BRIEF REPORT

Negative Predictive Value of Excluding an Embedded Snake Foreign Body by Ultrasonography

William F. Rushton, MD; J. Priyanka Vakkalanka, ScM; James H. Moak, MD; Nathan P. Charlton, MD

From the Division of Medical Toxicology, Department of Emergency Medicine (Drs Rushton, Vakkalanka, and Charlton), and the Department of Emergency Medicine (Dr Moak), University of Virginia School of Medicine, Charlottesville, VA.

Objective.—Numerous reputable sources for healthcare providers advocate routine imaging to rule out an embedded tooth or fang after a snake bite. The objective of this study was to determine whether these foreign bodies can be reliably excluded by bedside ultrasonography.

Methods.—All emergency medicine (EM) residents and faculty at a single institution were invited to participate. Two sets of 5 ultrasound gel phantoms were prepared using a method previously validated to have the same density as human tissue. In the first set of 5 phantoms, 1 snake fang was embedded to simulate a retained foreign body. Similarly, in the second set of 5 phantoms, 1 snake tooth was also embedded. Participants were asked to identify the presence or absence of a foreign body in each phantom using bedside ultrasonography. Year of training and confidence in excluding a snake foreign body were also recorded.

Results.—Each participant ($n = 27$) performed ultrasound imaging on 10 phantoms for a total of 270 samples. Range of experience included postgraduate year 1 (25.9%), postgraduate year 2 (29.6%), postgraduate year 3 (33.3%), and graduates of EM residency (11.1%). The sensitivity and negative predictive value for ruling out an embedded fang was 92.6% and 98.1%, respectively. The sensitivity and negative predictive value for ruling out an embedded tooth was 77.8% and 93.7%, respectively. Among all the phantoms, there was a sensitivity of 85.2% and a negative predictive value of 96%.

Conclusion.—Bedside ultrasonography performed by an EM physician is a feasible option to rule out embedded foreign bodies after a snake bite if imaging is warranted.

Key words: snake, pit vipers, ultrasound, foreign body, emergency medicine

Introduction

The care of patients with snake bites is standard practice for an emergency physician. In 2011 there were 6630 snakebite cases reported to the American Association of Poison Control Centers.¹ Currently, the prevalence of a retained snake tooth or snake fang in human tissue remains unknown, and there is a paucity of literature on retained snake foreign bodies; only two English case reports were found that detailed a retained snake tooth or fang.^{2,3} A review of one poison center's experience with 1679 pit viper (*Crotalinae*) bites reported over a 10-year period found no evidence of a retained snake tooth or

fang.⁴ Nevertheless, many healthcare providers continue to order routine imaging as part of wound management after a snake bite. They are not alone; several reputable guidelines for healthcare providers advocate for imaging to rule out a retained foreign body after snake bite.^{5–7}

Recently, other investigators have promoted bedside ultrasonography as a viable alternative to radiography to exclude several types of foreign bodies.⁸ The advantage of ultrasonography lies in its lack of ionizing radiation and availability at the bedside. Many soft tissue foreign bodies appear hyperechoic on sonography and may produce either shadowing or a reverberation artifact that allows them to be identified even when radiolucent on radiography. Furthermore, ultrasound guidance may play a role in removing the foreign body.⁸ The objective of this study was to determine whether embedded foreign bodies, such as a fang or tooth, can be reliably excluded by bedside ultrasonography in a simulated snake bite scenario.

Presented at the International Congress of the European Association of Poisons Centres and Clinical Toxicologists, May 29, 2014, Brussels, Belgium.

Corresponding author: William Rushton, MD, Division of Medical Toxicology, Department of Emergency Medicine, University of Virginia School of Medicine, PO Box 800774, Charlottesville, VA 22908 (e-mail: wrushton@gmail.com).

Methods

All emergency medicine (EM) residents and faculty at a single tertiary care center with a census of approximately 60,000 visits per year were invited to participate in this study. The study was approved by the University of Virginia's Institutional Review Board. Written consent was waived by the Board as there was minimal risk to study participants. Because the true incidence of a retained snake foreign body remains unknown, a priori we assumed a 20% prevalence with the understanding that this would likely underestimate our negative predictive value (NPV).

Two sets of 5 ultrasound gel phantoms were prepared using a method previously validated to have the same density as human tissue that has been used in other ultrasonography research.^{9,10} A gelatin and water suspension was made, after which psyllium-based fiber was introduced to act as a scattering agent to approximate the characteristics of human tissue. Blue dye was added to the model to obscure direct visualization of an inserted object.

In the first set of 5 phantoms, a snake fang was embedded approximately 1 cm deep in 1 of 5 phantoms to simulate a retained foreign body after a venomous snake bite. In the second set of 5 phantoms, a snake tooth was similarly placed approximately 1 cm deep in only 1 phantom. Both snake tooth and fang were obtained from a *Crotalinae* species. The fang measured 0.75 cm long and the tooth was 0.2 cm long. On each phantom, the approximate location of the snake bite was identified with a red mark, as bites in actual patients are usually apparent owing to puncture wounds, ecchymosis, and bullae.

Participants were informed that the incidence of retained foreign bodies is low, and they were then asked

to identify the presence or absence of a foreign body in each phantom using a SonoSite M-Turbo (SonoSite, Bothell, WA, USA) bedside ultrasound system. They were explicitly blinded to the knowledge that only 1 phantom in each set had a retained snake tooth or fang. Before the study, participants were shown an image of a fang (Figure 1) and tooth as seen on ultrasonography, but no other training was given. Each participant was allowed to scan at his or her own speed, determine the appropriate lighting, and choose either the high frequency or low frequency ultrasound probe. All work was done individually, and each phantom was scanned one at a time in random succession. Year of training, completion of a formal ultrasonography course in residency, and confidence in excluding a foreign body were also recorded.

STATISTICAL ANALYSIS

Each participant's set of 10 responses indicating the presence or absence of a foreign body was recorded on paper then entered into a Microsoft Excel spreadsheet. These responses were graded for accuracy, thereby identifying cumulative values of true positives, true negatives, false positives, and false negatives across all participants.

Ultrasonography test characteristics measured in this study included sensitivity (proportion of gels containing foreign bodies that were correctly identified), specificity (proportion of gels without foreign bodies that were correctly identified), positive predictive value (proportion of gels identified as having a foreign body that truly had a foreign body), and NPV (proportion of gels identified as not having a foreign body among those that truly had no foreign body). In addition to overall

Figure 1. Sagittal (left) and transverse (right) views of *Crotalinae* fang. The hyperechoic fang is represented by the white arrows. Posterior acoustic shadowing is indicated by the hollow arrows.

ultrasonography test characteristics, measurements were also stratified by the type of foreign body used (fang vs tooth). Furthermore, participants' overall scores for identifying foreign bodies across all 10 gels were evaluated as percentages.

To account for potential confounders, differences in mean overall scores were evaluated through a one-way analysis of variance test. All data were analyzed using SAS 9.3 software (SAS Institute, Cary, NC, USA).

Results

Twenty-seven subjects agreed to participate in this study; demographics are presented in Table 1. Range of experience included postgraduate year 1 (25.9%), postgraduate year 2 (29.6%), postgraduate year 3 (33.3%), and graduates of EM residency (11.1%). Twenty (74%) of the participants had completed a formal 2-week ultrasonography training course during their residency.

Each participant ($n = 27$) performed an ultrasound scan on 10 phantoms, for a total of 270 samples. Table 2 demonstrates the results of the data on the 5 fang simulated phantoms, the 5 tooth simulated phantoms, and the aggregate data. The sensitivity and NPV for ruling out an embedded snake fang were 92.6% and 98.1%, respectively. Similarly, the sensitivity and NPV for ruling out an embedded tooth were 77.8% and 93.7%, respectively. Among all the phantoms, there was a sensitivity of 85.2% and a NPV of 96%. Findings are summarized in Table 3.

The difference in accuracy was calculated through a one-way analysis of variance test, presented in Table 4. Although resident physicians were more likely to score better than attending physicians ($P = .004$), there was no difference by training year among the residents ($P =$

Table 1. Demographics of participants

Demographics	<i>n</i>	%
Total	27	100
Training year		
First	7	25.9
Second	8	29.6
Third	9	33.3
Attending	3	11.1
Formal ultrasonography training in residency		
Yes	20	74.1
No	7	25.9
Confidence in excluding foreign body by ultrasonography		
Low	4	14.8
Medium	16	59.3
High	7	25.9

Table 2. Results for foreign body identification by ultrasonography

Ultrasonography results	True results		Total
	Positive	Negative	
Fang only			
Positive	25	4	29
Negative	2	104	106
Total	27	108	135
Tooth only			
Positive	21	19	40
Negative	6	89	95
Total	27	108	135
Aggregate results (tooth and fang)			
Positive	46	23	69
Negative	8	193	201
Total	54	216	270

.394). Completion of an ultrasonography course during residency ($P = .804$) and self-reported confidence in excluding a retained foreign body ($P = .148$) also did not demonstrate a statistical difference in overall scores.

Discussion

Bedside ultrasonography is becoming an increasingly important tool for the clinician. Many emergency departments now have a portable ultrasound machine for patient evaluation, and emergency medicine residencies currently incorporate formal training in the use of ultrasonography in their curricula. Bedside ultrasonography allows the clinician to provide safe, efficient patient care without the use of ionizing radiation. The use of bedside ultrasonography to rule out a foreign body appears to be easy to learn, as training for the study participants was minimal. Participants were only shown a picture of the sonographic findings of a retained tooth and a retained fang in the gel model. They were then allowed to determine the best approach to evaluation based on prior experience. Many participants reported

Table 3. Ultrasonography test characteristics in foreign body identification

Characteristics	Test results (%)		
	Tooth only	Fang only	Aggregate results
Sensitivity	77.8	92.6	85.2
Specificity	82.4	96.3	89.4
Positive predictive value	52.5	86.2	66.7
Negative predictive value	93.7	98.1	96

Table 4. Comparison of overall scores by potential confounders

Comparisons	Mean score (%)	P value
Overall	88.1	
Training level (n = 27)		
Resident physicians	90.4	0.004
Attending physicians	70	
Postgraduate year (n = 24)		
1	87.1	0.394
2	91.3	
3	92.2	
Formal ultrasonography training in residency		
Yes	87.1	0.804
No	88.5	
Confidence in excluding foreign body by ultrasonography		
Low	87.5	0.148
Medium	85	
High	95.7	

that the high-frequency probe was more efficacious in finding the foreign body, although that was not explicitly studied.

It appears that bedside ultrasonography can safely rule out a retained foreign body after snake bite, avoiding the risk of ionizing radiation and the delay in obtaining radiography. In this study, the NPV was greater than 90% in the fang simulation, tooth simulation, and aggregate data. These results show efficacy comparable to a 1996 study that demonstrated a NPV of 96.5% and a sensitivity of 96.7% in a similar stimulated model investigating the use of plain radiography in detection of radiopaque foreign bodies in distal extremities.¹¹ The NPV in our study is also likely to be underestimated as we assumed a 20% prevalence in designing our model, and the true prevalence is probably much lower. Furthermore, the sensitivity was greater than 85% in both the fang and the aggregate data. The low sensitivity demonstrated in the tooth simulation likely reflects the small size of the tooth (it was difficult to see with the human eye). We speculate sensitivity and specificity would have increased if there had been a more formal training process. Further validation of these findings should be performed using a tissue model.

STUDY LIMITATIONS

There were several limitations to this study. This was a simulated experience using phantom gelatin models; therefore, applicability to real human tissue is unknown. Both the fang and the tooth were obtained from a

Crotalinae species, which may limit external generalizability to other genera of snakes. For instance, it is unknown whether *Elapidae* snake fangs, such as those belonging to the *Micrurus fulvis* found in the southeastern United States, would be as echogenic. In addition, because the entire tooth and fang were embedded in the phantom, it remains unclear whether retention of only part of the tooth or fang would affect the results. Furthermore, previous research suggests that participants perform better when being studied, which is known as the Hawthorne effect; that also may have biased our results. Finally, the sample size of this study was relatively small.

Conclusion

Because of the high NPV and sensitivity, bedside ultrasonography performed by an EM physician is a feasible option to rule out an embedded foreign body after snake bite and should be considered if imaging is warranted. This approach should reduce ionizing radiation, unnecessary costs, and time to disposition of patients with a suspected retained tooth or fang. Continued research remains warranted to determine the applicability to actual human tissue, generalizability to other snake species, and validity at other training centers.

References

1. Bronstein AC, Spyker DA, Cantilena LR, Rumack BH, Dart RC. 2011 Annual report of the American Association of Poison Control Centers' National Poison Data System (NPDS): 28th annual report. *Clin Toxicol (Phila)*. 2012;50:911–1164.
2. Sheard R, Smith G. Penetrating eye injury following a snake attack. *Eye*. 2003;17:279–280.
3. Weed HG. Nonvenomous snakebite in Massachusetts: prophylactic antibiotics are unnecessary. *Ann Emerg Med*. 1993;22:220–224.
4. Rushton WF, Dabrowski KH, Vakkalanka JP, Charlton NP. Incidence of retained snake foreign body following a snakebite [ACMT abstract]. *J Med Tox*. 2014;10:65.
5. Riley BD, Pizon AF, Ruha AM. Snakes and other reptiles. In: Nelson LS, ed. *Goldfrank's Toxicologic Emergencies*. 9th ed. New York, NY: McGraw-Hill; 2011:1601–1610.
6. Norris R. Snake venom poisoning in the United States. Stanford University Web. Available at: <http://emed.stanford.edu/education/Didactics/snakebites.htm>. Accessed March 5, 2014.
7. Vearrier D, Greenberg M. Snake bites diagnostic tests. Epocrates. Available at: <https://online.epocrates.com/u/2911945/snakebites/summary/highlights?cid%4emn0811>. Accessed March 5, 2014.

8. Olubaniyi BO, Bhatnagar G, Vardhanabhuti V, Brown SE, Gafoor A, Suresh PS. Comprehensive musculoskeletal sonographic evaluation of the hand and wrist. *J Ultrasound Med.* 2013;32:901–914.
9. Lo MD, Ackley SH, Solari P. Homemade ultrasound phantom for teaching identification of superficial soft tissue abscess. *Emerg Med J.* 2012;29:738–741.
10. Kendall JL, Faragher JP. Ultrasound-guided central venous access: a homemade phantom for simulation. *CJEM.* 2007;9:371–373.
11. Manthey DE, Storrow AB, Milbourn JM, Wagner BJ. Ultrasound versus radiography in the detection of soft-tissue foreign bodies. *Ann Emerg Med.* 1996;28:7–9.