ORIGINAL ARTICLE

A model for teaching bedside detection of glass in wounds

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Background: Emergency physicians often manage wounds contaminated with glass. Even when glass is visible on x rays, removal may require real-time bedside imaging.

Aim: To assess whether novices can be easily trained to accurately detect tiny glass foreign bodies (GFBs) using low-power portable fluoroscopy.

Methods: 21 medical students with no prior experience using fluoroscopy were taught to detect 1 mm GFBs in chicken legs either by training over three separate days or by training on 1 day. Skills were reassessed at 3 months. The number of mean correct responses was compared between groups using analysis of variance (ANOVA) and by examination of 95% CIs.

Results: Examination of CI overlap and ANOVA suggested that asymptotic accuracy was achieved after 15–30 training specimens. The final accuracy was similar between protocols, was comparable to prior accuracy reports of plain film radiography and was maintained in both protocols at the 3 month follow-up: 10.9 (0.3) and 12.0 (0.8; out of 15).

Conclusions: Novices can easily be taught to detect GFBs using fluoroscopy, with accuracy comparable to that achieved by radiologists using plain films. Further studies are needed to assess doctors' use of the technique in real patients.

Over 6.4 million cases of lacerations per year present to emergency departments in the US.¹ Glass is among the most frequent wound contaminants. Failure to diagnose and remove glass can lead to morbidity and is a frequent source of litigation for wound cases.² Plain film radiography can readily detect glass,³ but it is often still difficult to remove without real-time bedside images. Both ultrasound and low-power portable fluoroscopy have been used to detect and remove foreign bodies (FBs).^{4–6} Fluoroscopy can be advantageous as it does not require the use of gel in the surgical field and once positioned, can be operated hands-free with a foot pedal.

Low-power portable fluoroscopy is a modality that has become available in recent years for many possible uses for orthopaedists, plastic surgeons, emergency physicians, radiologists, hand surgeons and other surgical subspecialists. Its use has already been documented to reduce exposure to radiation and to time-off the unit for repeat films in fracture reduction⁷ and to help in the detection and removal of FBs from wounds.^{4–6}

We tested the hypothesis that low-power portable fluoroscopy for FB detection is an easy technique to achieve proficiency. A chicken leg model was used to teach novices to detect tiny glass foreign bodies (GFBs) using low-power portable fluoroscopy. Outcomes measured were

- training accomplished in a single session versus multiple days;
- accuracy compared with radiologists using plain film radiography;
- skill retention at 3 months;
- final confidence level of the learners; and
- fatigue induced by the training process.

The clinical application is that if novices can be taught to accurately detect tiny GFBs, this model can be widely used to train other individuals who may be called upon to manage FBs in wounds, such as emergency physicians or other consultants.

METHODS

This study was a prospective, randomised observational study of two teaching interventions at a large urban university teaching hospital. Subjects were 21 fourth-year medical student volunteers who had never used fluoroscopy. A chicken leg model was used because of similarity in size and structure to the human thumb, including skin, muscle and bone interfaces that simulate human models.^{5–8} GFBs of size 1 mm were selected to maximise the training effect and demonstrate proficiency, even though 1 mm-sized GFBs may not always require removal.

Two stab incisions were made in each leg with a #11 scalpel. Zero, one or two GFBs were placed in each incision. None of the legs contained more than two shards. An equal number of legs contained zero, one and two shards. Legs were arranged in a random order maintained throughout the study. Specimens were preserved between sessions by freezing and were thawed before the next day of scanning.

Students individually scanned specimens for GFBs using a low-power portable c-arm fluoroscope (system model number 60000, Fluoroscanner Imaging Systems, Premier Encore Unit, Bedford, Massachusetts, USA). To begin, the student was shown a fluoroscopic image of a 2 cm GFB, and the pedal to activate real-time imaging. The fluoroscope was left at its default parameter (noise suppression 16) and automatically adjusted power. Students were permitted to alter settings and specimen positions without instruction. Students were told that each specimen contained zero, one or two GFBs. They were permitted to inspect the legs for incisions but not permitted to probe the wounds. At baseline testing, the student would scan one leg at a time and answer zero, one or two GFBs, but no feedback or instruction was given. Responses were recorded as correct only when the student's verbal response exactly matched the number of GFBs present in the specimen. The instructor ensured that subjects did not give spurious correct responses based on seeing artefacts. Students were randomised

Abbreviations: ANOVA, analysis of variance; FB, foreign body; GFBs, glass foreign bodies

Table 1 Summary of two training protocols

Day	Protocol 1 (multiple-day training)	Protocol 2 (1-day training)
1	Baseline, TS 1	Baseline
14	TS 2	TS 1,2,3
28	TS 3	
3 months	Follow-up	Follow-up

Baseline; 15 legs of scanning without teaching to determine baseline accuracy. TS; training session. Each session involves 15 legs of scanning, with feedback and instruction given after each answer. Follow-up; return 30 days after the last TS to scan 15 legs without feedback to measure final accuracy/retention.

to one of two teaching interventions (see table 1 for summary of each group).

The "multiple training session" group had three training sessions consisting of 15 legs each, with 2 weeks off between each session. The "1-day training" group had all three 15-leg training sessions consecutively on the same day (rest was allowed after every 15 legs). All students began training with a set of 15 training legs. After every leg, the instructor provided feedback to enhance GFB detection (eg, varying noise suppression, voltage and amperage settings, varying the distance of the leg from the photomultiplier tube, using more real-time images). Students were shown any undetected GFBs, and advised how detection could have been enhanced for that specimen. Figure 1 shows an actual fluoroscopic image of a study specimen containing two 1 mm GFBs.

After completing the study, each subject completed a questionnaire designed to obtain measures of confidence in their newly acquired skills and fatigue induced by the training protocols. Subjects were asked to rate levels of mental fatigue, physical fatigue defined as eye strain and somnolence, and confidence in their ability to detect glass in chicken legs using fluoroscopy, using 10-point Likert-type scales.

Figure 1 Fluoroscopic image of an actual study specimen containing two 1 mm glass foreign bodies (arrows).

Statistical analysis

The mean number of correct responses was compared between the two learning protocol groups across five sequential testing sessions by comparing 95% CIs between groups across sessions, and also by conducting mixed-model analysis of variance (ANOVA).^{9,10} Follow-up analyses conducted to disentangle omnibus effects involved all possible pair wise comparisons via *t* tests for dependent or independent groups, as appropriate. Mean responses to survey items were compared between protocol groups using between-groups ANOVA. The final (follow-up) performance was compared between protocol 1 and protocol 2, and between prior reported data of radiologists using *x* rays,³ by examining overlap of 95% CIs.

For two-tailed $p < 0.05$, a sample size of 10 students in each group would provide 75.2% power using *t* tests (effect size = 1.25), and for the mixed-model ANOVA, it would provide 97% power to test the between-groups main effect (effect size = 0.9), and 100% power to test the within-groups main effect and the group-by-testing session interaction (effect sizes = 1.4). Because we desired 10 students in each group, we enrolled 11 students in each group, so that one student could drop out and yet the statistical power would still be satisfactory (for pragmatic reasons, all student volunteers had to be recruited for the study simultaneously).

RESULTS

Twenty-two subjects participated in the study between August 2003 and May 2004. Of these, 11 were randomised to protocol 1 and 11 to protocol 2. One subject from protocol 1 failed to return to complete training and was thus omitted. All other subjects had complete data: $n = 10$ for protocol 1; $n = 11$ for protocol 2.

The mean, SD and 95% CI for the number of correct responses, separately by training protocol, across five successive blocks: baseline, training blocks 1, 2 and 3, and follow-up are all shown (table 2). Each block contained 15 legs.

The data show that novices can be taught to detect tiny GFBs in a single session just as well as on divided days. When considered independently of block, the mean number of correct responses was comparable between the two training protocols: $F(1,20) = 0.1$, $p < 0.74$. Corresponding CIs between the two protocols overlap at every testing session.

Subjects reached asymptotic accuracy within a relatively short period, 15–30 training specimens. When considered independently of training protocol, the mean number of correct responses differed significantly across training blocks: $F(4,80) = 51.6$, $p < 0.001$. Follow-up pairwise within-subjects *t* tests indicated that mean number of correct responses increased significantly over successive training blocks between baseline and the second training block (all $p < 0.04$). Mean correct responding at the second and third training blocks, and at the follow-up block, was comparable (all $p > 0.70$). Thus, ANOVA suggests that mean accuracy increased significantly over time regardless of which protocol was used, with asymptotic mean performance achieved after exposure to 30 training block specimens. Comparison of the range of CI values within a testing block (eg, 4.4–7.9 for protocol 1 baseline, 9.3–11.4 for protocol 2 training session 1, etc) across testing blocks suggests that asymptotic performance is reached after 15 training block specimens, because 95% CIs for all training blocks and the follow-up block overlap each other. Thus, while central tendency (point) estimates of mean performance (ANOVA) indicated that the groups reached asymptotic performance after 30 training trials, dispersion estimates of overall performance (95% CIs) indicated that operators reached asymptotic performance after 15 training trials. It usually took 1–2 h to train on 15–30 legs.

Table 2 Glass foreign body detection accuracy shown separately by training protocol

Block	Protocol	Mean	SD (95% CI)
Baseline	1	5.7	2.3 (4.4 to 7.1)
	2	6.7	2.0 (5.5 to 7.9)
Training session 1	1	10.8	1.2 (10.0 to 11.4)
	2	10.3	1.6 (9.3 to 11.2)
Training session 2	1	12.2	0.8 (11.7 to 12.6)
	2	11.0	1.4 (10.2 to 11.8)
Training session 3	1	11.3	2.2 (9.9 to 12.6)
	2	11.6	1.1 (11.0 to 12.3)
Follow-up	1	10.9	2.3 (9.5 to 12.3)
	2	12.0	0.8 (11.5 to 12.5)

Protocol 1, multiple-day training group (blocks 1, 2 and 3 on separate days); protocol 2, 1-day training group (blocks 1, 2 and 3 on the same day). Mean, number correct out of 15.

Novices retain these skills after 3 months of follow-up. The 95% CIs at 3 month follow-up overlay the 95% CIs during all training blocks (table 2).

The accuracy of these novices was comparable to the reported accuracy of radiologists using plain film radiography in the same chicken leg model with the same-sized GFBs. Courter³ reported the accuracy of three staff radiologists each evaluating 24 specimens for 1 mm GFBs with plain film x rays: 83% overall sensitivity and upto 22% interobserver variation. This is comparable to our students' asymptotic accuracy: the upper bound of the 95% CI for follow-up performance was 12.3/15 (82%) for the multiple-session group and 12.5/15 (83.3%) for the 1-day training group. The lower bound of the 95% CI for Courter's estimate (68.0%) corresponded to a mean of 10.2 correct responses on our 15-point scale. Thus, by using fluoroscopy in a chicken leg model, our novices achieved accuracy comparable to attending radiologists using plain x rays in the same chicken leg model.

After training, students in both groups reported comparably high levels of confidence in their skills and little fatigue from the training process (table 3).

DISCUSSION

This study demonstrates that novices can be trained in a single session using a chicken leg model to detect tiny GFBs using low-power portable fluoroscopy as accurately as radiologists using plain films, can retain these skills and have confidence in their skills without having been excessively fatigued by the learning process. Previous literature on training of novices to detect FBs with low-power portable fluoroscopy is scant. The one prior fluoroscopy study³ that used the same chicken leg model and the same-sized GFBs had a similar accuracy (67–91% (15–24%) depending on whether there were 0, 1 or 2 GFBs) but fewer subjects (n=9) and used one training protocol for all subjects. It anecdotally reported fatigue without objective measurements, did not assess confidence or follow-up beyond 1 week and did not have sufficient data points to assess asymptotic accuracy. This study more powerfully confirms achieved accuracy and reports long-term retention, while demonstrating two different training strategies to be comparable. We define more precisely how much training would be required to reach asymptotic accuracy (15–30 legs) and refute the prior anecdotal report that such training is excessively fatiguing. We have demonstrated that subjects perform comparably better than radiologists using plain film radiography, and are confident in their skills.

Our training regimen for GFB detection is feasible for busy residents, fellows and attending doctors, for both novices and those with prior fluoroscopy experience. A 30-leg training protocol requires <90 min to complete. Training can be divided into two smaller 15-leg sessions on two different days, if that is

Table 3 Self-reported confidence and fatigue ratings on a Likert scale of 1–10

	Protocol 1		Protocol 2		p Value
	Mean	SD	Mean	SD	
Confidence	7.40	0.70	7.00	1.10	<0.34
Mental fatigue	2.50	1.08	3.45	1.75	<0.16
Physical fatigue	2.65	1.11	3.00	1.61	<0.58

Protocol 1, multiple-day training; protocol 2, 1-day training.

more practical, or can be completed in one session. Training would be even simpler for those with any prior experience using fluoroscopy: the 15–30 leg protocol could probably be abbreviated, or terminated early when accuracy asymptotes and the learner becomes confident and accurate. Less training would be needed for learning the basic operation and manoeuvring the device for those with prior experience. Such skills should be applicable to managing other radiopaque FBs as well.

The technique itself is not highly complicated. The user requires an orientation to the unit's basic functions such as on/off, pedal use, and power and noise suppression adjustment to enhance image quality whether obtaining still or real-time images. Then, the user can be taught some helpful strategies such as varying the distance of the specimen from the photomultiplier tube and when to use more still images or more real-time images.

Cost and resources for such training are minimal. Many institutions already possess the device in the radiology department or in the operative suite, so it can be borrowed. Training expenses include the human resource time for the instructor and supplies. Fluoroscopy manufacturers may provide a complementary instructor on request, as we experienced. Supplies required are chicken legs from a grocery store, basic instruments such as a scalpel and forceps, and broken glass.

Low-power portable fluoroscopy for FB management would be appropriate for several clinical settings. Emergency departments that see many FBs in wounds, such as those in industrial areas, are a natural setting. Hand clinics and occupational health clinics are other settings where FB cases may present or be referred to.

This technique would not replace plain film radiography as the initial screening modality, because plain films are readily available, use low radiation, are inexpensive and easy to interpret. Portable fluoroscopy would have a niche in aiding bedside removal of radiopaque FBs where exploration and localisation without real-time imaging is too difficult. Some patients might be spared a trip to the operating room for a larger exposure. More patients might have their FBs removed during the initial visit instead of later in the consultants' office, for a speedier recovery and return to activities.

The study has some potential limitations. This study used an in vitro model, not live human patients. Success can depend on the skill of the instructor. Our instructor, however, had no prior fluoroscopy experience and yet was easily trained in a short period by author SMG. Questionnaires were completed after follow-up, which may have introduced recall bias if subjects forgot how they felt 3 months earlier. We could not study skill retention beyond 3 months because the students graduated. However, we consider 3 months without using fluoroscopy a reasonable period to measure long-term skill retention.

For many complex reasons, it is a common scenario in educational research for two teaching models not to be statistically different when a final grade or accuracy is used as the sole outcome measure. It has been suggested that additional outcome measures should be used when studying the effects of teaching interventions in educational research.¹¹ We used amount of training to ascertain asymptote, skill retention, and learner confidence and fatigue as additional outcome measures.

In summary, medical students with no prior experience in fluoroscopy were taught to detect GFBs with accuracy similar to radiologists using plain films. Further studies need to assess doctors' use of the technique in real patients.

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