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Technical note

Ultrasound compared with projection radiography for the detection of soft tissue foreign bodies – A technical note

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ABSTRACT

Introduction: Soft tissue foreign bodies (STFBs) present a diagnostic challenge depending on their composition. Untreated complications can arise, namely infection through to loss of function. General (projection) radiography is recommended as the first line imaging examination. However, some STFBs are radiolucent, leading to false negative radiographs. The aim of this in vitro study was to compare ultrasound with projection radiographs for the detection of a range of different types of STFB.
Method: Ethical approval (for use of participants to evaluate images) was granted by the Higher Education Institute's departmental Ethics Committee. Seven hand phantoms were created from a water, gelatine and psyllium mix. A different STFB (radiolucent and radiopaque) was inserted into six phantoms, with the seventh being a control. Ultrasound and projection radiograph images were generated of each phantom. Participants (academics and radiography students) reviewed all images.
Results: 50 responses were received from a study population of approximately 400, (10 academics, 40 students). The ability of ultrasound to detect radiolucent foreign bodies performs well compared with projection radiography: sensitivity 94% versus 9%, specificity 90% versus 88%. For radiopaque foreign bodies the data was more mixed: sensitivity 96% versus 99%, specificity 90% versus 88%.
Discussion: These data suggest that ultrasound is superior to projection radiography for the detection of radiolucent STFBs. Limitations include the lack of formal postgraduate ultrasound training within the study population and a lack of simulated bony structure within the hand phantoms.
Implications for practice: Ultrasound has the potential to be a useful modality in the detection of STFBs, particularly radiolucent objects. There are associated challenges such as conducting ultrasound in the vicinity of a wound, but further exploration of this application of ultrasound is warranted.
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Introduction

Lacerations and puncture wounds represent a significant number of Emergency Department (ED) attendances in the United Kingdom (UK).[1] Such injuries frequently result in soft tissue foreign bodies (STFBs) due to the deposition of wooden splinters, gravel and shards of glass.[2] Left untreated these can cause infection and/or lead to complications such as loss of function and even cancer.[3–7] Guidance from the Royal College of Radiologists (RCR) and the National Institute for Health and Care Excellence (NICE) recommends general radiography as the primary modality of choice.[8–10] However, some STFBs are radiolucent[3,11] resulting in false-negative radiographs. This leads to late diagnosis, increased health complications and potential litigation costs to the National Health Service (NHS).[12,13]

Research has indicated that ultrasonography could be a viable non-ionising radiation alternative for STFB detection.[14–16] It's ability to diagnose STFBs of differing materials and densities (both radiopaque and radiolucent), has been suggested in numerous studies over a significant period of time[17–21] albeit studies of a heterogeneous nature.[3] The aim of this study was to investigate the role of ultrasound in the detection of STFBs through a controlled phantom study using a mixed method survey of academic staff and diagnostic radiography learners at the Higher Education Institute (HEI) where the author was enrolled on a pre-registration programme of study.

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Methods

Ethical approval for the use of participants to evaluate the images (academic staff and learners) was granted by the Higher Education Institute's departmental Ethics Committee under the process for approval of undergraduate research projects.

Phantom methods

Seven hand phantoms were created using a mixture of water, gelatine and psyllium (determined to be a suitable soft tissue mimic) inside rubber gloves.[16,22] Foreign bodies of varying materials, sizes and densities, representative of the range of STFBs found in practice were inserted into six of the seven gloves (in the central palmar area) by a colleague, so that the primary researcher undertaking the imaging would be blinded to the contents of each phantom. An equal quantity of radiopaque and radiolucent foreign bodies were selected. Table 1 provides further information on each phantom.

Imaging methods

Each phantom was imaged by a final year pre-registration learner (following appropriate education and training in the relevant modalities) under the guidance of appropriately qualified and experienced academic radiographers. For projection radiography a Siemens Multix Fusion tube and x-ray table were used together with an Agfa XD+14 image receptor. Dorso-posterior (DP) and lateral projections were performed using fine focus, a 100 cm source to image receptor distance, 55 kVp and 1.5 mAs. Fig. 1 shows a DP projection of a phantom containing a glass foreign body. As it was intended to evaluate the relative ability of ultrasound compared with projection radiography in detecting the presence of STFBs, site entry (wound) markers were not utilised for the projection radiographs.

For ultrasound imaging, a Siemens Acuson X700 with a 10.7 MHz linear probe was combined with the musculoskeletal presettings and the phantoms were imaged at a frame rate of 32 frames per second. Depth was adjusted manually. Images were downloaded from each imaging system, with the ultrasound cine images being converted to MP4 files. Fig. 2 shows a still image from the ultrasound cine showing the phantom with the thorn foreign body in situ.

Survey methods

Microsoft Forms was selected as the digital survey platform as it was available to the intended recipients via their university logins and supported the uploading of images and video. Participant information and consent, and reference to ethical approval, was included on the first page of the survey. The images themselves were then arranged in a random order i.e., the projection radiograph and ultrasound of the same phantom were not always presented sequentially. The Microsoft Form was set up such that responses were anonymous; hence participants were advised that their responses could not be identified for removal from the study should they wish to withdraw after they had submitted their responses.

Table 1
Phantom composition.

Phantom number	Material	Property	Size (cm)
1	Glass	Radiolucent	1.7 x 0.8 x 0.3
2	Thorn	Radiolucent	1.1 x 1 x 0.1
3 (control)	None	Not applicable	Not applicable
4	Plastic	Radiolucent	2.2 x 0.3 x 0.1
5	Gravel	Radiopaque	0.7 x 0.5 x 0.4
6	Stainless Steel	Radiopaque	3 x 0.1 x 0.1
7	Wood	Radiolucent	2.5 x 0.2 x 0.2

Figure 1. Projection Radiograph (dorso-palmar) of phantom with glass foreign body.

Figure 2. Ultrasound image of phantom with thorn foreign body.

The survey was constructed such that it contained a brief guide on the detection of foreign bodies with both projection radiography and ultrasound. Respondents were asked to indicate whether they were qualified or learner radiographers, and to indicate how much experience of ultrasound they have had. They were then asked to assess the images and videos and determine whether a FB was present. Following an initial pilot study (3 academics and 3 learners) which led to the refinement of some wording, the survey was circulated within the Medical Imaging community within the University via various electronic means (including discussion forums and information boards).

Results

A total of 50 responses were received from the survey from a population of approximately 400, equalling a response rate of 12%. Of these responses, 10 were academics and 40 were pre-registration learners. 24 participants (48%) reported having less than one month experience of ultrasound.

Fig. 3 shows the comparative detection rates of each type of foreign body. The difference in mean score between academics and students was less than 1%, therefore, both academic and student results are displayed together. It can be observed that ultrasound performs better for the radiolucent foreign bodies i.e., thorn, plastic and wood. Using a paired t-test, these differences were found to be statistically significant with $p < 0.01$ in all three cases. It is of note that 12% of respondents thought they had identified a foreign body in the control phantom on the radiographic images, and 10% on the ultrasound images.

The sensitivity and specificity for both modalities were also calculated as shown in Table 2.

Discussion

This study has demonstrated that ultrasound is effective for detection of certain STFBs that are not as well detected by projection radiography, namely those made of organic matter (wood and thorn) and plastic. Wood is the most common STFB so better detection using ultrasound has the potential to reduce complications from undetected FBs.[3,23] Projection radiography has 99% sensitivity for radioopaque FBs so is slightly superior to the findings for ultrasound from this study (96%) and a study by Carneiro et al.[11] However, in many cases the composition of the FB is unknown at presentation and 38% of STFBs may be missed due to their radiolucency.[16] A further advantage for the use of ultrasound may be its ability to localise adjacent vessels and tendons[3] thereby facilitating safe ultrasound guided extraction.

Table 2
The sensitivity and specificity of general radiography and ultrasound in STFB detection.

Modality	Foreign Body Type	Sensitivity	Specificity
Projection radiograph	All	53%	88%
Ultrasound	All	95%	90%
Projection radiograph	Radiolucent	9%	88%
Ultrasound	Radiolucent	94%	90%
Projection radiograph	Radiopaque	99%	88%
Ultrasound	Radiopaque	96%	90%

Despite nearly half of participants (48%) having limited experience observing and/or practicing ultrasound, the ability to detect STFBs in ultrasound was high in this study. A brief guide was provided as part of the survey which may have assisted with participants' ability to detect STFBs[24] and a study completed by Nienaber et al.[25] has demonstrated that physicians were able to effectively scan and detect STFBs after an interactive session of only 20 min, with a sensitivity of 96.7%. Nevertheless, it could also be argued that the relative ease of visualisation is indicative of the effectiveness of ultrasound as an imaging modality in relation to the detection of STFBs and its efficacy could be anticipated to be higher in a cohort of experienced practitioners.

Limitations

It should be noted that the phantoms only replicated soft-tissue and were composed of a homogeneous material. Hence this study's findings may not be applicable to more bony parts of the body (such as fingers). There would therefore be benefit in repeating this study

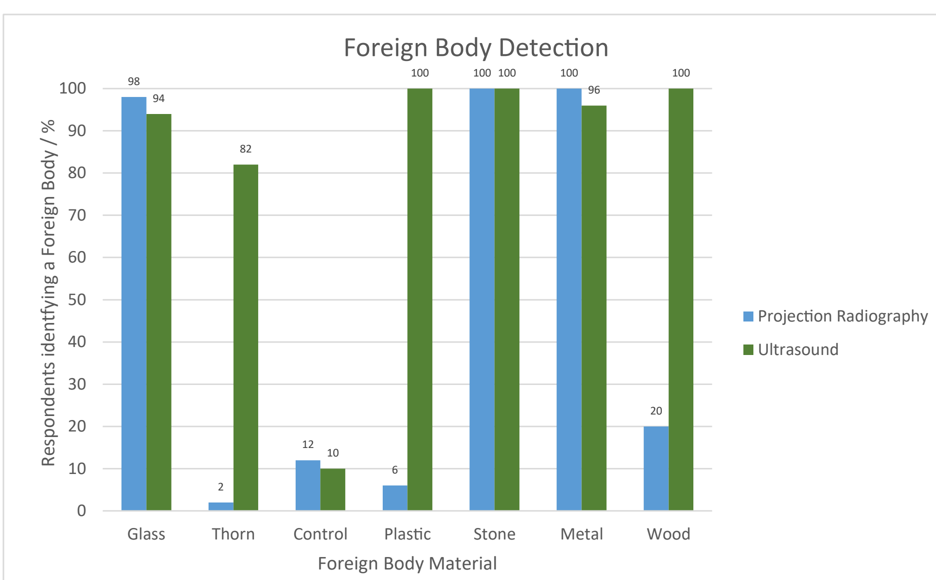

Figure 3. Accuracy of foreign body detection by study participants.

with more sophisticated phantoms that also simulated bone, or in vivo. Conversely, this may have resulted in STFBs being more visible than would be expected on the projection radiographs due to the absence of any materials mimicking normal bone anatomy overlaying the simulated STFBs within the phantoms. Study participants were either on a general radiography pathway or were a radiography academic so were not qualified sonographers, and had not received any formal postgraduate training in this modality. Further work would benefit from recruiting those healthcare professionals who would be likely to undertake and interpret such ultrasound examinations in practice.

The literature also suggests that some patients may find the pressure of the ultrasound probe on a painful wound painful although various strategies for addressing this have been identified[14,26,27]. As this study was phantom based, this aspect was not explored but would be an essential component of any future in vivo research.

Implications for Practice

A clear benefit of utilising ultrasound rather than projection radiography is the elimination of a dose of ionising radiation. There is also a potential improvement to patient pathways. Increasingly Emergency Departments (ED) are utilising Focussed Assessment with Sonography for Trauma (FAST) scanners, which are capable of imaging STFBs of the hand.[11,28] Utilising ultrasound rather than projection radiography may enable its use physically within the Emergency Department (ED) setting, potentially at the same time as the patient undergoes their physical examination,[29] and ultrasound could also be used to guide STFB extraction. Whilst some organisations are exploring nurse led point of care ultrasound[6,30] the use of ultrasound for STFB detection may also provide an opportunity for role development for ED based radiographers.

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Conflict of interest statement

None.

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