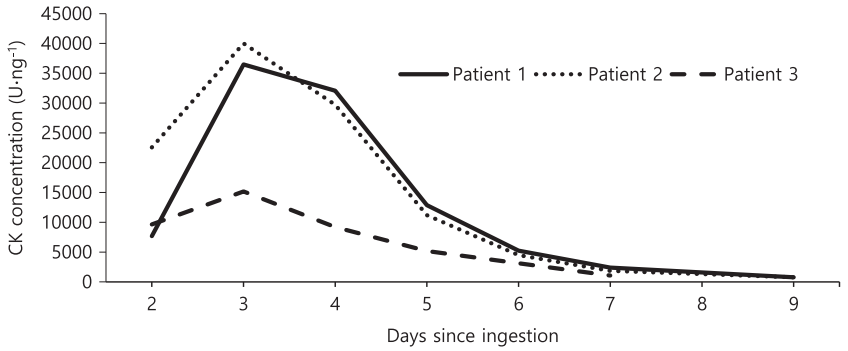

Figure 2. Serum creatine kinase concentrations in 3 hospitalized patients.

cardiotoxicity due to ion fluxes, high acidemia, hypotension and hypoperfusion, and myocardial stretch due to aggressive fluid resuscitation.[12] However, the possibility of direct myocardial damage caused by a mycotoxin cannot be completely ruled out, and further study is required. Therefore, to differentiate myocardial infarction from rhabdomyolysis, it should be necessary to obtain the patient's full history of the present illness, as well as to carry out serial electrocardiogram and cardiac profile analyses, echocardiography, and CK-MB proportion analysis.

Nonpoisonous edible *R nigricans* can be mistaken for poisonous *R subnigricans*. The most useful characteristic for differentiating *R subnigricans* from *R nigricans* is the color change that occurs after scratching the fruiting body. Both species have whitish flesh that is tinged reddish brown when scratched. Subsequently, the color of *R nigricans* turns black, whereas that of *R subnigricans* is persistent.[13] However, classifying these species based only on this color change is difficult and unreliable, and the expertise of a mycologist is essential for accurate identification. In this case, we sent a picture of the mushrooms eaten by our patients to a mycologist via mobile phone, who immediately identified the mushrooms as *R subnigricans*, which is known to cause rhabdomyolysis. Recently, cycloprop-2-ene carboxylic acid was isolated and identified as the fatal toxin of *R subnigricans*. However, identifying this compound is difficult due to its instability; the concentration of a solution of this toxin by drying, a common technique in chemical separation and isolation steps, promotes its polymerization. Thus, the usefulness of this toxin as a unique marker of genuine *R subnigricans* is limited. However, to discriminate genuine *R subnigricans* from similar but unclassified *Russula* species, cyclopropylacetyl-(R)-carnitine could serve as a unique chemical marker, which is sufficiently stable under ordinary experimental conditions and easily recognizable. It can be a useful marker specific to *R subnigricans*.[5] To the best of our knowledge, this is the first report of cyclopropylcetyl-(R)-carnitine in the urine of patients with mushroom poisoning.

In mushroom poisoning, toxicity varies based on the ingested amount, mushroom age, the season when the mushrooms were picked, the geographic location, and

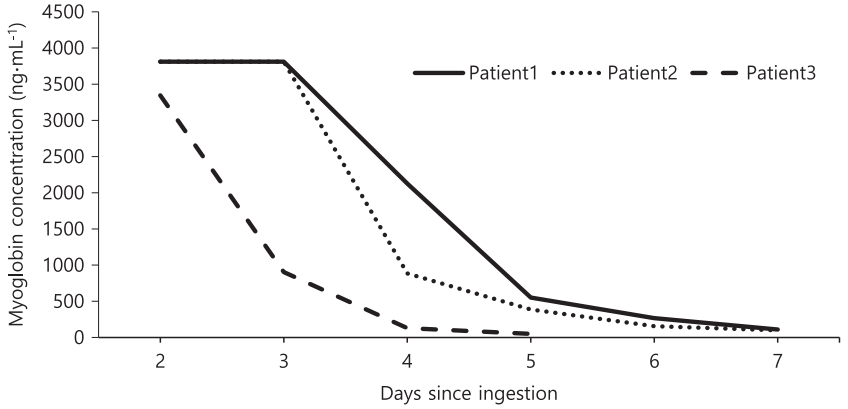

Figure 3. Serum myoglobin concentrations in 3 hospitalized patients.

the way in which the mushrooms were prepared prior to ingestion.[14] In our case, the patients ingested the same mushrooms, and only Patient 4 developed nausea, vomiting, and diarrhea immediately after eating, whereas the rest of the patients had no specific symptoms. However, 24 h after ingestion, the rest of the family developed nausea, vomiting, and myalgia, and severe rhabdomyolysis was diagnosed. It was difficult to determine the intake in detail. Patient 4 may have ingested less mushrooms or absorbed a lower amount of toxins because of vomiting and diarrhea. Cyclopropylacetyl-(R)-carnitine was detected in the urine of all patients, but its concentrations were not determined. In the future, using a quantitative test could be helpful for assessing its toxicity.

Mushroom poisoning with rhabdomyolysis is usually associated with volume depletion due to vomiting, diarrhea, and the sequestration of water in damaged muscles. Early and vigorous replacement of fluids is the first step in rhabdomyolysis management.[15] The related hyperkalemia must also be promptly treated. However, early hypocalcemia should not be treated unless it is symptomatic or if severe hyperkalemia is present, as calcium loading could increase the precipitation of calcium phosphate in necrotic muscles.[16]

As various mushroom species cause various toxicities, it is difficult to diagnose and treat patients with mushroom poisoning in the emergency department. A picture of the ingested mushrooms along with patient blood and urine assessments should be sent to a mycologist to help in the accurate diagnosis and identification of mushrooms. Patients with a history of mushroom ingestion and ongoing symptoms should be observed or admitted until the symptoms resolve and organ damage is excluded, or until the mushroom has clearly been identified as nontoxic.

Conclusions

Four people from 1 family ingested wild mushrooms, *R subnigricans*. Three developed severe rhabdomyolysis, and 1 of them was misdiagnosed with NSTEMI. *R subnigricans* should be considered in mushroom poisonings with rhabdomyolysis. To confirm the exact diagnosis, cyclopropylacetyl-(R)-carnitine can be a useful marker specific to *R subnigricans.*

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CASE REPORT

The Sting of a White Flannel Moth Caterpillar (*Norape ovina*)

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The purpose of this report is to describe a case of urticarial dermatitis, or erucism, caused by the white flannel moth caterpillar (*Norape ovina*) in central Virginia. Many caterpillars are known to cause erucism, with the puss caterpillar (*Megalopyge opercularis*) being the most reported culprit in the United States. White flannel moth caterpillars are expected to cause erucism as they belong to the same family as the puss caterpillar (Megalopygidae) and have similar venom-containing hairs, but no reports of the reaction or clinical course have been documented in the medical literature. A subject was stung by a white flannel moth caterpillar after it fell on his neck while clearing brush with a machete. The subject experienced immediate pain and developed a raised, erythematous rash where the caterpillar had fallen. The rash, referred to as erucism, was painful for 1 d and improved slowly over the course of 2 wk, but a small area of discoloration remained 2.5 mo after contact. Symptoms were managed by the subject at home and no medications were administered. The white flannel moth caterpillar inflicts erucism similar to that caused by the more commonly mentioned puss caterpillar. If only local symptoms are sustained from contact with a white flannel moth caterpillar, it can be safely and effectively managed with over-the-counter medications similar to the management for erucism induced by other caterpillar species. Irrigation and removal of urticating hairs with adhesive tape may help reduce the pain and is recommended, though not performed in this case.

Keywords: stinging caterpillar, urticarial dermatitis, erucism, urticating hairs, Lepidopterism

Introduction

Caterpillars are the larval stage of moths and butterflies belonging to the order Lepidoptera. There are over 50 species of caterpillars, referred to as stinging caterpillars, that are considered toxic and have urticating hairs that secrete venom when broken or placed under pressure.[1] This venom is irritating to humans and can cause a painful, local urticarial dermatitis known as erucism. Systemic symptoms, referred to as Lepidopterism, include diffuse urticaria, headache, nausea, vomiting, and wheezing.[2] The exact makeup of caterpillar venom is not known, but it does contain peptides, hyaluronidase, phospholipase A, and a histamine-releasing substance.[2] The puss caterpillar (*Megalopyge opercularis*) is the venomous caterpillar most reported to cause erucism in humans with over 3,000 cases reported to a Texas poison center from 2000 to 2016.[3] Though several other species of caterpillars in North America are known to cause erucism (Table 1), reports of human encounters with them are not common in the literature.

The white flannel moth caterpillar (*Norape ovina*) is a type of caterpillar native to North America that ranges from Washington, DC to Missouri and south to Florida and Texas.[4] While the adult moth is white, the caterpillar is yellow, black, and red with 11 pairs of yellow spots from which arise clusters of short needle-like urticarial hairs or spines (Figure 1). Because it is in the same family (Megalopygidae) as the puss caterpillar and has urticating hairs, it is thought to cause similar symptoms as the puss caterpillar, although there are no human reports of an encounter with a white flannel moth caterpillar. We report the first case in the literature of a human exposure to a

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Table 1. Scientific classification of a select North/South American caterpillars known to have urticating hairs

Scientific classification of select North/South American stinging caterpillars			
Common name	*Family*	*Genus*	*Species*
White flannel moth	Megalopygidae	Norape	ovina
Puss caterpillar	Megalopygidae	Megalopyge	opercularis
Black flannel moth	Megalopygidae	Megalopyge	crispate
Io moth	Saturniidae	Automeris	io
Buck moth	Saturniidae	Hemileuca	maia
Giant silkworm moth	Saturniidae	Lonomia	obliqua
Saddleback	Limacodidae	Acharia	stimulea

while flannel moth caterpillar resulting in erucism to illustrate the similarities in treatment to other Megalopydigae caterpillar encounters.

CASE REPORT

One summer in central Virginia, a 43-y-old male was riding a lawn mower while clearing brush under a tree with a machete. As he was cutting overhead branches, he felt a severe, searing pain on the left side of his neck. Initially, he thought that he had been poked by a branch, but when he reached up to brush off his neck, a caterpillar fell onto the lawn mower (Figure 1). He felt pain on his hands immediately after brushing off the caterpillar but that soon subsided after 2 min and no rash developed. The severe pain on his neck lasted 40 min, but a constant burning persisted for 1 d following the sting. He reported the sting feeling more severe than a bee sting but less severe than a previous caterpillar sting from a buck moth caterpillar (*Hemileuca maia*).

A wheal surrounded by erythema developed on the neck at the site of caterpillar contact. Progression of the rash is documented in Figure 2. A slight skin discoloration remained 2.5 mo after the sting with no associated symptoms. The subject did not seek any medical care and did not use any pain medication or antihistamines. He did not irrigate or decontaminate the site of contact with the caterpillar. No systemic symptoms or clinically significant long-term sequalae were reported.

Discussion

True stinging caterpillars are known to cause severe pain and cutaneous symptoms upon contact with their urticating hairs. While systemic symptoms or anaphylaxis can occur after a caterpillar sting, the most common reaction is local pain and a rash at the site of contact.[3] While erucism from the puss caterpillar (*M opercularis*) is the most commonly reported in the literature, this is the first reported case of such induced by the white flannel moth caterpillar (*N orvina*). The erucism in this case caused less severe pain when compared to the sting of a buck moth caterpillar (*H maia*); however, the skin discoloration persisted for months before eventually subsiding.

Caterpillars are thought to cause skin irritation and pain through multiple different mechanisms. Urticating hairs can cause dermatitis through direct irritation or from venom associated with the hair.[5] Contact with nonvenomous urticating hairs (setae) in caterpillars results in delayed local itching, swelling, and erythema from local irritation and inflammation.[5] Although few data are available, the symptoms likely take longer to develop than the symptoms from a venomous caterpillar sting. Stings from true venomous caterpillars result in immediate local symptoms within minutes including pain, erythema, and swelling secondary to venom components deposited when the hair breaks the host's skin.[1,5,6] The immediate pain caused in this case supports the presence of venom in the hairs of the white flannel moth caterpillar.

General treatment of caterpillar stings includes decontamination of the urticating hairs with adhesive tape and irrigation in addition to symptom control with medications such as ibuprofen, acetaminophen, topical

Figure 1. White flannel moth caterpillar (*Norape ovina*). Original photograph by Nathan Charlton.

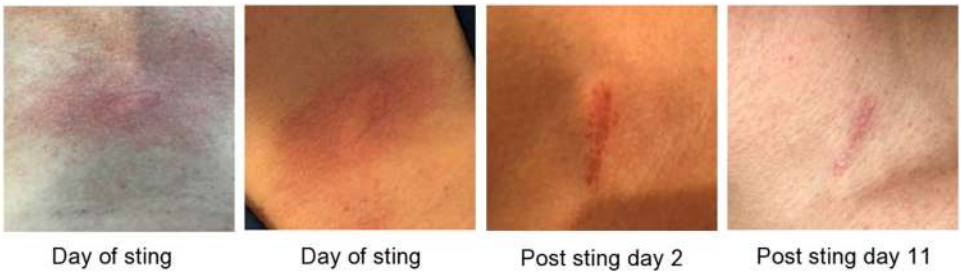

Figure 2. Progression of rash caused by white flannel moth caterpillar sting (*Norape ovina*). Original photographs by Nathan Charlton.

corticosteroids, and antihistamines.[1-3] The majority of North American puss caterpillar stings reported to poison centers are managed at home.[3] If symptoms are severe enough and the patient presents to the hospital, parental analgesics may be required for pain control. One study in South America found that local injections of lidocaine may also quickly alleviate severe pain.[6] Although there is an antivenom for the dangerous *Lonomia obliqua* caterpillar found in South America, which can cause life threatening coagulopathy, none exists for North American caterpillars.[7] Systemic Lepidopterism and anaphylaxis are less common than the localized dermatitis seen in this case, but it is pertinent to monitor for symptoms after an encounter and seek medical care immediately if symptoms arise.[2,8]

Conclusions

Although this is only a single case, the limited local dermatitis suggests that symptoms from an encounter with a white flannel moth caterpillar (*N ovina*) are similar to those from the puss caterpillar and the expectation is that symptoms can also be safely managed at home. No interventions were performed in this case, but removal of the caterpillar hairs with adhesive tape is recommended and may have helped to decrease the duration of pain and skin discoloration in this case. The patient should be monitored for systemic symptoms or allergic reaction and additional guidance could be obtained from a local poison center or primary care provider.

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CASE REPORT

Tiger Shark Attack on a Scuba Diver in New Caledonia

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Herein we report an unprovoked shark attack on a scuba diver in New Caledonia. The species responsible for the attack was identified as a tiger shark (*Galeocerdo cuvier*), based on both the victim's testimony and forensic examination. The victim suffered significant loss of soft tissues from one thigh, which resulted in hemorrhagic shock. Even though the event occurred at a remote location, miles away from the nearest hospital, appropriate first aid, immediate deployment of an alert system, and prompt helicopter transfer by an emergency rescue team allowed the victim to be transferred to an intensive care unit in stable condition and to undergo surgery within 4 h of being bitten. Early coverage of exposed bone was performed, followed up with negative pressure dressing, antibiotic treatment, hyperbaric oxygen therapy, and a split skin graft. In spite of the massive muscular loss incurred, the victim was able to regain her ability to walk within 6 wk of the incident. Shark attacks on scuba divers are rare and seldom reported, especially in New Caledonia.

Keywords: bite, hemorrhagic shock, muscular loss, emergency, surgery, hyperbaric oxygen therapy

Introduction

Shark attacks have been reported in New Caledonia (including the Loyalty Islands, Isle of Pines, Belep Islands, and uninhabited islands in the exclusive economic zone of New Caledonia) over the past 4 decades.[1-3] The annual number of shark attacks has increased over the past 20 y, with up to 2 events reported per year. This represents a twofold rate increase relative to the last 2 decades of the 20th century.[3] Nineteen percent of documented incidents have been fatal,[3] in keeping with global rates reported by the International Shark Attack File (ISAF) maintained by the Florida Museum of Natural History (https://www.floridamuseum.ufl.edu/shark-attacks/). Most documented shark bites are associated with spearfishers (49% of all victims).[3] These are classified as "provoked attacks" because the vibrations and blood associated with speared fish draw the sharks in. The remaining 51% of shark attacks have been on freedivers, swimmers, surfers, and net fishers, and they are classified as "unprovoked."[3] Over the past 10 y, there has also been an increase in the incidence on attacks on kitesurfers and windsurfers with the increase in popularity of these activities in New Caledonia.[3]

The coral reefs and lagoons of New Caledonia have long beckoned recreational scuba divers from around the world. Attracting sharks through baiting is strictly prohibited in this country.[4] Nevertheless, shark encounters are common, especially with schools of grey reef sharks (*Carcharhinus amblyrynchos*) and with whitetip reef sharks (*Trianodon obesus*) in passes and on the external slopes of the reefs. Silvertip sharks (*Carcharhinus albimarginatus*), tawny nurse sharks (*Nebrius ferrugineus*), great hammerheads (*Sphyrna mokarran*), and whale sharks (*Rhincodon typus*) are also encountered occasionally. Species considered dangerous to humans,[1-3] such as tiger sharks (*Galeocerdo cuvier*) (Figure 1), bull sharks (*Carcharhinus leucas*), and great white

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Figure 1. Tiger shark (*Galeocerdo cuvier*). Photo credit: Yves Lefèvre.

sharks (*Carcharodon carcharias*), are rarely encountered by recreational scuba divers in this area.[2]

Figure 2. Wetsuit worn by the victim at the time of the attack. Photo credit: Claude Maillaud.

Clinical Case

In late December 2020, around noon, a 42-y-old female divemaster and 2 other divers undertook a reef dive in a remote spot of the western coast of New Caledonia, located 160 km north from the main town, Nouméa. Scuba divers rarely frequent this site because it is not readily accessible. Earlier on the same day, another boat unsuccessfully tried trolling for fish in the same area. The fisherman eventually speared a parrotfish but chose to leave the spot because inquisitive reef sharks, assumed to be grey reef sharks (*Carcharhinus amblyrynchos*), were seen in the area.

The 3 divers took 5 min to descend a coral reef wall to 36 m (118 ft) depth. Surface water temperature was 26°C (79°F) according to local weather records and is assumed to have been 24°C (75°F) at a depth of 36 m (118 ft). The divers left the wall and swam away into open water, aiming to reach a rock and coral formation a short distance from the main reef. Visibility was around 15 m (49 ft). The divemaster led, while the 2 other divers followed her roughly 10 m (33 ft) behind. She was wearing a black wetsuit, black buoyancy control device, pink mask, gray fins, and no jewelry. A large shark swam into the area suddenly approaching the divemaster from the below and behind, bit her on her left thigh, and went away as abruptly as it had appeared. Profusely bleeding from a deep wound on the injured limb, the divemaster was assisted on her ascent by one of the other divers. No decompression stop was taken, nor was one necessary, as the dive had just started when the accident occurred. The injured diver was pulled out of the water and lifted aboard the dive boat, and an alert was launched 10 min after the incident. A makeshift wound dressing was applied to reduce the bleeding by another diver, who happened to be a medical doctor. The lesion extended high into the gluteal region, preventing the application of a tourniquet as it would have had to be positioned over exposed muscle and bone. Upon reaching the shore, 40 min after the bite, care of the patient was transferred to firefighters and an intensive care anesthetist who was present on site. The patient was immediately transferred to the local medical center. She reached the local medical center less than 1 h after she had been bitten. She was clinically assessed to be in hemorrhagic shock. Vascular repletion with 1 L of crystalloid was initiated along with morphine (7 mg), ketamine (10 mg), and midazolam (1 mg) analgesia intravenously, and oxygen 15 $L \cdot min^{-1}$ (high flow mask). The helicopter emergency rescue team arriving from the New Caledonia Territorial Hospital, located in Nouméa, landed 85 min after the bite. Two units of packed red blood cells were infused, as well as an antibiotic (amoxicillin-clavulanic acid 2 g/200 mg) and an anti-fibrinolytic drug (tranexamic acid, 1 g). Vascular repletion with crystalloids and analgesia (4 mg of midazolam, 20 mg of ketamine, given as boluses, along with a continuous infusion of 20 mg intravenous morphine hydrochloride) were administrated during the 45 min flight to Nouméa to stabilize the patient. On arrival at the intensive care department of the New Caledonia Territorial Hospital, 2.5 h after the bite, the injured diver remained hemodynamically stable (with blood pressure 88/65 mm Hg and pulse rate 92 $beats \cdot min^{-1}$ under continuous noninvasive monitoring), but with acute anemia (hemoglobin was 6.4 $g \cdot dL^{-1}$). She remained conscious, and her pain was under control. A CT arteriogram was performed to assess bone, soft tissue, and vascular damage. A soft tissue lesion on the CT scan showed a 33 cm wide defect in the lateral aspect of the

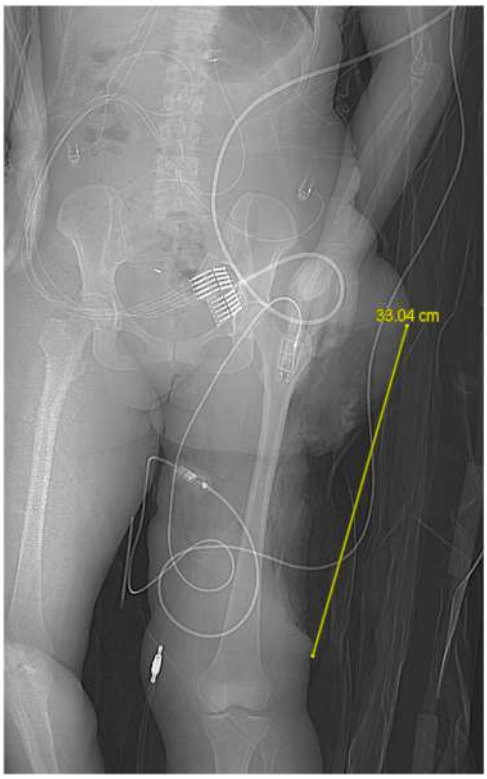

Figure 3. CT scout view of the CT arteriogram of the wound. Photo credit: Joseph Fournier.

thigh. The soft tissue had been stripped from the femur over a 20 cm stretch without fracturing the bone nor damaging any of the main blood vessels. A certified hyperbaric physician confirmed that no therapeutic recompression was required, according to the French government decompression table.[5]

The patient underwent general anesthesia and was transferred to the operating room approximately 4 h after the bite. She received 4 more units of packed red blood cells along with 2 units of fresh frozen plasma, 1 unit of platelet concentrate, and 1.5 g of fibrinogen and was infused with norepinephrine 2 $mg \cdot h^{-1}$ via a syringe driver pump. The lesion consisted of lacerations of the lateral aspect of the thigh, extending over 33 cm, with complete stripping of soft tissue over a length of 20 cm over the femur, including iliotibial tract, the lower portion of the gluteus medius, vastus lateralis, the upper two-thirds of the vastus intermedius, and one-half of the biceps femoris. Perforating branches of the femoral artery were ligatured. No damage to the common femoral artery was seen. The sciatic nerve was exposed without damage. After debridement, the femur was exposed over the 20 cm (8 in) affected area. Local rotation flaps of lacerated muscle and a biceps femoris split were used to cover bone exposition.

The patient was subsequently treated with a negative pressure dressing. She received amoxicillin-clavulanic acid, 2 g/200 mg 3 times a day, and gentamycin 160 mg daily, as a prophylactic antibiotic treatment. Wound swabs at Day 4 showed contamination with *Pseudomonas aeruginosa*, *Klebsiella aerogenes*, and *Shewanella putrefasciens*. Tazocilline (piperacillin and tazobactam) treatment was initiated at 20 g daily for 14 d due to the persistence of positive *P aeruginosa* swab at Day 10 postoperatively. In addition, she underwent 16 sessions of hyperbaric oxygen therapy (2.5 atm for 90 min) to potentiate antibiotic against *P aeruginosa*, protect the skin graft, and mitigate the risk of anaerobic soft-tissue infections. The patient remained contaminated with *P aeruginosa* until Day 30, when a split skin graft was performed, allowing for discharge from the hospital after 6 wk. Functional recovery was good in the early stages, allowing for knee extension against gravity and weight-bearing with a walking frame at the time of discharge to a rehabilitation center. Three months after the accident, the patient was able to walk up to 10 min at a time without aid.

Forensic examination of the wetsuit the victim was wearing at the time of the attack was conducted a few days after the incident. Both upper and lower jaws of the animal made arc-shaped, single, clear, sharp cuts without any shredding that were fully symmetrical (Figure 2). These

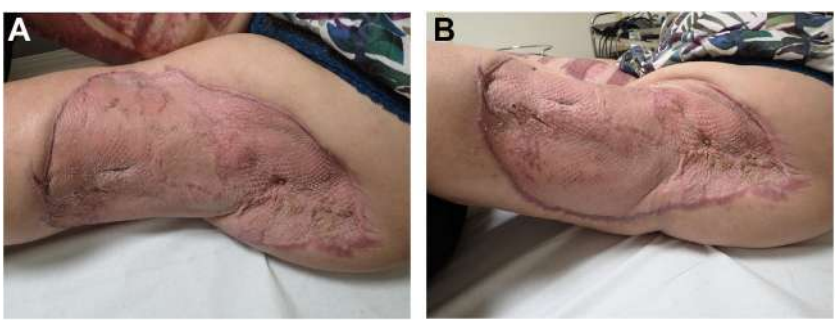

Figure 4. Front (A) and back (B) views of the wound scar. Photo credit: Claude Maillaud.

findings are consistent with a bite from a tiger shark *Galeocerco cuvier*, whose teeth are similarly shaped and evenly spaced in both jaws. The diameter of the bite was estimated to be 33 cm (13 in), consistent with the data from the CT scout view of the CT arteriogram (Figure 3). The shark's size was estimated to be approximately 4 m (13 ft) in length. This matched the description given by the victim, who stated she spotted a 4 m (13 ft) tiger shark swimming away from her immediately after she was bitten. Later examination of photographs of the wound confirmed the identification. Photographs of the wound were taken 4.5 mo after the bite (Figure 4A and 4B). Sharp, clean cuts are still visible on both edges of the wound scar, which are a hallmark of tiger shark bites.[6]

The case was recorded in the ISAF as No. 6610.

Discussion

Unprovoked shark attacks on scuba divers are considered unusual events.[7,8] From 1954 to 2020, the International Shark Attack File recorded 2753 confirmed unprovoked shark attacks worldwide, including those on divers. Over the same period, there were 106 confirmed unprovoked shark attacks on scuba and hookah divers worldwide. Scuba and hookah divers account for only 4% of the victims. Of the 2753 cases, 284 were fatal. An additional 43 cases where the body was not recovered but sharks were implicated were confirmed by witness or gear recovered. Twelve percent of confirmed unprovoked shark attacks occurring between 1954 and 2020 were lethal. By comparison, 21 of the 106 confirmed unprovoked shark attacks on divers (20%) were lethal.

White sharks (*Carcharodon carcharias*) were involved in 30 confirmed unprovoked attacks on divers. Eight of these were fatal. Thirteen of these occurred in North America, while 11 occurred in Australia. Five attacks on divers are ascribed to the oceanic whitetip shark (*Carcharhinus longimanus*), 1 of which was fatal. All were reported from Egypt (at the same Marsa Alam location) in 2009 and 2018. Tiger sharks (*Galeocerdo cuvier*) have been responsible for 8 attacks on divers between 1990 to 2020, 3 of which were fatal. Those cases were recorded in Mexico (n=2, both lethal, at the same Santa Rosa reef, on Isla Cozumel), Western Australia (n=2, including the hookah diver case), Central America (n=2, Panama, Costa Rica), and Pacific Ocean islands (n=2: Fiji, Guam). None have been reported from the French Pacific islands. Fifteen other species have been implicated in confirmed unprovoked shark attacks on scuba and hookah divers. These include bites by grey reef sharks (*Carcharhinus amblyrynchos*) (5 cases) and the wobbegong (*Orectolobus* spp) (6 cases, all recorded in Australia).

The primary concern associated with shark bites is blood loss due to blood vessel damage. The relationship between prognosis and the major vessels severed was summarized by the Durban classification.[9] "Beach treatment," using "Feinberg packs"—emergency packs that allow beach rescuers to provide early primary care to victims, as they contain vascular filling solutions, intravenous infusion sets, morphine and norepinephrine vials, wound dressing, antiseptics, and tourniquets—were promoted in areas of the Natal Coast (Republic of South Africa) where shark attacks were prevalent.[9] More recently, a shark-induced trauma scale was introduced, which scores several factors such as patient's blood pressure, location of the injury, functional impairment from the injury, and complexity of the treatment required and allows for a determination of the level of the injury to predict prognosis.[10] Nevertheless, based on our experience in shark attack management in New Caledonia, we consider that time elapsed before the victim is given first aid is the most influential factor. The country's main island is 400 km long and 50 km wide; the total length of the coastline is around 3400 km, and the coral reef extends 8000 km^2. The New Caledonia Territorial Hospital is located in Nouméa, at the southern extremity of the main island. It has the only aeromedical emergency rescue team in the country, and it serves the main island and the 4 Loyalty Islands, 180 km away from Nouméa. Thus, for a victim with hemorrhagic wounds, the time elapsed between the onset of the bite and access to an emergency medical rescue team and/or an intensive care unit is crucial; moreover, as shown in this particular case as well as in a previous case,[11] tiger shark bites can result in a hemodynamic shock without any of the major arteries being severed. In this case, the appropriate deployment of first aid supervised by a medical professional and the immediate launch of the alert system allowed a helicoptered emergency rescue team carrying red blood cells to reach the victim within 1 h of being contacted. This made it possible for the victim to reach the intensive care department with ameliorated hemorrhagic shock despite the severity of her wound.

Notwithstanding extensive muscular damage, the patient's ambulatory function appears well preserved. This is likely a consequence of the lack of vascular or nerve injury from the bite. Early management and coverage of exposed bone, along with negative pressure dressing, antibiotic treatment, and hyperbaric oxygen therapy, resulted in an adequate split skin graft result, despite contamination. Expert advice was sought regarding the use of latissimus dorsi free flaps, which would have necessitated transfer to an off-island referral center, but the patient elected to have treatment in New Caledonia.

Conclusion

Although rare, tiger shark attacks can lead to life-threatening injuries, where exsanguination from blunt trauma can lead to death. Scuba divers are seldom at risk of such accidents. In the case reported here, first aid and resuscitation, followed by prompt intensive care prior to early surgery, ensured the victim's survival, despite the severity of the wound. The functional prognosis was jeopardized by muscular loss. Early management of the wound followed by skin graft made it possible for the patient to walk 6 w after the attack.

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Authorization has been given by the victim to publish the case and to reproduce Figures 2, 3, 4A, and 4B.

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WILDERNESS & ENVIRONMENTAL MEDICINE 2022; 33(3): 363

WILDERNESS IMAGE

Denali Sunrise

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Denali (63.0691°N, 151.0062°W), once known as Mount McKinley, is the highest peak in North America at 6190 m (20,320 ft).

Denali roughly translates to the "Great One" in the local Athabaskan language. It was first climbed in 1913 by Walter Harper, a young Athabaskan guide, and a team led by Hudson Stuck, the bishop for the Episcopal Church in Alaska. They climbed it from the north, dog sledding in for weeks, and starting the glaciated portion of the climbing at about 1500 m (~5000 ft). That left 4500 vertical meters (~15,600 ft) yet to climb, or more than twice the elevation gain from Everest Base Camp to its summit.

Denali has featured significantly in wilderness medicine lore, whether from the pioneering frostbite work of Alaskan physician William Mills,[1] along with Bradford Washburn,[2,3] to more recent work focusing on altitude medicine at the Denali Medical Research Center.[4]

Through 2006, over 30,000 people attempted the mountain, with about 50% summitting and nearly 100 losing their lives in the attempt.[5] While not technically difficult to climb, the 6000-m altitude, combined with high latitude, creates a challenging environment including a long approach, numerous crevasses, intense cold, very high altitude, and ferocious storms. Prior to COVID-19 about 1000 climbers a year attempted the peak.

This photo was taken from the south, southeast at sunrise on the vernal equinox from Denali Lake, 75 km away. The elevation there is about 200 m (~700 ft), meaning the summit towers almost 6000 m above.

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WILDERNESS & ENVIRONMENTAL MEDICINE 2022; 33(3): 364–5

WILDERNESS IMAGE

Tityus silvestris Pocock, 1897 in Palm Trees in a Region of Central Amazon

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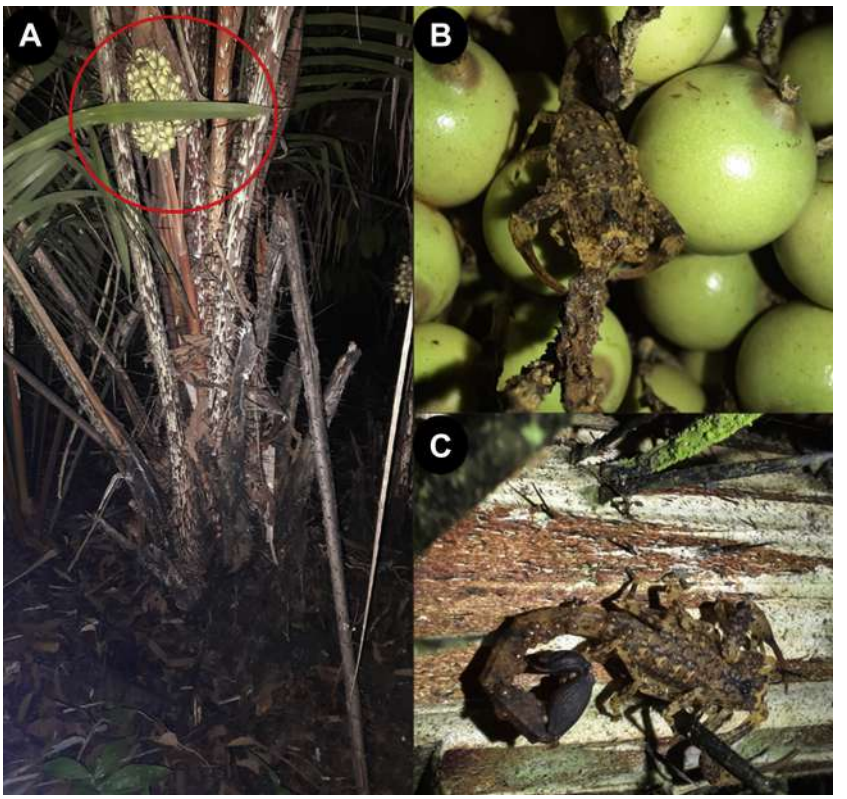

Figure 1. Palm tree in the Central Amazon (2°47'52.3"S 60°03'24.9"W). A, The red circle indicates where *Tityus silvestris* was found in *Astrocaryum* sp. B, An adult female in the bunch of fruits. C, An adult male in the petiole. Photo: JG Martins.

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The Arecaceae family accommodates palm species that are densely distributed in the Amazon basin.[1] Some of these plants are of economic importance, such as *Bactris gasipes* Kunth, which had populations domesticated by Native Americans.[2] In the Amazon, palm trees can be used to build houses and canoes,[2] and fruits are an important part of the local diet, such as

açaí (*Euterpe precatoria*), tucumã (*Astrocaryum aculeatum*) and pupunha (*Bactris gasipes*).[1] In addition to these foods, products such as palm hearts and dendê oil come from palm trees.[1] In the Amazon, several rural communities usually collect the fruits and edible parts of palm trees manually.[2] However, these plants may host different dangerous animals that seek shelter and prey.[2,3] During scorpion collection in the central Amazon (Manaus region), Amazonas, Brazil, in September 2019, we found 20 specimens of *Tityus silvestris* (Pocock, 1897) in spiny palms (*Astrocaryum* spp.). An adult female was found in a bunch of fruits, while an adult male was detected in the petiole of the plant (Figure 1A, B). Currently, the state of Amazonas, Brazil, is home to 48 species of scorpions distributed in 3 families, namely, Buthidae, Chactidae and Hormuridae.[4-6]

The scorpion *Tityus silvestris* was originally described from the Lower Amazon region, Pará, Brazil.[4] However, it has a wide distribution in "terra firme" forests in the Brazilian Amazon and in other Amazonian regions, such as French Guiana and Peru.[5] This scorpion measures between 25 and 45 mm in total length and is generally yellowish in color with dark spots scattered throughout the body.[6] A clinical record of *Tityus silvestris* envenomation in the city of Manaus, Amazonas, Brazil reported that the envenomed patient required antivenom therapy and intensive care.[7] Due to its morphological characteristics, such as small size and color, *Tityus silvestris* can be imperceptible in palm trees. The relative risks of handling the fruits or extracting edible parts from these plants can be reduced with the use of protective equipment such as leather gloves and boots that can prevent accidents with venomous animals hiding in palm trees.

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WILDERNESS & ENVIRONMENTAL MEDICINE 2022; 33(3): 337–9

CASE REPORT

Point-of-Care Ultrasound Findings in a Case of Botfly Myiasis Contracted in the United States

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Botfly infiltration is a rare cause of pediatric skin manifestations in the United States, but should be considered in nonhealing wounds even in nontravelers. We describe the case of a healthy 6-y-old female who had never traveled outside of the southeast United States, presenting with a nonhealing skin lesion. The point-of-care ultrasound (POCUS) findings suggested subcutaneous parasitic infiltration. This case demonstrates the role of POCUS in identification of subcutaneous parasitic infiltration, and differentiation from other, more common skin lesions.

Keywords: Dermatobia, cuterebra, myiasis, POCUS

Introduction

Infiltration of human tissue by a fly larva is called myiasis.[1-5] The most common site for infiltration is the skin. Presentations include furuncular, wound, and migratory myiasis.[1] Several fly species can cause human myiasis, but the human botfly, *Dermatobia hominis*, is the only species of botfly whose larvae ordinarily parasitize humans.[1] Most cases of human furuncular myiasis seen in the United States are caused by the human botfly and are acquired during travel in Central and South America. When the infiltration is acquired in the United States, rodent botfly larvae from the genus *Cuterebra* are among the most commonly implicated species.[4] The rodent botfly is an obligate parasite of squirrels, mice, and rabbits.[1] The adult fly lays its eggs on foliage. If a human inadvertently comes into contact with an egg, the heat of the skin causes the egg to hatch. Once hatched, the larva burrows under the skin to complete its life cycle.

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Patients infiltrated with botfly larvae typically present with a red, indurated area that may be painful or itchy. When there is no history of travel to endemic areas, these lesions are typically diagnosed as abscesses or cellulitis and treated with antibiotics, only for treatment to fail. Use of point-of-care ultrasound (POCUS) allows clinicians to directly visualize an area of cellulitis and differentiate it from an abscess. The extent of an abscess can be determined with POCUS, which aids in the decision whether to drain it surgically. POCUS can also demonstrate other subcutaneous lesions. Application of color Doppler interrogation helps detect vascular flow within a lesion, aiding the diagnosis. Presence of a rod-like shaped apparently vascular structure may suggest a larva, and guide the clinician toward asphyxiation techniques for removal, rather than incision and drainage.

Case Report

A 6-y-old girl presented to the emergency department (ED) with 5 d of an itchy, red skin rash on the left upper chest wall. She was a long-term resident of North Carolina and had not recently traveled outside of the state, had no fever or constitutional symptoms and had otherwise been well. On her presentation to the ED, she had normal vital signs. On physical exam, there were 2 lesions on the left upper chest wall resembling insect "stings" with surrounding redness and induration but no

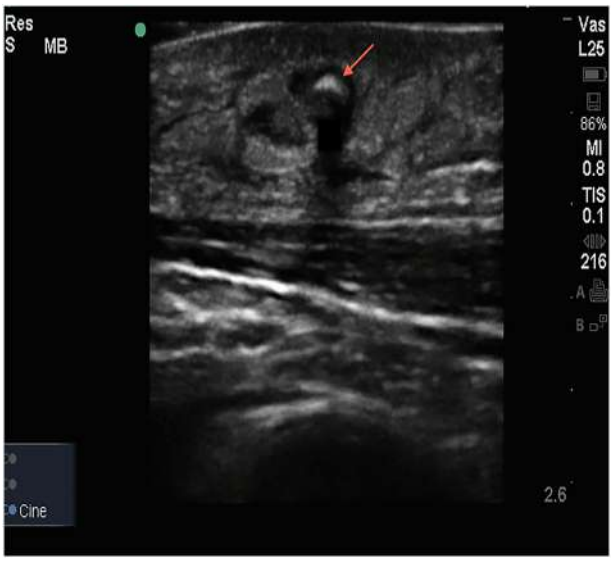

Figure 1. Ultrasound images of skin lesion containing cutaneous bot fly larva (arrow) with posterior shadowing and surrounding inflammatory changes (cobblestone appearance) but no abscess cavity.

fluctuance. No retained stinger was seen. The patient was treated for presumed cellulitis with a 10-d course of clindamycin.

She returned to the ED in 7 d. The area had initially improved, but now had become irritated again and drained a small amount of serous fluid. She had remained afebrile, with no other symptoms and had continued to take her antibiotic as prescribed. On this second visit, she had a punctate lesion with a black center on her left upper chest and a 1.5 cm area of surrounding redness and induration but no fluctuance. No fluid could be expressed from the punctum. POCUS examination of the area in question was performed. A rod-like echogenic structure with posterior shadowing in a hypoechoic cavity was noted. Color Doppler was not used (Figure 1). The family did not recall any injury that could have left a residual foreign body, but they did think it was possible that an insect had stung her.

There was no stinger visible in the skin on the first or second visit. The treating physicians felt the reddened area might be a sign of fat necrosis from the prior infection or more likely might be a foreign body based on the ultrasound findings. The family was instructed to cover the wound with antibiotic ointment, finish the oral antibiotic course, and follow up with a pediatric surgical specialist if the wound did not heal within the next several days.

The following day, during wound care, the family noted the punctate central area had opened slightly and drained serous fluid. Coincidentally, the family had a previously scheduled well-child check with their pediatrician that day. During that visit, the pediatrician noticed the central opening of the reddened area on the patient's upper chest. When the pediatrician squeezed the surrounding skin, there was movement in the opening of the reddened area. The pediatrician probed the opening and used forceps to remove a small white larva. The larva was preserved in alcohol and later identified as the second instar (larva) of a fly in the genus *Cuterebra*, likely a squirrel botfly. The patient fully recovered. Her wound healed without a scar.

Discussion

The infiltration of living, human tissue by a fly larva is termed myiasis. Myiasis is classified clinically according to the type of body tissue involved. The most common type of myiasis is cutaneous myiasis. Presentations include furuncular, migratory, and wound myiasis.[4,6]

Human and rodent botfly larvae typically produce single lesions. Myiasis from other species may present with multiple lesions.[4] Local inflammation can cause itching. Patients may also describe lancinating pain at night or may feel movement in the skin.[7-9] Normally, patients are not ill. However, certain species of botfly such as *Cordylobia rodhaini,* found in sub-Saharan Africa, can lay multiple eggs causing a systemic inflammatory reaction with fever and lymphadenopathy.[8] Initial presentations are typically attributed to skin infections such as cellulitis or abscesses. In a patient with a nonhealing wound, clinicians should consider botfly infiltration in the differential diagnosis.[10] While a history of travel makes the diagnosis more likely, this case illustrates that it is not required. In the United States, most accidental human infiltrations occur in the northeast.[1] To our knowledge, there is only 1 prior report of furuncular myiasis acquired in North Carolina.[1]

POCUS is used frequently in EDs and in some clinics.[11] In a furuncle, a botfly larva appears on ultrasound as a hyperechoic line with posterior shadowing and no abscess cavity[5] (Figure 1). Often, the body segmentations are visible. On live imaging, movement may be detected, and on color Doppler vascular flow may be seen.[12]

Removal of a botfly larva can be accomplished by asphyxiating it with an ointment, nail polish, or pork fat. This forces the larva to emerge through its breathing hole, allowing it to be grasped with forceps. The surrounding furuncle can be squeezed to help with the expulsion of the larva.[8,10] Surgical removal with simple incision and drainage may be necessary if the patient presents later in the course of larval development or is so distraught that

waiting for asphyxiation would cause undue emotional distress.[4] Fortunately, botfly larvae release bacteriostatic substances that make infection unlikely. Although antibiotics are sometimes necessary to treat secondary bacterial infections, there is no need for prophylactic antibiotics.[4] Most patients recover uneventfully after the removal of a larva.[4]

Conclusions

We report an unusual case of botfly infiltration in a region where it is uncommon. In areas where botfly myiasis is common, the diagnosis is usually apparent based on history and physical exam. In this case, the clinicians did not make the diagnosis of botfly myiasis on the first 2 presentations to the ED despite characteristic findings on POCUS. Failure to make the diagnosis was likely caused by a lack of familiarity with botfly myiasis. This case illustrates that it is possible to acquire botfly myiasis in the United States. Familiarity with the characteristic ultrasound findings may help clinicians recognize this condition.

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Author Contributions: Data acquisition (CAD, JP, KH); drafting and critical revision of the manuscript (CAD, JP, KH); and approval of final manuscript (CAD, JP, KH).

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WILDERNESS & ENVIRONMENTAL MEDICINE 2022; 33(3): 340–3

CASE REPORT

Detectable Digoxin Concentrations in 3 Patients with Ramps Misadventure

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Allium tricoccum (commonly known as "ramps") is an edible plant known for its strong garlic-like odor and onion flavor. Unfortunately, *A tricoccum* mimics such as Lily of the Valley (*Convallaria majalis*) and False Hellebore (*Veratrum viride)* can lead to foraging errors and subsequent patient harm/toxicity. We describe 3 adults who foraged and ate what they believed were *A tricoccum* and then subsequently became symptomatic with detectable digoxin concentrations. A 41-y-old woman, 41-y-old man, and a 31-y-old man presented to the emergency department after ingesting an unknown plant that was believed to be *A tricoccum.* On arrival to the emergency department, the patients were hypotensive and bradycardic. They had detectable digoxin concentrations ranging from 0.08 ng·mL^{-1} to 0.13 ng·mL^{-1}. One patient received 20 vials of digoxin antibody fragments. All 3 patients recovered without complication. Laboratory analysis of plant specimen was positive for cyclopamine, a teratogenic alkaloid found in *Veratrum californicum*. *A tricoccum* foraging errors can be a source of morbidity given their similarity in appearance to plants like *C majalis* and *V viride*. *C majalis* causes a detectable digoxin concentration via its cardiac steroid compound (convallatoxin) that is similar to digoxin. *V viride* contains alkaloid compounds (such as veratridine) that can cross react with digoxin assays and lead to a falsely elevated digoxin concentration. Clinicians should be prompted to think about ingestion of *C majalis* or *Veratrum spp.* when patients present with bradycardia, gastrointestinal symptoms, and detectable digoxin concentrations after plant ingestion and/or foraging for *A tricoccum*.

Keywords: foraging, veratrum, allium tricoccum, plants, ramps

Introduction

Allium tricoccum (family Amaryllidaceae), commonly known as "ramps" or "wild leeks" is an edible plant known for its strong garlic-like odor and onion flavor (Figure 1). It is a perennial plant that exists as a cluster of bulbs with flat, green leaves. Ramps are a highly coveted item by plant foragers for their culinary roles, their versatility allowing the plant to be consumed in many ways—fried, pickled, in soups, or raw. Some cultures used ramps as a remedy to treat ailments such as colds and earaches, and others have festivals (https://www.richwooders.com/ramp/ramps.htm) revolving around the versatility of the plant.[1,2] Unfortunately, mimics of *A tricoccum* like lily of the valley (*Convallaria majalis;* Family *Asparagaceae*), autumn crocus (*Colchicum autumnale;* Family *Colchicaceae*), and false hellebore (*Veratrum viride;* Family *Melanthiaceae*) can lead to "look-alike" foraging errors and subsequent patient harm/toxicity.

C majalis is a perennial flowering plant that contains convallatoxin, a cardioactive steroid that has similar effects as digoxin. As a result, inadvertent consumption of this plant can mimic digoxin toxicity. *C autumnale* is a perennial flowering plant that contains colchicine, a xenobiotic that is extremely concerning in overdose given its potential to cause morbidity and mortality and no available antidote. *V viride* is a perennial herbaceous

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Figure 1. *Allium tricoccum.* (Public domain image.)

plant that contains alkaloids (such as veratridine) that cause nausea, vomiting, diarrhea, and bradycardia.

We describe 3 adults who foraged and ate what they believed were ramps and then subsequently became symptomatic with detectable digoxin concentrations.

Case Report

A 41-y-old woman, a 41-y-old man, and a 31-y-old man, each with no significant medical history, presented to an emergency department 1.5 h after ingesting an unknown plant. Earlier that day, the youngest in the group went into their backyard and identified what he believed to be *A tricoccum.* The plant was harvested and included as an ingredient in tacos. Thirty minutes after ingesting the tacos, all 3 patients began complaining of an abnormal sensation in their throat, and 2 patients began vomiting. On arrival to the emergency department, all 3 patients were hypotensive and bradycardic, the lowest being the 41-y-old woman who had a blood pressure of 81/43 mm Hg, with a heart rate of 44 beats·min^{-1} (Table 1). Initial laboratory studies are shown in Table 1.

All 3 patients received intravenous fluids in addition to oral activated charcoal. One patient (41-y-old female) received 20 vials (800 mg) of digoxin specific antibody fragments for hypotension and bradycardia with subsequent improvement in her HR and BP. Aside from sinus bradycardia, no electrocardiographic changes were observed. All 3 patients were admitted overnight and recovered the next day without complication. Approximately 12 h after ingestion, repeat blood testing was negative for digoxin in 2 patients and 1.3 ng·mL^{-1} in the patient treated with digoxin specific Fab.

In the case of the 3 patients above, pictures of the plant were only able to be obtained after discharge (Figures 2 and 3). Because of the appearance of the plant suggesting *V viride* but the positive digoxin concentrations suggesting *C majalis*, we obtained laboratory testing of the plant.

A sample of plant material, including roots, stem, leaves, and flowers was ground in a Stein mill with liquid nitrogen. A 1.0 g sample of ground plant material was next extracted with 10.0 mL of methanol by shaking for 5 min with a GenoGrinder at 750 rpm with 2 steel ball bearings. The suspension was centrifuged at 1295 × g for 5 min. The resulting supernatant was diluted by 1/10 in methanol and filtered through a 0.22 micron Millipore Millex filter (PES) for analysis. Analysis was performed by high-performance liquid chromatography (Thermo Scientific Ultimate 3000) combined with high resolution mass spectrometry (Thermo Scientific Q Exactive Orbitrap, Waltham, MA). The chromatographic separation was done at 35°C using an Agilent Eclipse Plus C18 RRHD column (2.1 × 100 mm, 1.8 micron). The flow rate was 0.35 mL/min with 0.1% formic acid in water (mobile phase A) and 0.1% formic acid in acetonitrile (mobile phase B). Gradient elution was done with 1% mobile phase B for the first 1.5 min, followed by ramping up to 98% B at 9.5 min, holding at 98% B for an additional 4 min, and then re-equilibrating at 1% B for 4 min. Electrospray ionization was done in positive ion mode recording across 75 to 1125 m/z for full ms (50,000 resolution) and across 50 to 750 m/z for ms^2 (25,000 resolution). Reference standards of convallatoxin, cyclopamine, and veratridine were run for comparison and confirmation. Qualitative analysis was negative for both convallatoxin and veratridine, but was positive for cyclopamine. Cyclopamine is a teratogenic alkaloid found in *Veratrum californicum.*

Discussion

Misadventures with ramps are an unfortunate consequence of foraging without proper training on plant

Table 1. Patient characteristics and laboratory values

Age (y)	*Sex*	*Symptoms*	*Lowest BP (mm Hg)*	*Lowest HR (beats·min^{-1})*	*Initial Potassium (mEq·L^{-1})*	*Initial digoxin concentration (ng·mL^{-1})*	*Repeat digoxin concentration (ng·mL^{-1})*
41	Female	Abdominal cramps, vomiting, abnormal sensation in throat	81/53	44	3.6	0.08 (~4.25 h from time of ingestion)	1.3 (~12.5 h from time of ingestion)
41	Male	Abdominal cramps, vomiting, abnormal sensation in throat	103/66	51	3.8	0.09 (~4.5 h from time of ingestion)	<0.1 (~12.25 h from time of ingestion)
31	Male	Abdominal cramps, vomiting, abnormal sensation in throat	95/53	76	3.1	0.13 (~4 h from time of ingestion)	<0.1 (~12 h from time of ingestion)

identification. When these misadventures result in emergency department visits, patients do not always bring the plant with them for clinicians to see. Furthermore, even if they do, identification of the plant is not easily done.

Based on the appearance and laboratory testing of the plant, it seems extremely unlikely that this plant was lily of the valley. As a result, the detectable digoxin concentrations in all 3 patients were likely false positives. A previous study had identified that steroidal alkaloid compounds in *V viride* cross reacts with a clinical digoxin immunoassay, but this study did not include *V californicum* or cyclopamine.[3] Like any case report claiming an association, there are areas of uncertainty, the greatest of which in this case is that the actual plant ingested was not the one tested. The plant sent for testing was acquired by one of the patients who went back to the yard and location where the original plant was obtained, but this is not without potential for error.

Our patients all experienced bradycardia and hypotension, which is reported with *V viride* and *Veratrum parviflorum*.[3-5] In the case of *V parviflorum*, the authors found the plant contained not just verazine, veratramine, and veratridine, but also cyclopamine. It is possible that the many steroidal alkaloids present in *Veratrum* species contribute to bradycardia and hypotension when ingested.

Figure 2. Potential *Convallaria majalis* vs *Veratrum viride* vs *Allium tricoccum* identified by patient in same location as original plant.

Figure 3. Likely *Veratrum spp* plant nearby original plant foraged.

The patient who received digoxin antibody fragments in this report reportedly had a good response, with immediate improvement in heart rate and blood pressure. Although prior research has demonstrated that digoxin antibody fragments do not bind steroidal alkaloid extracts (jervine, ribigirvine, solanidine, veratraman) from *V viride,* we do not know how this applies to other steroidal alkaloids or even cyclopamine.[3] Further research is needed to understand the role of digoxin antibody fragments in *Veratrum spp* testing.

LIMITATIONS

There are a few notable limitations here—first, it is unclear if the sample sent for testing was the same as the plant the patients had ingested. Furthermore, it is possible that the sensitivity of the laboratory testing was not high enough to detect other alkaloids that were present. Lastly, although it is tempting to suggest that cyclopamine caused a false positive digoxin concentration, this has never been reported. In light of this, we caution healthcare providers about attributing false positive digoxin concentrations to only *V viride* and to instead be cautious of all *Veratrum* species.

Conclusions

Clinicians should be prompted to think about ingestion of *Convallaria majalis* and *Veratrum spp* when patients present with bradycardia, gastrointestinal symptoms, and detectable digoxin concentrations after plant ingestion and/or ramp foraging.

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CASE REPORT

Early Use of Iloprost in Nonfreezing Cold Injury

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Nonfreezing cold injury (NFCI) is caused by prolonged exposure to cold, usually wet conditions and represents a separate pathological entity from frostbite. The pathophysiology of NFCI is characterized by vasoconstriction and microcirculatory disturbance. Iloprost, a synthetic prostaglandin analogue with vasodilatory properties is a recognized adjuvant treatment in frostbite; however, its role in NFCI is unclear. We present a case of a 29-y-old man with severe NFCI to both forefeet after prolonged immersion in cold seawater. Initial treatment with passive rewarming, analgesia and aspirin was initiated. Infusion of iloprost was used within 24 h from presentation and was well tolerated. This resulted in reduced tissue loss compared to the apparent tissue damage documented during the initial assessment. Delayed surgical intervention allowed minor debridement and minor toe amputations, maintaining the patient's ability to ambulate. This case demonstrates the safe use of iloprost in acute NFCI and highlights the importance of delayed surgical intervention in patients presenting with severe NFCI.

Keywords: cold exposure, immersion, prostacyclin analogue, vascular disease

Introduction

Nonfreezing cold injury (NFCI) occurs when tissues are exposed to cold temperatures (below 15°C) for prolonged periods of time, usually greater than 48 to 72 h.[1] Tissue freezing does not occur, differentiating NFCI from frostbite. NFCI largely affects extremities, most commonly feet exposed to cold and wet environments. A number of named conditions including "trench foot" and "immersion foot" are synonyms for NFCI, where either immersion or cold are the precipitating factors.[2]

Proposed mechanisms of injury in NFCI have been extrapolated from animal studies. The true mechanisms have yet to be fully established in humans. There are several postulated mechanisms, including reperfusion injury after prolonged vasoconstriction.[2] Persistent vasoconstriction may result in capillary endothelial injury as well as leucocyte and platelet aggregation with subsequent microvascular thrombosis.[2,3] Damage to nerve tissue occurs through both ischemic and direct cold-induced injury.[2] Upon rewarming, free radical formation results in further endothelial damage and tissue edema.[1,2] Cold induced vasodilation attempts to disrupt persistent vasoconstriction, cycling every 5 to 10 min providing core temperature is maintained.[1] Although some of these mechanisms may be also found in frostbite, the key difference is that tissue freezing does not occur in NFCI.

NFCI provides diagnostic challenges and can present with few objective signs.[2] It often progresses through 4 clinical phases.[3] The initial cyanotic phase occurs where the extremity is insensate and painless due to severe vasospasm.[2] During rewarming, the prehyperemic phase begins with some circulatory improvement and a blanched or mottled appearance may be seen.[2] After rewarming, the hyperemic phase occurs, where the extremity is often painful, oedematous, and swollen.[2] Pulses may be present; however, there is frequently microcirculatory impairment evidenced by prolonged capillary refill time.[2] Hyperalgesia and paresthesias may also occur.[2] Blistering, eschar formation, and desquamation may occur in severe cases, although gangrene is rare.[2] The posthyperemic stage is characterized by abnormal response to cold such as rapid onset of vasospasm or hyperemia, as well as cold sensitivity and parasthesias that may persist years after injury.[2] Not all

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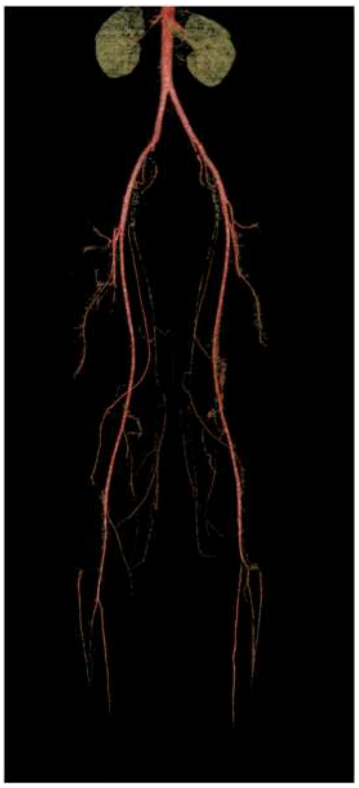

Figure 1. Computed tomography angiogram reconstructions demonstrating intact major vessel with spasm of pedal arteries bilaterally.

phases are always present and frequent overlap and varying durations of each phase occurs.[2] This variation is likely related to the severity of the vasoconstriction and the inflammatory process resulting from tissue damage.[2]

Given the role of vasoconstriction in NFCI, iloprost has been proposed as possible treatment modality. Already a recognized treatment of acute frostbite, iloprost is a synthetic prostaglandin I2 analogue with vasodilatory properties.[4] It has an inhibitory effect on platelet aggregation and also stimulates release of endogenous tissue plasminogen activator, resulting in a thrombolytic effect.[5] The intravenous infusion is started at 0.5 mcg·kg·min^{-1}, incrementally increased every 30 min by 0.5 mcg·kg·min^{-1}, up to a maximum of 2 mcg·kg·min^{-1}. Common side effects such as sweating, headache, or hypotension can be managed with reduction of infusion rate. The infusion is commonly prescribed for 5 to 8 d.

Case Presentation

A 29-y-old man with a history of substance abuse presented with severe pain and numbness in his feet, having spent 3 d trapped in a tidal cave on the coastal shoreline. The patient had no previous history of cold exposure. During this time, both feet, in socks and shoes, were intermittently submerged in sea water. Ambient temperatures at the time of injury ranged from 4 to 10°C with an average seawater temperature of 10°C. He was found hypothermic with a tympanic (infrared) temperature of 34°C. On presentation to the emergency department, he remained cold-stressed at 35.8°C on tympanic reading but was hemodynamically stable. Both feet were cold, pale, and without discernable capillary refill up to the ankle. Pulses were absent, but bilateral weak monophasic extremity doppler signals were present. Blood tests showed an elevated white cell count of 22.3 10^9·L^{-1}, normal electrolytes, and renal function but a creatinine kinase of 21454 u·L^{-1}. A working diagnosis of a severe NFCI was made.

Initial treatment of cold exposure was started with patient warming and passive rewarming of both feet, intravenous paracetamol analgesia, and intravenous fluids. Paracetamol was initially chosen because of concern for acute kidney injury with the high creatinine kinase. Repeat renal function testing was normal, however, with the patient maintaining good urine output without myoglobinuria. Computerized tomographic angiography (Figure 1) demonstrated reduced contrast flow in all 3 runoff vessels consistent with severe vessel spasm without any occlusive lesions. On telephone discussion with author CI of the British Mountaineering Council frostbite advice service, aspirin 75 mg and ibuprofen 400 mg were also administered.

Despite initial management, the patient was still experiencing severe pain and pregabalin was added alongside opiate analgesia on advice from anesthesiology. Passive rewarming of the feet was stopped at this point and the feet were lightly dressed.

The patient was admitted to the high dependency unit for ongoing pain management and monitoring of renal function. A fentanyl epidural and morphine patient-controlled analgesia pump was provided due to ongoing intractable pain. In the high dependency unit, dusky discoloration was noted in all toes, more severe on the plantar surface of both feet. After further telephone discussion with author CI, an iloprost infusion was started within 24 h of presentation. This was continued initially for 5 d but extended to 10 d because the initial 5 were tolerated well and clinical improvement was noted (Figures 2 and 3).

On days 5 to 7 of iloprost infusion, the patient reported sweating and headaches. This resolved with reduction of the infusion rate. Pain control improved throughout the course of the infusion. A rise in serum transaminases was also noted at this time, returning to normal on discharge. Two weeks after initial presentation to hospital, the patient was discharged to a rehabilitation hospital on paracetamol, ibuprofen, and aspirin for ongoing

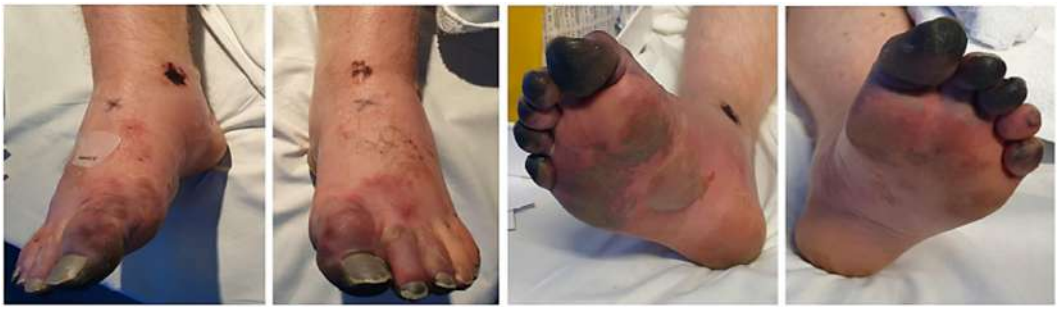

Figure 2. After 6 d of iloprost infusion.

rehabilitation. Aspirin was continued until surgery with the aim of further reducing any tissue loss secondary to microvascular thrombosis.

Sixteen weeks after admission, elective debridement of both feet was performed. Bilateral distal hallux amputations, left second, right fourth and fifth toe amputations were performed under regional anesthesia. The patient retained a significant amount of tissue on both hallux amputations sites and was ambulatory on discharge from a community hospital. The distal toes had remained painful and regular paracetamol analgesia was still required for walking although outside the affected area no abnormal sensation was reported.

The patient recovered well postoperatively but was lost to follow-up despite multiple efforts to contact him.

Discussion

To the best of our knowledge, this case represents the first use of several treatment strategies. Initial management with aspirin, as used in frostbite, was used to reduce cold-induced platelet aggregation.[6] Ibuprofen was chosen as analgesia in addition to suppressing the inflammatory response. This was used alongside recommended basic management including passive rewarming and limb elevation.[1,6] Given the history of substance misuse, computerized tomographic angiography was used to rule out occlusive lesions. In this case, it demonstrated the marked vasospasm typical to NFCI.

Iloprost was utilized in this acute setting with the rationale of reducing the extent of tissue injury in the affected extremities through its vasodilatory and thrombolytic effects. Further administration did result in side effects, although these rapidly resolved on reduction of infusion rate. Previously reported use of iloprost in NFCI describes a single patient who experienced NFCI 20 y prior to presentation with chronic pedal pain and loss of function.[7] After treatment with iloprost, a 4-wk improvement was noted.[7] Recurrence of symptoms occurred after this period and subsequent infusion resulted in worsening symptoms and increasing analgesic requirements.[7] In chronic settings, tissue damage has already occurred and may explain the poor response to iloprost. Attempting to reduce the length or severity of the microcirculatory disturbance and therefore tissue damage in the acute setting appears beneficial. Unfortunately, the patient was lost to follow-up. Therefore, it is

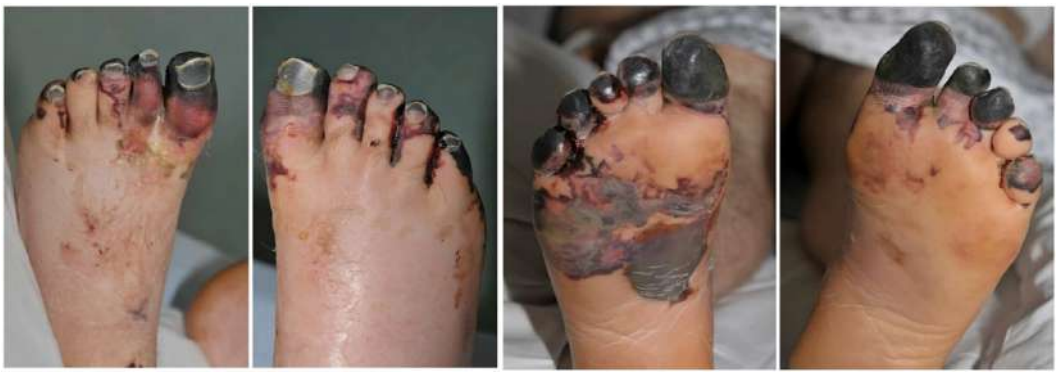

Figure 3. Improvements in appearance seen on Day 13 after 10 d of iloprost infusion.

unclear whether there was any long-term benefit in iloprost administration in NFCI.

Pain management was challenging in this case given the history of substance misuse. Neuropathic pain is often treated with amitriptyline (50–100 mg orally) with or without pregabalin.[2] Currently, there is no evidence of the most effective agent against neuropathic pain in NFCI, although amitriptyline has been the first line agent in the UK armed forces protocol since 1982.[2] Involvement of anesthesiology for consideration of regional block or epidural may be appropriate and was key to successful pain management in this case.[8,9] Unfortunately, it was not clear from the documentation as to why pregabalin was chosen as opposed to amitriptyline. This is likely due to the lack of awareness in managing NFCI.

This case also highlights the importance of delayed surgical management in NFCI. Surgical management is undertaken once the full extent of the injury is understood, as demarcation can take several days to months.[3] The extent of the apparent tissue damage changed significantly during the patient's inpatient stay; early surgery would have resulted in unnecessary loss of viable tissue. Therefore, surgical treatment should be delayed in line with recommendations for frostbite.[6,10]

Conclusions

NFCI is an entity with variable presentation and history of exposure to cold and wet conditions should alert the clinician to its possibility. Key factors in the management of NFCI include passive rewarming, analgesia, and delayed surgical management. Iloprost may have a role in the acute management of NFCI.

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CASE REPORT

The Use of Intravenous Lidocaine as an Analgesic Modality in the Austere Environment: Two Cases

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Providing effective analgesia for trauma in austere settings is particularly difficult and often complicated by equipment and medication limitations and harsh environmental conditions. Common modalities that are employed in conventional clinical practices may not be available or pragmatic in austere environments. Furthermore, side effects such as sedation, altered mentation, or hypoxemia require additional resources and attention. We report 2 cases that demonstrate the use of intravenous lidocaine for the management of acute pain, secondary to trauma, in an austere environment. In the first, the administration of intravenous lidocaine reduced pain, secondary to a tibia fracture, thereby facilitating splinting. In the second, a patient, who had sustained rib fractures, was also treated with intravenous lidocaine. In this case, the analgesic effects of the medication resulted in reduction in pain and improvement in pulmonary function. Of note, the narrow therapeutic window of this modality was made evident as both patients transiently experienced tinnitus following the initial lidocaine bolus. This report describes 2 cases in which intravenous lidocaine was used to manage acute pain, in an austere environment, while avoiding many of the detrimental effects that accompany alternative analgesics.

Keywords: local anesthetic administration, austere medicine, pain management

Introduction

Providing effective acute pain management in an austere prehospital environment is a particularly challenging task. Although numerous factors are likely attributable to complicating this task, a lack of medications, equipment limitations, and limited availability of medically trained personnel are all likely contributors.[1,2] To overcome this challenge, medical providers must look for reliable, pragmatic, compact, lightweight, and durable analgesic modalities. According to current literature, these modalities must not have significant side effects, including excessive sedation or hemodynamic instability.[1]

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Although current evidence is not yet robust,[3] there is a growing interest in utilizing intravenous lidocaine as an analgesic modality in both the austere and combat environments.[4,5] However, the narrow therapeutic index, need for ongoing monitoring, necessary infusion equipment, and requirement that lipid emulsion be accessible[6] all have been thought to restrict the use of intravenous lidocaine in such environments. The availability of lipid emulsion, an important therapy for local anesthetic systemic toxicity, also influences the decision-making process of implementing regional and systemic local anesthetics.

Despite the previously described limitations, this retrospective report of 2 cases shows the benefit of utilizing intravenous lidocaine to treat acute pain in the austere environment.

Case Report

We report cases from a clinic in Southeast Asia, where pharmacologic analgesics were restricted to ketamine,

paracetamol, and lidocaine. While the supply of lidocaine was robust, only 6000 mg of ketamine and 5000 mg of paracetamol were available. For this reason, the clinic typically reserved ketamine use for emergent procedural sedation (eg, cricothyroidotomy, chest tube placement, endotracheal intubation) and paracetamol for management of fever or mild pain. As a result of local counter-narcotics policies, opioids were not available. Additional constraints included unreliable electricity, no refrigeration, infrequent resupply, no access to radiography or ultrasonography, no infusion pumps, and a medical staff of only 2 providers, a paramedic and a physician. Since temperature control was not available, a reliable supply of lipid emulsion could not be maintained. Infusions were established by adding 1 $mg{\cdot}kg^{-1}$ of 1% (10 $mg{\cdot}mL^{-1}$) lidocaine to a known volume of crystalloid solution. Then, using the tubing drop factor ($drops{\cdot}mL^{-1}$) and the infusate concentration ($mg{\cdot}mL^{-1}$), the drop rate ($drops{\cdot}min^{-1}$) was calculated for an infusion of 1 $mg{\cdot}kg^{-1}{\cdot}h^{-1}$.

Case 1 - we treated a 22-y-old female, who presented with a fractured left tibia and fibula as a result of falling from a moving motorcycle. Upon presentation, the patient complained of pain localized to the site of the fracture, which was specifically described as constant and 8/10 in severity on the defense and veterans pain rating scale (DVPRS).[7,8] The patient was then monitored with continuous pulse oximetry, manual noninvasive blood pressure manometry, and 3-lead electrocardiography. After ensuring that no life-threatening injuries were present, establishing intravenous access, and determining that the affected extremity was neurovascularly intact, we treated the patient with a 1 $mg{\cdot}kg^{-1}$ bolus of intravenous lidocaine over approximately 2 min. Of note, the patient did report transient tinnitus. Within 2 min of completing the bolus, the pain began to subside to 3/10 in severity (DVPRS). This analgesic effect lasted for approximately 40 min and facilitated splinting. The patient was then released with oral paracetamol for analgesia.

Case 2 - we treated a 38-y-old male, with a prior history of opioid use disorder, who presented with a fractured left posterior fifth rib as a result of falling from a ladder over 2 m high. Of note, this patient was also concurrently serving as a medical assistant. On initial physical assessment, the patient appeared to be splinting with shallow breaths at a respiratory rate of 35 $breaths{\cdot}min^{-1}$. Continuous 3-lead electrocardiography, pulse oximetry, and manual noninvasive blood pressure manometry were initiated. The patient's oxygen saturation on pulse oximetry was 93%, while on room air. The patient complained of a sharp pain, localized to the site of the fracture, was worsened by deep inspirations, and rated at a 9/10 in severity (DVPRS). On examination, bilateral breath sounds could be auscultated, trachea was midline, and no jugular venous distension was observed. After establishing intravenous access, we initiated a 1 $mg{\cdot}kg^{-1}$ bolus of intravenous lidocaine over 2 min, followed by an ongoing infusion of 1 $mg{\cdot}kg^{-1}{\cdot}h^{-1}$ for 2 h. Within 5 min of initiating the intravenous lidocaine bolus, the patient felt the pain resolve to a dull pain, with a severity of 4/10 (DVPRS). More importantly, the patient's respiratory rate improved to 18 respirations per minute, and the saturation on pulse oximetry improved to 98%. The patient did describe transient tinnitus. Once pain was reduced to a more tolerable level, the patient was able to be transported to a nearby location, where he was able to resume his clinical duties and would have access to additional care. However, he did complain that the pain began to increase again approximately 30 min after discontinuation of the intravenous lidocaine infusion.

Discussion

Effective pain control and management of trauma can be difficult in an austere environment, often complicated by limited resources and personnel. Pain control options are frequently limited by what is immediately available, weight or bulk of agent, equipment needed for administration, route of administration, and availability of intravenous access. Lidocaine is often made available in these settings because local and regional anesthetic techniques are currently recommended as both an effective and safe modality in the treatment of acute pain.[2] In both of these cases, regional anesthetic techniques would have likely been beneficial. However, a properly trained provider was not available. This pair of cases represent an austere environment, where many commonly used analgesic modalities for moderate to severe pain were not readily available. Although ketamine was available, the immediate supply was limited and its use may have compromised the patients' sensorium and cognitive function, a costly side effect in this setting. Even when administered in doses as low as 0.1 to 0.4 $mg{\cdot}kg^{-1}$, intravenous ketamine may result in undesirable psychotomimetic effects.[9] The risk of local anesthetic systemic toxicity, a constellation of mainly cardiovascular and neurologic side effects, is typically seen when serum lidocaine concentrations exceed 5 to 10 $mcg{\cdot}mL^{-1}$. Prior studies suggest that these toxic levels can be avoided by using low dose infusions and boluses less than 1.5 $mg{\cdot}kg^{-1}$.[10,11] Although the patients described in this study briefly experienced tinnitus, intravenous lidocaine provided analgesia without considerably compromising mental status. Given the contextual limitations, implementation of this modality in austere environments may prove to be

advantageous with reduced dosing, careful administration, and even as a component of multimodal analgesia.

Intravenous lidocaine infusions utilized in the treatment of acute pain have been studied in the perioperative setting, where this modality results in reduced pain scores and opioid requirements after abdominal surgeries. Additionally, intravenous lidocaine may have an analgesic benefit in intrathoracic and orthopedic surgeries.[12] Lidocaine has also been shown to treat chronic neuropathic pain, as seen in diabetic neuropathy or complex regional pain syndromes. It has anti-nociceptive, anti-hyperalgesic, and anti-inflammatory activity[6] that can uniquely provide prolonged pain relief without the concomitant sedative or hypnotic effects seen by other analgesic medications. A recent study found that lidocaine administration was associated with a decreased incidence of chronic postsurgical pain.[13] These properties of lidocaine likely result not only from the blockade of voltage-gated sodium channels, but also from the inhibitory activity at various other sites, to include the NMDA and muscarinic cholinergic receptors.[6]

Intravenous lidocaine has a small therapeutic window with a high risk for toxicity. Therefore, use of this modality in conventional clinical settings requires that lipid emulsion be readily available. Side effects for this modality include slurred speech, tinnitus, perioral paresthesias, and, rarely, cardiovascular collapse or seizures.[6,12] Transient tinnitus, which was experienced by the 2 described patients, is considered a minor adverse effect that often occurs even at serum lidocaine concentrations as low as 5 mcg·mL^{-1}. The more severe effects, such as cardiovascular collapse, typically do not occur until a serum concentration of 10 mcg·mL^{-1} is reached. Providers also need to be mindful of the contraindications to systemic lidocaine, such as heart failure, cardiac dysrhythmias, medication allergy, hepatic impairment, renal impairment, or seizure disorders.[12] Proper training, clinical experience with this modality, and appropriate equipment during the administration of systemic lidocaine are necessary factors that provide safety but also limit employment of this modality.

The cases described here occurred at a single remote clinic, where treatment was restricted by limited resources and personnel. Additional research is required to identify best practices for the administration of intravenous lidocaine for the management of pain in austere and prehospital settings, as well as optimal patient populations and methods of administering the infusions. The scalability and feasibility of using lidocaine infusions for analgesia at points of injury must also be further evaluated. Future clinical investigation may find intravenous lidocaine to be a safe and effective alternative analgesic modality. This modality may warrant consideration in situations where traditional options have been exhausted, are unavailable, or are deemed unsuitable.

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CASE REPORT

Black-Spot Toxicodendron Dermatitis With Varied Presentation

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This article describes the clinical presentation, differential diagnosis, and treatment of 2 unrelated cases with different presentations of black-spot Toxicodendron dermatitis. In the first case, a healthy 7-y-old male presented with a rash consisting of black dots with localized surrounding erythema on the left arm. The rash then progressed to a vesicular, pinpoint, raised rash spreading to the face, arms, and neck. In the second case, a 4-y-old male presented with non-pruritic, black, flat, non-erythematous lesions that did not progress. This patient's older sibling had been diagnosed with poison ivy 1 wk prior, and they attended the same child care where the poison ivy was thought to be acquired. In both cases, diagnosis of black-spot Toxicodendron dermatitis was made. The black spot of Toxicodendron dermatitis is caused by urushiol oxidation on exposure to air. The subject may or may not go on to develop allergic contact dermatitis after the exposure. Diagnosis of this dermatitis is made on clinical presentation, with careful consideration of history, distribution, and lesion morphology. When allergic dermatitis does develop as in the first case, systemic treatment with oral steroids is recommended. In both of these cases the black dots completely resolved in 2 to 3 wk. Dermatologic referral for dermoscopy and biopsy may be necessary if the dermatosis does not resolve as anticipated.

Keywords: poison ivy, rashes, urushiol, pruritus

Introduction

Poison ivy species (*Toxicodendron radicans*), poison oak (*T diversilobum*), and poison Sumac (*T vernix*) plants in the *Toxicodendron* genus are one of the most common causes of allergic contact dermatitis, affecting 10 to 50 million Americans per year.[1] They are expected to become more common with increasing CO_2 and fragmentation of habitats.[2,3] Approximately 50 to 75% of the population are sensitive to urushiol (a colorless oleoresin), the substance in plants of the genus *Toxicodendron* that causes allergic contact dermatitis[4] and are therefore at risk for allergic reactions. The prevalence of sensitivity decreases in larger, urban areas where such plants are less common, 10 to 15% of the population does not react to a concentration 1000 mg of urushiol.[4] The peak frequency for sensitization occurs between the ages of 8 and 14 with less sensitization in infants.[5] Contact with any portion of the plant can potentially trigger a skin reaction. If the plant is traumatized, the sap is extruded, hardens, and the plant seals off the resin channels. Black dots may be visualized on the surface of the plants of the genus *Toxicodendron* in areas of trauma.[6] On exposure to air, urushiol in the sap oxidizes, polymerizes, and turns black, causing black skin discoloration.[7,8]

Black-spot poison ivy dermatitis is a rare presentation of poison ivy dermatitis first described in 1923. Black, enamel-like deposits were found on the hands of gardeners who were exposed to *Toxicodendron* sap.[9] Fewer than 25 cases have been reported in the literature prior to 2011.[10,11]

Histologic evaluation of these black spots demonstrates resin on the surface of the stratum corneum with a neutrophilic infiltrate and areas of epidermal necrosis beneath it, in contrast to typical poison-ivy dermatitis, which reveals superficial perivascular infiltration without evidence of resin or necrosis.[12,13] Dermoscopy reveals a jagged, homogeneous, brown lesion with a red rim,

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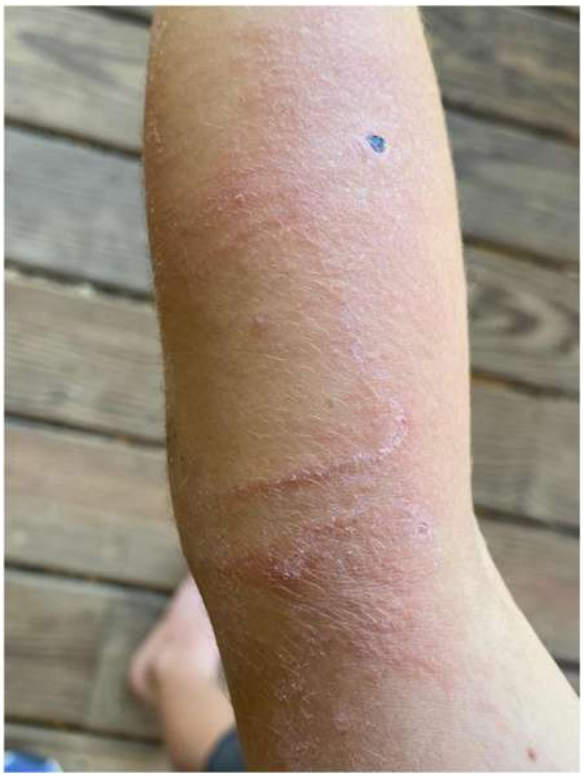

Figure 1. Case 1: Triangular-shaped black lesion on left arm with surrounding erythematous, vesicular rash extending from upper arm through elbow to lower arm.

suggesting uneven diffusion of urushiol within the stratum corneum.[14] The black spot tends to appear within 1 h of contact with urushiol and typically falls off in 1 to 2 wk.[15] Among those sensitive to urushiol, allergic symptoms after exposure are typically seen between 24 and 48 h, with a range of 5 h to 15 d.[16] While the most typical presentation of black-spot Toxicodendron dermatitis will have both the black dots and other classical signs of poison ivy dermatitis, 10 to 15% cases will only present with black spots in people who are not sensitive to urushiol.[12]

Case Reports

CASE 1

A 7-y-old otherwise healthy boy presented in early summer to a pediatric clinic in central Virginia for an evaluation of a rash located on his left arm. This rash was first noted 1 wk prior as black dots that did not wash off with soap and water. The guardian initially thought that the black dots were drawn with a permanent black marker. Two days before presenting to clinic, the patient developed nonpruritic, raised inflamed areas around the black dots, prompting the visit. The patient's guardian had applied hydrocortisone cream without response. The patient had no other symptoms and no history of atopic dermatitis. The patient lived near the woods. He had no known exposures to insects, new foods, skin products, medications, or plants. On physical exam, all vitals were normal, and there were no abnormalities except for the skin findings. Examination of the skin revealed linear, raised, blanchable, erythematous areas on the neck measuring 2 cm at the greatest length with pinpoint vesicles, as well as linear, raised, blanchable, erythematous areas on the left arm measuring 3 cm at the greatest length with pinpoint vesicles around 3 black lesions (Figure 1).

Based on the clinical distribution the clinical distribution of the rash, time course, and potential exposure living by the woods, a diagnosis of black-spot poison ivy dermatitis was made. Poison ivy predominates in central Virginia. Since the rash was localized, the patient was given triamcinolone 0.1% ointment for treatment of the local allergic reaction. Follow-up was recommended if skin findings worsened or any new symptoms developed. Five days later, the guardian called for concern that the rash was spreading and was now causing severe itching. The physical exam was unchanged except for skin findings, which had significantly worsened. The rash was now raised, blanchable, erythematous with some pinpoint vesicles and had spread to both arms, the right cheek, right ear, and neck with areas measuring up to 9×4 cm. The patient was diagnosed with poison ivy dermatitis with significant allergic reaction. The patient was prescribed a taper of oral prednisone at a starting dose of 1 $mg \cdot kg^{-1} \cdot d^{-1}$ and cetirizine at 5 mg daily. Oral steroids are recommended for treatment of allergic reactions for a course of 2 to 3 wk to prevent rebound dermatitis.[17] The patient was also advised to continue calamine lotion and oatmeal baths for comfort. Pictures were sent to the dermatologist, who confirmed the diagnosis. The patient's guardian reported significant improvement of erythematous areas after 24 h. The rash resolved in 5 d. The black dots disappeared after 2 to 3 wk.

At the time of the initial presentation, the differential diagnoses included: contact dermatitis, eczema herpeticum, scabies, skin trauma, foreign body, writing implement marks, foreign body, nevus, or skin melanoma. The areas were flat, nontender, and non-purulent. The black lesions did not appear to be superficial enough to be secondary to a writing implement. The areas of erythema and linear vesicles on the arm at initial presentation were consistent with the distribution of poison ivy or poison oak dermatitis. The element of linearity highly favors a plant dermatitis, with the linear lesions roughly

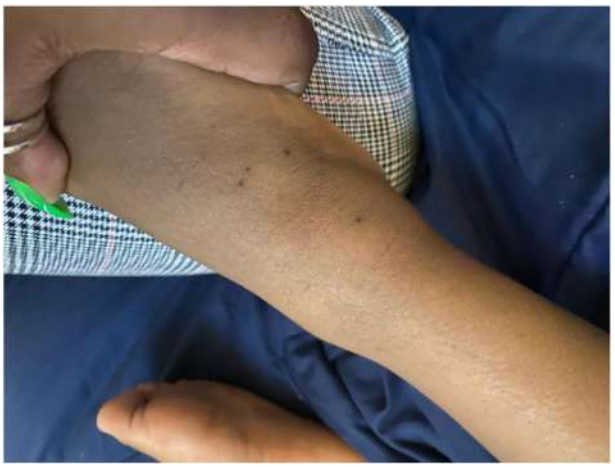

Figure 2. Case 2: Black lesions on right lateral ankle.

corresponding to sites on the arm that could be physically brushed by the offending plant. The patient recovered well. If the black dots had persisted, a referral to a dermatologist and possible biopsy would be indicated.

CASE 2

A 4-y-old boy with a history of developmental delay presented in the early summer for evaluation to the health care provider with a 1-wk history of a non-pruritic, black dot rash around his ankles bilaterally. The patient's guardian noted he had black dots on his ankles and a black dot on his left elbow. The patient had no history of atopic dermatitis or other symptoms. He had no known exposure to insects, new foods, medications, or skin products. The guardian reported that because the patient had a developmental delay, it would be challenging to assess whether this rash was causing discomfort. The patient's guardian reported that the older sibling had been diagnosed with poison ivy 1 wk prior by another health care provider. This improved with topical hydrocortisone. The guardian reported that the sibling may have been exposed to poison ivy from the day care center that both children attended.

The remainder of the exam was normal except for the skin findings: non-tender, flat, black macules on the lateral portion of the ankles and the left elbow (Figure 2).

Because the black dots were a new presentation and the sibling had been diagnosed with poison ivy dermatitis 1 wk prior, black dot poison ivy dermatitis was diagnosed. The guardian was advised to follow up if the rash worsened or new symptoms developed. Because the rash resolved completely in 2 to 3 wk, the patient did not require further evaluation.

Discussion

Symptomatic treatment of black-spot poison ivy can include soothing topical treatments, oral antihistamines, high-potency topical corticosteroids, or oral glucocorticoids. Topical corticosteroids are most beneficial during the early stages of allergic contact dermatitis.[18] For severe dermatitis, particularly involving the face or inguinal region, oral glucocorticoids are indicated.[19,20] Expected outcome of black dot poison ivy dermatitis with treatment is full recovery. Lesions should be monitored for secondary bacterial skin infection and treated with antimicrobial therapy if indicated. Measures to prevent further allergic reactions include wearing protective clothing and avoiding poison ivy or poison oak. For clothing, wool is most protective along with leather gloves.[8,21] If a person comes in contact with poison ivy/oak, recommendations include washing the area with Zanfel[22] (a mixture of alcohol solubles and surfactants), Tecnu (a mixture of mineral spirts, propylene glycol, octylphenoxy-polyethoxyethanoal, and mixed fatty acid soap), or isopropyl alcohol. Clothing should be laundered, and tools should be washed with a dilute solution of bleach.[8]

Black dot poison ivy typically resolves in 1 to 2 wk, although this can take longer, as in the cases we presented. Failure of the rash to resolve in 3 wk should prompt a dermatology referral. Time course of rash resolution may assist in determining if dermatology referral and biopsy are indicated and depending on the clinical evolution may be unnecessary.

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CASE REPORT

A Rare Case of Limb-Threatening Injury Secondary to Extrinsic Vascular Compression Following Crocodile Bite

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Crocodile bites lead to fatal and nonfatal outcomes in humans. Mugger crocodiles (*Crocodylus palustris*) and saltwater crocodiles (*Crocodylus porosus*) are common in India. Most crocodile bites can cause severe injuries, especially to the extremities, due to the substantial bite force of the crocodile, which typically leads to extensive tissue damage, fractures, amputations, and vascular injuries. We report the case of a crocodile bite victim who presented with features of acute limb ischemia, was found to have vascular thrombosis of the common femoral artery, and was experiencing complete compression of the femoral vein due to external vascular compression by a hematoma. We discuss various injury mechanisms sustained in crocodile bites and the roles of point-of-care ultrasound and continuous tomography angiography, which could help identify these injuries. After thrombectomy and hematoma evacuation the patient recovered and was discharged without any physical dysfunction.

Keywords: extremity trauma, vascular injury, point-of-care ultrasound, acute limb ischemia, reptile bite

Introduction

Humans receiving bites from wild animals are often the result of 2 things: self-defense by the animal, or the victim is mistaken as the animal's prey as the creature hunts for food.[1] A multicenter study sponsored by the World Health Organization reported an annual incidence of animal bites in India of about 2%, with a higher incidence in rural areas and among poor or low income groups.[2] Human–crocodile conflict is a rare event, and crocodilian attacks on humans are challenging to quantify. Though crocodile bites on humans are common in Africa, Australia, and South and Central America, they are relatively uncommon in India, especially in the southern regions of country. One possible reason for the decreased total incidence of crocodile bites might be that they occur in very remote areas and may go underreported. India's most common crocodile habitats are in deep water rivers, lakes, and artificial bodies of water—they are found in various regions of India, including parts of Andaman and Nicobar Islands (Figure 1). Crocodiles are usually aggressive during the winter mo of November and December, when their mating season starts. The risk of human–crocodile conflict has increased as a result of increasing human activity in rivers and their natural habitats.[1] There is little published literature outlining the initial assessment and management of crocodile bites.[1] We report a rare case of a crocodile bite in an adult patient who sustained a limb-threatening vascular injury due to extrinsic compression of common femoral artery by a hematoma.

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Case Report

A 50-y-old man was brought to the emergency department after being bitten by a 3-m-long crocodile on his left lower limb and iliac region while washing himself by the river banks at 1630. He was taken to a nearby tertiary care hospital where his wound was dressed and his left lower leg was placed in a splint before he was then sent to our trauma center via ambulance. On arrival at 1904, he was conscious and oriented, with a Glasgow Coma Scale of 15, pulse rate of 74 beats·min^{-1}, blood pressure of 140/80 mm Hg, respiratory rate of 14 breaths·min^{-1}, O_2

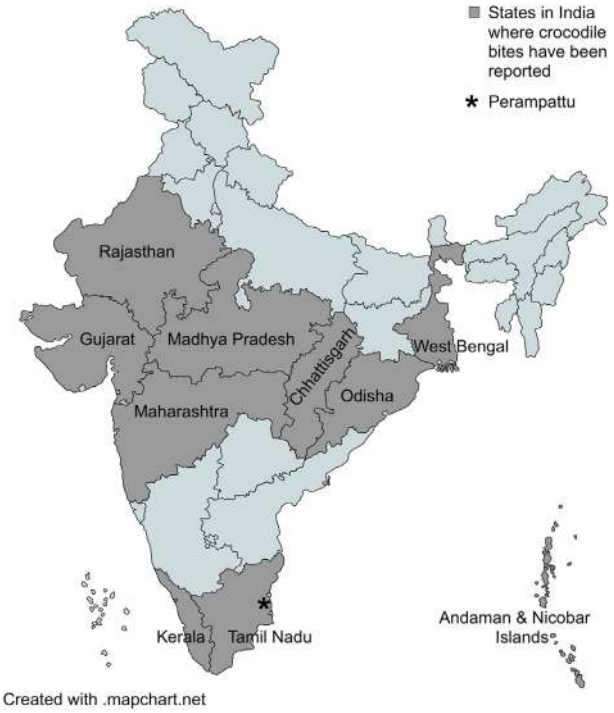

Figure 1. Map of India showing regions where crocodile bites have been reported to date, and location of Perampattu village (marked as *) where the patient sustained the attack.

saturation of 98% on room air, and finger capillary refill time of less than 3 s. On local examination, 2 significant lacerations were found in the left iliac region: the first being 3×2×1 cm (length×depth×width), and the second being 4×3×1 cm (length×depth×width). In addition, the patient had a laceration measuring about 3×2 cm (length×width) in the anterolateral aspect of left thigh and 3 other puncture wounds in the anterolateral left thigh (Figure 2A). The patient also had a 1×1 cm (length×width) laceration in the lateral aspect of left knee and 2 lacerations (8×5 cm and 2×1 cm, length×width) in the lateral aspect of the left leg (Figure 2B). Pulses in the left-sided femoral, popliteal, anterior tibial, posterior tibial and dorsalis pedis arteries were not felt. However, pulsations were felt in the right lower limb distal artery.

The wound was cleaned thoroughly and dressed, tetanus toxoid and tetanus immunoglobulin were administered, and the patient was given ceftriaxone and metronidazole as empiric antibiotics. Our bedside point-of-care ultrasound revealed no color flow in the left popliteal, anterior tibial, posterior tibial, and dorsalis pedis arteries—right femoral artery color flow was present. While checking for color flow in the left femoral artery, we found a hematoma (6.2×2.5 cm) in the muscular plane that was completely compressing the left common femoral vein, which had collapsed and was also compressing the left distal common femoral artery, as evidenced by no color flow in the artery distal to the hematoma (Figure 3). No vascular contrast extravasation was seen on computed tomographic (CT) angiography, but a filling defect was noted in the left distal external iliac artery and proximal common femoral artery (Figure 4). Our vascular team was informed immediately and the patient was taken to the operating room. Intraoperatively, no vascular injury was noted, but a soft thrombus was found in the left common femoral artery extending into the left external iliac artery. This was possibly due to extrinsic compression and stasis caused by the overlying hematoma. Thrombectomy was performed and the hematoma was evacuated—intraoperative wound culture was not taken. The postoperative course was uneventful. The patient received 10 d of ceftriaxone and metronidazole in addition to wound care. No signs of infection were noted in the postoperative period. Due to the patient's multiple wounds, he remained in the hospital for 2 wk and was fully ambulatory at discharge.

Discussion

There are 23 different species of crocodiles worldwide of which the mugger crocodile (*Crocodylus palustris*) and saltwater crocodile (*Crocodylus porosus*) are common in India. Crocodiles are more commonly distributed in the Andaman and Nicobar Islands, West Bengal, Kerala, Odisha, Gujarat, Chattisgarh, Rajasthan, Madhya Pradesh, Maharashtra, and Tamil Nadu (Figure 1).[3] Our patient sustained a bite from a 3-m-long crocodile along the banks of the Kollidum River in Tamil Nadu, a state in

Figure 2. (A) Bite wounds on left thigh and inguinal region and (B) bite wounds on left knee and left leg.

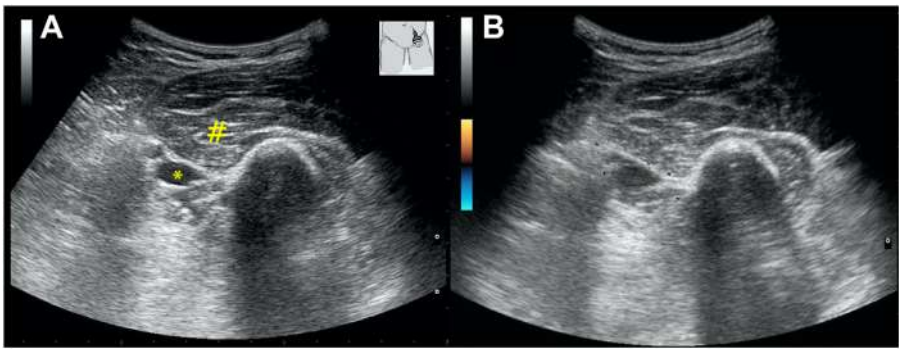

Figure 3. (A) Ultrasound image showing hematoma (marked as #) compressing left common femoral artery (marked as *). (B) Color Doppler image showing no color flow in the left common femoral artery.

the southern part of India where mugger crocodiles are commonly reported.[4] Most adult crocodiles are >3-m-long and have enormous biting capacity. The muscles used for opening their mouth are weak but the force with which they bite is powerful enough that it makes it very difficult for the victim to escape. Of all the 23 species of crocodiles, the measured average bite force exerted by sexually matured adults was found to range between 900 to 8983 N (202–2019 lb).[5] Even though most crocodile bites are reported as unprovoked, the true nature of these attacks is uncertain.[1] Humans often encounter crocodiles when they bathe and wash clothes along the banks of a river. Cases of human–crocodile encounters have also been reported among fishermen and people snorkeling.[1]

The mechanisms of injury in crocodile attacks include deep puncture and tearing wounds from their long sharp teeth as well as blunt injuries from the crocodile's strong bite force and battering from the tail of the animal.[6] The penetrating force can cause penetrating vascular trauma and hematomas, and the shearing forces can cause extensive tissue damage, blunt vascular trauma, fractures, and amputations. The anatomic distribution of wounds commonly include injuries to the extremities, which is consistent with the attack behavior of the crocodile that involves striking from below or from the side. In fact, a retrospective review of crocodile bites in southern Malawi found that >80% of soft tissue injuries were in the extremities.[6] In our case, a similar pattern was seen with injuries in the left lower limb, with multiple penetrating injuries probably caused by the long conical teeth of the animal.

Prehospital management is vital in crocodile bite victims since these bites typically occur in remote areas and transport to the hospital may be delayed. Therefore, emergency medical services personnel should focus on immediate hemorrhage control, immobilization of affected body part, early wound decontamination, and rapid transport to a trauma center. Currently, there are no

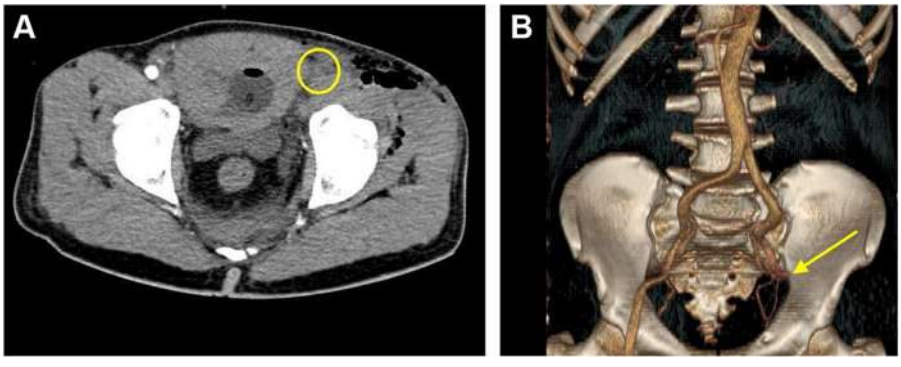

Figure 4. (A) Computed tomographic angiography showing filling defect in the left distal external iliac and left proximal common femoral artery (marked with yellow circle). (B) 3-dimensional reconstructed image showing complete cutoff of flow beyond external iliac (marked with a yellow arrow).

Table 1. Mangled extremity severity score (MESS) score.[14,15] MESS ≥7 predicts low likelihood of limb viability

Component	*Points*
Skeletal soft tissue injury	
Low energy	1
Medium energy	2
High energy	3
Very high energy	4
Limb ischemia (if limb ischemia presents >6 h, score is doubled)	
Pulse reduced or absent but perfusion normal	1
Pulseless; paresthesia, diminished capillary refill	2
Cool, paralyzed, insensate, numb	3
Shock	
Systolic BP always >90 mm Hg	0
Transient hypotension	1
Persistent hypotension	2
Age (y)	
<30	0
30–50	1
>50	2
Total	14

data about the utility of prehospital antibiotics for animal bites. Although a sepsis trial of prehospital antibiotics did not show any survival benefit when antibiotics were administered in an ambulance, recent recommendations and studies have suggested a possible benefit for early antibiotics administration.[7–9] Hence, early antibiotics may be considered when longer transport time is anticipated. In addition to the injuries caused by bites, there are case reports of victims being dragged into water and sustaining complications due to drowning.[10] Emergency medical services teams should also focus on airway stabilization and starting the patient on oxygen if patient is hypoxic.

As with all trauma patients, routine primary assessment and stabilization after advanced trauma life support protocols must be followed when crocodile bite victims present to the emergency department. Due to the possibility of extensive soft tissue injuries and vascular damage, these patients may present with profound hemorrhagic shock. Hemorrhage control and activation of massive transfusion protocols are critical steps in managing these patients. To prevent further vascular damage, early immobilization of the injured limb is advisable. Copious wound washing and emergent debridement should be done for all wounds to mitigate the possibility of wound infections in crocodile bite wounds. Multiple microorganisms can grow in the wound due to the unusual flora in crocodile teeth and the oral cavity—gram-negative bacteria and anaerobes are commonly found.[6,11] *Pseudomonas pseudomallei, Pseudomonas aeruginosa, Enterococcus sp, Aeromonas hydrophila, Enterobacter agglomerans, Citrobacter diversus,* and *Clostridium* species are the main organisms that have been isolated from wound swabs of studies of crocodilian bite microbiology.[12,13] Antibiotic coverage must cover gram-negative rods and anaerobic organisms. Doxycycline should specifically be included in cases of crocodile bites because *Vibrio vulnificus* has also been shown to grow from the wounds.[11] Wounds sustained by crocodile bites are usually contaminated, therefore every patient with an unknown history of immunization or <3 doses has to be given tetanus toxoid and tetanus immunoglobulin.

Multiple scoring systems like the mangled extremity severity score (MESS); predictive salvage index; nerve injury, skeletal injury, shock, and age score; limb salvage index; and Hannover fracture scale have been suggested for predicting the extent of injuries in extremity trauma.[14] MESS scoring is commonly used to estimate the viability of an extremity after trauma and to determine need for salvage vs empiric amputation (Table 1).[15,16] In our patient, the score was calculated as 7, predicting a low likelihood of limb viability. Using the MESS scoring system, this assumes that the crocodile bite has been a high-energy mechanism.

Crocodile bites can present with both blunt and penetrating vascular injuries.[1] Duplex ultrasonography and CT angiography are the common diagnostic modalities used to evaluate a patient with a suspected vascular injury. In our case, although we initially suspected vessel injury (given the penetrating nature of the wound), intraoperatively, we found that a large hematoma had compressed the vessel, causing stasis and soft thrombus formation, which caused pulselessness. At this point, the use of point-of-care ultrasound was pivotal. The ultrasound showed a hematoma that completely occluded the femoral vein as a result of extrinsic compression and compression of the common femoral artery (CFA). In this case, it appeared that extrinsic compression and stasis had caused an acute thrombus to form in the CFA. The ultrasonographic appearance of an acute thrombus has been reported to be hypoechoic or anechoic.[17,18] The absence of color flow in color Doppler of the CFA confirmed this hypothesis in our patient. Acute compartment syndrome after a crocodile bite has been reported, leading to vascular compression and presenting with features of acute limb ischemia.[19] The anterior compartments of the thigh and lower leg are the most common locations for compartment syndrome in the lower extremity. However, in our patient, other clinical features of compartment syndrome (such as pallor, paresthesia and paralysis) were absent. Direct extrinsic arterial compression could have

resulted in a similar presentation to that seen in our patient, and has been reported in the literature. The literature has documented 1 case report of extrinsic femoral artery occlusion after internal fixation of an acetabular fracture and 3 other cases of thrombosis after extrinsic iliac artery occlusion post acetabular fracture repair.[20] A few other rare cases of extrinsic vascular compression by external bodies have been reported, including lymphangioma, neurofibroma, fecal impaction, and leiomyoma.[21–23]

Apart from the penetrating vascular injury reported in crocodile bites, they can also present with blunt vascular injuries due to the unique mechanism of injury. There are multiple case reports of injuries to the external iliac, common femoral, and common iliac arteries as a result of blunt trauma without concomitant bone fractures in patients who sustained road traffic accidents.[24] One such reported injury is motorcycle-scooter-handlebar syndrome, where the vascular injury occurs without any bony fracture.[25] The mechanism of this injury has been thought to be due to intimal tear or inner circumferential intimal fracture. The inguinal portion of the CFA is tethered by arterial branches, periadventitial connective tissue, and femoral sheath, and this portion is vulnerable to compression against the superior pubic ramus. Hence, similar injuries should also be suspected when managing patients who present with crocodile bites.

Conclusions

The key elements for managing crocodile bite injuries—both in prehospital and in-hospital settings—should focus on hemorrhage control, immobilization of extremities, and early identification of vessel injuries caused by the enormous bite force. Both blunt and penetrating vascular injuries are commonly seen with crocodile bites. Extrinsic vascular compression causing arterial thrombosis also needs to be evaluated as a potential differential diagnosis. Point of care ultrasound and CT angiography are very useful tools in identifying these injuries. In addition to maintaining focus on advanced trauma life support guidelines, emergency care providers must focus on thorough wound washing, debridement, and appropriate antibiotic coverage for gram-negative rods and anerobic organisms due to the unusual oral flora of crocodiles.

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Letters to the Editor

Nonsteroidal Anti-Inflammatory Drugs Are Safe and Appropriate for the Treatment of Copperhead Envenomations

To the Editor:

We read with interest the recent study by Buchanan and colleagues regarding snakebites reported to the Kentucky Regional Poison Control Center.[1] While we appreciate their important contribution to the medical literature on snake envenomation, we believe that certain points raised in their manuscript require clarification.

Buchanan and colleagues state that "use of non-steroidal anti-inflammatory drugs [NSAIDs] should be avoided for pain control in favor of opiates because they may potentiate venom's effects on platelet aggregation and coagulation." They do acknowledge that there is "little evidence to suggest [NSAIDs] should be avoided in copperhead bites," but consistently classify aspirin and NSAIDs as "contraindicated therapies" in their text and in Table 3.

There is in fact good evidence that NSAIDs are safe in patients suffering copperhead envenomation. A retrospective cohort study of 147 patients with copperhead envenomation treated in Missouri found that there was no significant difference in coagulation parameters between patients tread with NSAIDs and patients treated without NSAIDs; additionally, there were no bleeding events attributable to NSAID therapy.[2] This finding has been confirmed by secondary retrospective analysis of large clinical trials.[3] This is likely because copperhead envenomation generally does not produce clinically significant or severe coagulopathy, as has been demonstrated in multiple studies in many regions of the United States using both conventional coagulation tests[4-7] and thromboelastography.[8] When perturbations in coagulation parameters do occur, they are typically mild[5,9] and not associated with bleeding.[5]

The existing evidence is of course limited by the retrospective nature of the available studies as well as potential limitations in follow-up and definitive identification of envenomating species. Nevertheless, we are not aware of any published cases of medically significant bleeding following the use of NSAIDs to treat patients with copperhead envenomation.

We routinely use NSAIDs in the treatment of pediatric and adult patients with copperhead envenomations and have found the practice safe and effective. We agree that many patients with copperhead envenomation may benefit from opioid therapy, but find that NSAIDs are generally opioid-sparing, and may completely control pain in some cases. Although it remains appropriate to avoid NSAIDs in patients with rattlesnake envenomations, given the high rates of associated significant coagulopathy,[9] we believe that NSAID therapy is safe and appropriate in patients with copperhead envenomations.

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The Use of Unethical Research in Wilderness Medicine Education

This letter was accepted as an important commentary on presentation ethics, but as a point of clarification the conference being discussed was not a Wilderness Medical Society event. — Editor-in-Chief

To the Editor,

Last year, I attended a virtual conference on wilderness medicine. The topics were carefully chosen and the speakers were well prepared. Although I missed the pre-pandemic routine of sitting next to and chatting with like-minded colleagues from around the globe in the conventional conference venue, I very much enjoyed having the content zoomed in to the privacy, comfort, and safety of my home.

All of that suddenly ended when one of the speakers, lecturing on hypothermia and describing the case of an accidental cold water immersion patient, displayed a chart from a publication circa 1945 depicting the duration of human immersion in cold water and its effect on mortality. Circles on the chart represented the number of Dachau prisoners who lived and died after they were immersed in cold water. To be clear, these were concentration camp inmates who were involuntarily and brutally tortured in order to find out how long they could live in cold water. Many died. Of the survivors, many suffered additional torture as Nazi scientists subjected them to rewarming techniques.

There was no warning that this would be forthcoming or included in the presentation, and upon seeing this slide, I became temporarily incapacitated. Although the study was described as "highly unethical," the speaker then went on to report the findings, concluding that cold water immersion can cause death quite rapidly. The slide remained on the screen for 34 seconds.

How did an otherwise highly engaging lecture on hypothermia devolve so rapidly and unexpectedly? Why did the speaker choose to insert immorally acquired "findings" into a wilderness medicine conference? Was this the best evidence available in order to meet an educational objective? I waited for weeks and months to see if the content would be challenged and/or censored by conference organizers or withheld from the online recordings. At time of this writing, as far as I am aware, none of this has occurred.

Dissemination of Nazi research at scientific meetings has happened before, and although this was the first time I witnessed use of materials in a virtual broadcast forum, others have had similar experiences.[1] Why should we care?

The arguments for and against the use of "information" or "data" gathered from unethical research have been discussed elsewhere.[2-4] The speaker at the conference I attended was not using the information collected by Nazi scientists to study hypothermia for the betterment of humanity nor to introduce a topic and discussion at the intersection of wilderness medicine and bioethics; rather, the speaker seemed to be presenting the findings as part of a scientific review of the subject. This seems like an odd choice. A review[5] of the experimental design and analysis of the reported results demonstrates that the Dachau hypothermia experiments are "scientifically useless."[6]

Regardless of scientific merit, I do not know why anyone would select to use data obtained through unethical research in an educational presentation. Perhaps the speaker believed that the material did have educational value. Perhaps the speaker was not aware of the controversy that exists in citing Nazi research as a means of understanding and tackling contemporary issues in wilderness medicine. Ignorance may have played a role in the decision to do so; however, ignorance can be dangerous too.

Hypothermia is an especially important topic to the wilderness medicine community and rightfully deserves its place in a conference agenda and curriculum. As a wilderness medical society, we must ask ourselves, is it permissible to inject the findings and conclusions derived from unethical research into our educational offerings and scholarly work? If the answer is no, then we must speak up against the use of this information to prevent it from becoming embedded in medicine and science. Wilderness medicine societies, fellowship programs, and other training institutions should consider implementing curricula and policies to address and educate about these and other bioethical issues that exist within our specialty.

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