Original Article

Ultrasound Evaluation of Soft-Tissue Foreign Bodies by US Army Medics

David L. Driskell[1]*, J. Barton Gillum[2], Jonathan D. Monti[2], Aaron Cronin[2]

[1]Department of Emergency Medicine, Blanchfield Army Community Hospital, KY, USA, [2]Department of Emergency Medicine, Madigan Army Medical Center, Tacoma, WA, USA

Abstract

Objective: The study's primary objective was to determine army medics' accuracy performing bedside ultrasound (US) to detect radiolucent foreign bodies (FBs) in a soft-tissue hand model. Secondary objectives included the assessment of US stand-off pad effects on soft-tissue FB detection rates and assess established FB detectable lower limit size of 2 mm. **Methods:** Prospective, single blinded, observational study of US-naïve Army medics' abilities utilizing bedside US to detect wooden FBs in a chicken thigh model with or without an US stand-off pad. After a 2 h training period, medics' abilities to detect 1–3 mm FB utilizing a SonoSite® M-Turbo US and 13–6 MHz linear probe were assessed. **Results:** After a 2 h training period, 28 medics had a sensitivity and specificity of 73% and 78% detecting 1–3 mm FBs utilizing standard US equipment. The medics' sensitivity and specificity were both 78% in detecting radiolucent FBs 2 mm and larger without a stand-off pad. The sensitivity and specificity decreased to 48%, 62%, and 67% when utilizing a stand-off pad to detect 1, 2, and 3 mm soft-tissue FBs. Sub 2 mm detection rates decreased from 82% for 2 mm FB to 64% for 1 mm FBs without utilizing a stand-off pad. **Conclusion:** Army medics with minimal US experience successfully identified FBs embedded in hand models with accuracies similar to radiologists and emergency medicine physicians. However, radiolucent FB detection sensitivity and specificity decreased in US-naïve Army medics utilizing stand-off pads. In addition, this study reconfirmed the lower limit of FB detection rates at 2 mm. These results support Army medics' utilization of US to evaluate for superficial radiolucent FBs of the hand.

Keywords: Army medics, chicken model, foreign bodies, stand-off pad, ultrasound

Introduction

Foreign body (FB) detection is often difficult in clinical practice secondary to the high incidence of retained radiolucent material and the associated conventional imaging challenges.[1-9] Greater than one-third of soft-tissue FBs are radiolucent.[2,4] Difficulty detecting radiolucent FBs with conventional imaging coupled with limited or incomplete history increases the risk of missing FBs on initial evaluation.[1,2,5,9,10] The sequela of missed FBs are commonly cited for litigation.[9,11,12] In addition, retained FBs result in pain, inflammation, and increased risk of infection.[3,9,13,14]

The hand is the most common site of soft-tissue FBs in the United States.[13,15,16] From 65% to 95% of FBs were found in the hands and feet,[10,11,13,16] FBs of the hand are associated with damage to neurovascular and tendinous structures.[3,4,10,11,16] Greater than 65% of patients with soft-tissue FBs present for care within the first 24 h to 48 h. Early diagnosis of soft-tissue FBs can potentially decrease the sequela of retained FBs.

Military personnel are at increased risk of soft-tissue injuries from FBs secondary to construction with wood and injuries from improvised explosive devices. Military personnel are also exposed to forests and densely vegetated areas in austere combat environments. Finally, medical evacuation is associated with significant cost as well as increased risks to evacuation personnel and equipment.

Ultrasound has many potential applications and has been increasingly pushed forward for evaluation of trauma patients.

Received: 17-05-2016 **Accepted:** 19-12-2017 **Available Online:** 05-07-2018

Access this article online	
Quick Response Code:	**Website:** www.jmuonline.org
	DOI: 10.4103/JMU.JMU_12_18

Address for correspondence: Dr. David L. Driskell, Department of Emergency Medicine, Blanchfield Army Community Hospital, Fort Campbell, KY, USA. E-mail: david.l.driskell.mil@mail.mil

How to cite this article: Driskell DL, Gillum JB, Monti JD, Cronin A. Ultrasound evaluation of soft-tissue foreign bodies by US army medics. J Med Ultrasound 2018;26:147-52.

The portability of ultrasound (US) devices make it useful for multiple military applications.[17,18] In addition, US has been shown to be sensitive in detecting FBs even when utilized by minimally trained personnel.[2,3,19] Its multifunctionality, far-forward availability, and sensitivity in detecting FBs may decrease evacuation requests and operational costs.

More costly modalities utilized to detect radiolucent FBs include plain radiographs, computed tomography (CT), and magnetic resonance imaging (MRI). Turkcuer *et al*. and Levine *et al*. cite plain radiographs as unreliable in detecting radiolucent soft-tissue FBs.[2,13] CT is associated with increased ionizing radiation exposure, cost, and sensitives from 0% to 60% detecting wood FBs. MRI is associated with both increased cost compared to other imaging modalities and is not available to many emergency departments.[6,9,12,20] Therefore, plain radiographs, CT, and MRI may not represent the optimal study to exclude radiolucent soft-tissue FBs.

This prospective observational study evaluated army medics' accuracy in detecting wooden FBs implanted into hand-tissue models, utilizing standard Army US equipment. The tissue model chosen best replicates the most commonly presenting anatomical site of FB injury, while the selected FB material represents the most commonly encountered radiolucent FB.[1,10,11,13,15,16] Secondarily, this study assessed the impact of US stand-off pad usage during the US evaluation of soft-tissue radiolucent FBs embedded within hand models. Finally, the FB dimensions for this study were based on several studies suggesting dimensions <2 mm are associated with rapidly declining imaging detection sensitivity and specificity.[9,15,21]

Methods

Study design and setting

This was a prospective, single-blinded, observational, study conducted at the Charles A. Anderson Simulation Center on the 3rd and 4th of March 2015. The sensitivity and specificity of army medics detecting wooden FB implanted into tissue models were assessed utilizing existing military US equipment. The Madigan Army Medical Center, Department of Clinical Investigation granted the study approval.

Participants

Volunteer army medics were recruited from Joint Base Lewis McChord from November 2014 to February 2015. Exclusion criteria included medics reporting any US experience or who were unable to participate in the 1 h didactic and 1 h hands-on training sessions. No protected health information or personally identifiable information was collected on any study participant.

Training

All study participants underwent a 1 h didactic and 1 h hands-on training session before data collection. The didactic portion consisted of 15 PowerPoint® slides depicting basic US physics and FB images. The slides illustrated FBs as well as tissues with varying echogenicity, reverberation artifacts, and posterior shadowing artifacts. During the hands-on portion, participants used high fidelity Phantom® tissue models to practice US detection of FBs.

Equipment

The study utilized two M-Turbo US machines manufactured by SonoSite® and coupled with 13–6 MHz linear transducers. Standard large Esteem® stretchy nitrile latex-free surgical gloves were filled with 250 ml of tap water for use as stand-off pads.

Models

Twenty food grade chicken thighs with femur lengths of 7–9 cm were used as the hand thenar eminence models for this study. All chicken thigh models had a 1 cm wide incision to a depth of 1 cm placed by the primary investigator utilizing a 15 blade scalpel oriented at a 45° angle transverse to the femur. Following the incision all 20 models were irrigated with 30 cc of normal saline before placement of the FBs. Eight of the 20 chicken models had no embedded FB, while four had 1 mm, four had 2 mm, and four had 3 mm wooden FBs embedded. The wooden FBs consisted of standard flat toothpicks cut to lengths of 1, 2, and 3 mm. These models were placed inside Esteem® stretchy nitrile latex-free surgical gloves to replicate the appearance of the thenar eminence. Each glove was then stapled to cardboard to remove all air between the glove and chicken-tissue surface. Each chicken model's incision site was marked on each glove [Figure 1]. Ten chicken thigh models were randomized for each day, consisting of four models without FBs, two with 1 mm FB, two with 2 mm FB, and two with 3 mm FB. Fellowship trained US providers conducted pretest and posttest scans daily to ensure the placement of FBs in each model.

Execution

Each medic was presented with 20 randomized chicken models which they individually evaluated for the presence of FBs without stand-off pads followed by utilizing stand-off pads.

Primary data analysis

FB detection for each chicken model was recorded, yielding sensitivity and specificity as well as positive and negative predictive values for each different-sized FB. The Fisher's Exact Chi-square test was used to compare the findings with or without the standoff.

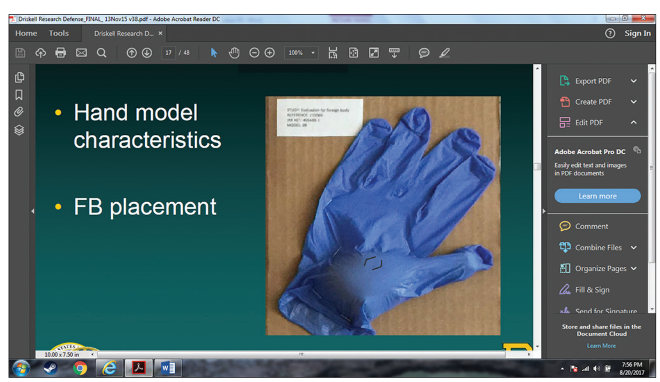

Figure 1: Thenar Eminence Model picture

Results

A total of 31 army medics reported to the study conducted at the Charles A. Anderson Simulation Center on the 3rd and 4th of March 2015. Three medics with previous US experience were excluded, leaving a total of 28 medics to participate. Two medics were unable to complete the 10 stand-off pad scans. The data consists of the 28 medics not excluded who completed a total of 540 scans over the 2 days, 280 scans without a stand-off pad, and 260 scans with the stand-off pad. Table 1 illustrates the total numbers of FBs detected and missed in this study, both with and without the use of a stand-off pad. Table 2 illustrates the sensitivity and specificity with or without the stand-off pad.

On day one, a statistically significant difference ($P = 0.019$) was observed between the two 3 mm models without a stand-off pad. Nine of the ten medics detected the FB on one model while only three of the ten medics detected the FB on the other model. In contrast, on day two, no statistically significant difference ($P = 0.087$) was observed between the two 3 mm models without a stand-off pad. Seventeen of 18 medics detected the 3 mm FB in one model compared to 12 of the 18 medics detecting the FB on the other model without the use of the stand-off pad. No statistical difference was found between the day 1 ($P = 0.58$) or day 2 ($P = 1.0$) 1 mm models and the day 1 ($P = 1.0$) or day 2 ($P = 0.65$) 2 mm models and the day 2 ($P = 0.087$) 3 mm models.

Discussion

US has become particularly useful for the military secondary to its portability and for its diagnostic imaging capability for a growing number of bedside applications. The need for real-time diagnostic information in the emergency room spurred this movement, as technology improved US has been pushed to prehospital care.[22,23] Army medics perform at the combat mission level. They are first to render patient care while deployed in these frequently austere environments. They are often the sole medical provider and pushed far forward within remote locations with limited medical supplies. The medics ability to recognize pathology and provide actionable information to higher echelons of care impacts evacuation and therefore combat power and mission capability. This study suggests that medics can effectively utilize US without stand-off pads to detect soft-tissue radiolucent FBs with accuracy comparable to other medical providers. In addition, medics reconfirmed the current lower limit of FB detection at 2 mm.[6,9,12,15,21,24] This study adds to a growing body of literature suggesting that US is a valuable tool in the hands of many health-care professionals, as well as having a legitimate role in prehospital emergency care.[18,22,25-27]

The primary objective of this study was to evaluate Army medic's ability to detect radiolucent FBs embedded within a chicken thigh model. It was hypothesized that army medics would detect radiolucent soft-tissue FBs with the same accuracy as other health-care providers.[2-4] This study utilized a chicken thigh model based on prior validation as cited within multiple US study's assessing various health-care professionals.[2,3,19,28] The chicken thigh sonographically resembles the human soft tissues and bony anatomy of the hand.[2,3,19] The thigh's musculature and femur provide a high fidelity hand model representing the most common FB

Table 1: Test performance by FB size (1-3 mm) without stand-off pad (n=280) and with stand-off pad (n=260)

Modality	Size (mm)	Totals scans	FB present	Found	Missed	95% CI	*P*
Linear probe alone	1-3	280	168	123	45	66.0-79.3	0.003
Linear probe + stand-off pad		260	156	90	66	49.8-65.1	
Linear probe alone	1	168	56	36	20	37.0-59.2	0.1203
Linear probe + stand-off pad		160	52	25	27	51.1-75.5	
Linear probe alone	2	168	56	46	10	52.0-73.5	0.032
Linear probe + stand-off pad		160	52	33	19	69.9-90.2	
Linear probe alone	3	168	56	41	15	47.9-73.5	0.221
Linear probe + stand-off pad		160	52	32	20	60.3-83.1	
Modality	**Size**	**Totals scans**	**FB absent**	**FP**	**TN**	**95% CI**	***P***
Linear probe alone	No FB	280	112	25	87	15.5-30.9	0.025
Linear probe + stand-off pad		260	104	38	66	27.9-46.1	

Fisher exact χ^2. FP: False positive, TN: True negative, FB: Foreign body, CI: Confidence interval

Table 2: Test performance characteristics for ultrasound without (n=280) and with stand-off pad (n=260)

Modality	Percentage (95% CI)			
	Sensitivity	Specificity	PPV	NPV
Linear probe alone	73 (65.7-79.6)	78 (68.6-84.7)	83 (75.8-88.5)	65 (57.0-73.7)
Linear probe + stand-off pad	58 (49.5-65.5)	67 (57.3-75.9)	72 (63.7-80.0)	51 (42.7-60.0)
Linear probe alone ≥2 mm	78 (68.6-84.7)	78 (68.6-84.7)	78 (68.6-84.7)	78 (68.6-84.7)
Linear probe + stand-off pad ≥2 mm	62 (52.4-71.6)	67 (57.3-75.9)	65 (55.3-47.7)	64 (54.4-73.0)

CI: Confidence interval, PPV: Positive-predictive value, NPV: Negative predictive value injury site reported in the United States, which accounted for 35%–55% of FB injuries.[10,11,13,15,16] A retrospective review by Rockett *et al*. of 20 patients with retained soft-tissue wooden FBs noted the depths to be between 0.4 and 1.6 cm.[14] Therefore, this study utilized a 1 cm FB insertion depth based on both this retrospective study and on validating the studies conducted with FB-embedded tissue models.[2-4,10,19-21,28] A 45° angle from the chicken femur's long axis was chosen to best represent the expected injury pattern due to reaching, grasping, or falling on an outstretched hand.

The findings in this study suggest that army medics with 2 h of US training can detect FBs embedded in chicken thighs with similar sensitivities and specificities as radiologists and emergency medicine physicians in similar studies as illustrated in Table 3.[3,23,28] Of all previously cited studies, Turkcuer *et al*.'s US study of radiologists detecting 5 mm FBs embedded in chicken thighs utilizing 12 MHz linear probes closely resembles this study's methods. No statistically significant difference existed between the radiologists in Turkcuer's detection of FBs and the army medics within this study. In addition, three emergency medicine physicians following a 1 h training session had similar sensitivities and specificities detecting 15 mm wooden FBs within a chicken thigh model utilizing 8 MHz linear transducers.[3] Ultrasound-naïve nurses receiving a 2 h training period had similar sensitivity and specificity detecting larger 15 mm FBs in chicken breast models.[19] Overall, this study's medic participants achieved similar detection rates as other medical professionals utilizing 13–6 MHz linear transducers detecting radiolucent wooden FBs at the lower end of US detectability.[6,9,12,15,24,21]

Frequently cited, historical cadaveric US studies assessing FBs are of limited clinical relevance.[23,29] Crystal *et al*. placed 5 mm FB over muscular areas of the arm and leg and achieved a comparatively lower sensitivity ranging from 40.8% to 72.3% and specificity ranging from 30% to 66.7% utilizing a 10–5 MHz linear transducer.[23] These studies are clinically less useful when considering most of the FBs are found in the hand and foot.[10,11,13,15,16] Furthermore, Crystal's stated limitations suggest that cadavers may not be the optimal model for ultrasound research and cited tissue changes may have occurred during the processing and embalming or as a result of the previous injuries or pathology.[23,29] These tissue changes included calcifications and dehydration of the dead tissues as well as a lack of inflammatory reactions secondary to FB implantation, likely leading to decreased US detection.[23,29] Limitations of cadaveric studies make them clinically inconsequential.[23,29]

A secondary objective of this study was to assess the detection rates of soft-tissue FBs with the use of stand-off pads. The American College of Emergency Physicians web articles recommends the use of stand-off pads to improve superficial FB detection.[24,30] It was hypothesized that detection rates during the study would also increase with the use of stand-off pads.[24,30] This study used water-filled surgical gloves as stand-off pads as they are already used in clinical practice readily available in austere environments and are field expedient.[24,25,30] Army medics during this study had decreased sensitivity and specificity in detecting FBs ($P = 0.003$) when utilizing stand-off pads. It was noted that many of the medics failed to stabilize their probe hand while using the stand-off pad compared to when the probe was placed directly over the chicken thigh. It also appeared that more of a fanning technique was used by some of the medics when the transducer was pressed into the stand-off pad which may have resulted in a less comprehensive evaluation of the soft tissues. The data suggest that stand-off pads may not be useful in the hands of US-naive medics.

Of note, medics detected 82% of 2 mm and 73% of 3 mm without a stand-off pad, compared to 63% of 2 mm and 61% of 3 mm with a stand-off pad. This decreased detection was found to be statistically significant ($P = 0.019$) between the two different, day 1, 3 mm models. Nine of the ten medics detected the FB in one 3 mm model compared with three of the ten medics in the other 3 mm model without a stand-off pad. The validating sonographer noted the FB of the 3 mm model which subsequently had a low-detection rate was located within a superficial fascial plane and was nearly perpendicular to the fascial plane, with similar echogenicity as the fascial plane. This may explain the detection rate for the 2 mm FB being 82% compared to 73% in detecting the 3 mm FB.

In addition, this study assessed the current lower limit for detecting soft-tissue FBs. Although clinical relevance of retained FBs based on the size has not been clearly defined, several studies cite infection as the most common presenting

Table 3: Comparison of health care providers

Provider	Size (mm)	Accuracy (%)	Sensitivity	Specificity	PPV	NPV
Medic	2-3	78	78	78	78	78
Emergency medicine residents			85	82	83	85
Emergency physician	15	80	70	90	88	75
	15	77	69	84	82	73
	15	84	82	87	86	83
Radiologist	15	83	83	83	83	83
Nurse practitioner	15		78	50	83	44
Emergency medicine physicians	15		83	75	91	60

PPV: Positive predictive value, NPV: Negative-predictive value, FB: Foreign body complaint for retained radiolucent FBs.[9-11,20] A retrospective study by Rockett *et al*. noted infection in ten of the 20 patients with surgically removed soft-tissue wooden FBs that ranged in size from 3 mm to 4.5 cm.[20] It was assumed that smaller FBs would be detected with the use of high-frequency13–6 MHz linear probes. Several studies suggest that below 2.5–3 mm sensitivity and specificity will rapidly decline when utilizing 7.5–10 MHz linear probes.[6,9,12,15,21,24] Utilizing cadaver feet, Jacobson *et al*. showed that sensitivity and specificity for detecting a 5 mm wooden FB was 93.3% and 96.7%, with 7.5–10 MHz linear array transducers.[21] However, the sensitivity dropped to 86.7% while detecting 2.5 mm wooden FBs.[21] Medics in this study found 64% of 1 mm and 82% of 2 mm utilizing a 13–6 MHz linear probe without a stand-off pad. The data suggest that the sensitivity and specificity drops below 2 mm.

Aras *et al*. and Mizel *et al*. noted that CT and US have decreased FB detection rates when the FB was in close to the bone.[5,6] US detection was decreased when located in proximity to bone.[6] Multidetector CT scans performed using 1 mm collimation scans of sheep heads revealed 1 cm FB specifically located between muscle and bone are less visible.[5] Although not statistically significant ($P = 0.08$) individually, FBs noted to be in close to the bone during the pretest, and posttest validation scans become statistically significant when compared together ($P = 0.03$). It can be inferred that location is important, as reduced distance from the bone are associated with decreased detection rates.

Future studies assessing US skill retention could assist determining requisite refresher training frequency and duration. Studies analyzing the impact of probe technique on detection rates could help optimize and improve the education of scanning techniques. Evaluating the depth, location, and size of FBs in clinical practice could help optimize treatment and the need for removal of retained FBs.

Limitations

This study has several limitations. Most importantly is that chicken models were used and the fidelity with human hands has not been validated. Location of FBs within the hand is not well described in the literature, and therefore sensitivities and specificities of a model with FB placement may not reflect the actual location of FB during trauma to a human hand. Although location appears to change detection rates, this study was not designed to look for this and further study to clarify this and its role clinically will be needed.

The SonoSite®M-Turbo US and 13–6 MHz linear probe was utilized, and different sensitivities and specificities may result with different machines or lower frequency probes. Training retention following a 2 h block of instruction is not known. The study was not designed to test for or alleviate US fatigue, as all the steps were in the same order for each participant over both days. The study was not designed to capture appropriate US technique and compare it with the accuracy locating soft-tissue FBs.

Conclusion

The study suggests that medics trained in FB evaluation with US have similar sensitivities and specificities as radiologists and emergency medicine physicians in similar studies. It can be inferred from the results that using stand-off pads in personnel with limited US experience have decrease sensitivity and specificity. The study also confirmed that sensitivity and specificity decreases with FB <2 mm.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Gooding GA, Hardiman T, Sumers M, Stess R, Graf P, Grunfeld C, *et al.* Sonography of the hand and foot in foreign body detection. J Ultrasound Med 1987;6:441-7.
2. Turkcuer I, Atilla R, Topacoglu H, Yanturali S, Kiyan S, Kabakci N, *et al.* Do we really need plain and soft-tissue radiographies to detect radiolucent foreign bodies in the ED? Am J Emerg Med 2006;24:763-8.
3. Orlinsky M, Knittel P, Feit T, Chan L, Mandavia D. The comparative accuracy of radiolucent foreign body detection using ultrasonography. Am J Emerg Med 2000;18:401-3.
4. Tahmasebi M, Zareizadeh H, Motamedfar A. Accuracy of ultrasonography in detecting radiolucent soft-tissue foreign bodies. Indian J Radiol Imaging 2014;24:196-200.
5. Aras MH, Miloglu O, Barutcugil C, Kantarci M, Ozcan E, Harorli A, *et al.* Comparison of the sensitivity for detecting foreign bodies among conventional plain radiography, computed tomography and ultrasonography. Dentomaxillofac Radiol 2010;39:72-8.
6. Mizel MS, Steinmetz ND, Trepman E. Detection of wooden foreign bodies in muscle tissue: Experimental comparison of computed tomography, magnetic resonance imaging, and ultrasonography. Foot Ankle Int 1994;15:437-43.
7. Graham DD Jr. Ultrasound in the emergency department: Detection of wooden foreign bodies in the soft tissues. J Emerg Med 2002;22:75-9.
8. 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.
9. Tintinalli J, Stapczynski J, John Ma O, Cline D, Cydulka R, Meckler G, *et al*. Tintinalli's Emergency Medicine: A Comprehensive Study Guide. Ch. 43, 44, 50, 263, e299.3. 7th ed. New York: McGraw-Hill; 2010.
10. Shrestha D, Sharma UK, Mohammad R, Dhoju D. The role of ultrasonography in detection and localization of radiolucent foreign body in soft tissues of extremities. JNMA J Nepal Med Assoc 2009;48:5-9.
11. Hill R, Conron R, Greissinger P, Heller M. Ultrasound for the detection of foreign bodies in human tissue. Ann Emerg Med 1997;29:353-6.
12. Jacobson JA, Powell A, Craig JG, Bouffard JA, van Holsbeeck MT. Wooden foreign bodies in soft tissue: Detection at US. Radiology 1998;206:45-8.
13. Levine MR, Gorman SM, Young CF, Courtney DM. Clinical characteristics and management of wound foreign bodies in the ED. Am J Emerg Med 2008;26:918-22.
14. Blankenship RB, Baker T. Imaging modalities in wounds and superficial skin infections. Emerg Med Clin North Am 2007;25:223-34.
15. Daniel J, Cody K, Panebianco N, Shofer F, Ku B, Dean A, *et al.* Small retained foreign bodies: What is the limit of detection using current emergency ultrasound equipment? Crit Ultrasound J 2012;4 Suppl 1:A12.
16. Friedman DI, Forti RJ, Wall SP, Crain EF. The utility of bedside ultrasound and patient perception in detecting soft tissue foreign bodies in children. Pediatr Emerg Care 2005;21:487-92.

17. Rockett MS, Gentile SC, Gudas CJ, Brage ME, Zygmunt KH. The use of ultrasonography for the detection of retained wooden foreign bodies in the foot. J Foot Ankle Surg 1995;34:478-84.
18. Larry M. American College of Emergency Physicians. Pearls and Pitfalls. Available from: http://www.acep.org/content.aspx?id=83271. [Last accessed on 2015 Jun 10].
19. Milian M, Lin M. American College of Emergency Physicians. Pearls and Pitfalls. Available from: http://www.acep.org/Clinical-Practice-Management/Ticks-of-the-trade-Finding-the-foreign-bodyUtility-of-Ultrasonography/. [Last accessed on 2015 Jun 10].
20. Schlager D. Ultrasound detection of foreign bodies and procedure guidance. Emerg Med Clin North Am 1997;15:895-912.
21. Nelson BP, Chason K. Use of ultrasound by emergency medical services: A review. Int J Emerg Med 2008;1:253-9.
22. Monti JD, Younggren B, Blankenship R. Ultrasound detection of pneumothorax with minimally trained sonographers: A preliminary study. J Spec Oper Med 2009;9:43-6.
23. Atkinson P, Madan R, Kendall R, Fraser J, Lewis D. Detection of soft tissue foreign bodies by nurse practitioner-performed ultrasound. Crit Ultrasound J 2014;6:2.
24. Walcher F, Weinlich M, Conrad G, Schweigkofler U, Breitkreutz R, Kirschning T, *et al.* Prehospital ultrasound imaging improves management of abdominal trauma. Br J Surg 2006;93:238-42.
25. Lapostolle F, Petrovic T, Lenoir G, Catineau J, Galinski M, Metzger J, *et al.* Usefulness of hand-held ultrasound devices in out-of-hospital diagnosis performed by emergency physicians. Am J Emerg Med 2006;24:237-42.
26. American College of Emergency Physicians. ACEP Policy Statement: 2008 Emergency Ultrasound Guidelines. Approved by ACEP Board of Directors. American College of Emergency Physicians; October, 2008.
27. Daymude M, Mehta S, Gruppo L. Use of emergency bedside ultrasound by emergency medicine physician assistants: A new training concept. J Physician Assist Educ 2007;18:29-33.
28. Nienaber A, Harvey M, Cave G. Accuracy of bedside ultrasound for the detection of soft tissue foreign bodies by emergency doctors. Emerg Med Australas 2010;22:30-4.
29. Saboo SS, Saboo SH, Soni SS, Adhane V. High-resolution sonography is effective in detection of soft tissue foreign bodies: Experience from a rural Indian center. J Ultrasound Med 2009;28:1245-9.
30. Crystal CS, Masneri DA, Hellums JS, Kaylor DW, Young SE, Miller MA, *et al.* Bedside ultrasound for the detection of soft tissue foreign bodies: A cadaveric study. J Emerg Med 2009;36:377-80.