Technical Report

Acquisition of Spine Injection Skills Using a Beef Injection Simulator

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Background: Students of interventional spine procedures typically learn needle injection technique using cadaver specimens or live patients in an operating room. This can be expensive, inefficient, uncomfortable to patients, and requires a significant time commitment from teaching staff.

Purpose: To present a simple and inexpensive simulator using a cut of beef as an injection model that can be used to teach certain components of interventional spine injection needle technique in a more efficient and cost effective fashion.

Basic Procedures: A needle injection practice model using beef muscle attached to a plastic base was constructed. Students of interventional spine pain were instructed in C-arm x-ray operation and basic needle handling technique, then performed a series of mock injection procedures using this simulator. Procedure time, fluoroscopy time, and accuracy were measured.

Main findings: Speed, accuracy of needle placement, and fluoroscopy time of the subjects improved with the number of practice sessions completed. The subjects felt better prepared to perform live patient procedures as a result of this training.

Conclusions: Use of an inexpensive beef injection model is a valid, reliable, and feasible adjunct to teaching C-arm x-ray operation and spine injection needle technique to beginning students of intervention spine pain management.

Keywords: models, educational ; models, anatomic; models, structural

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Every year, hundreds of physicians enroll in training programs to learn the techniques of various spinal injection procedures. For the beginners, basic skills that need to be mastered include:

1. How to identify a target point and then accurately position the C-arm fluoroscope at the optimum starting position for the given procedure using a minimum of operating room time and fluoroscopy time.
2. How to use proper needle handling techniques and fluoroscopic x-ray imaging to safely guide a needle tip from the body surface through soft tissues to a specified target point using a minimum of operating room and fluoroscopy time.

Although these 2 components represent only a small part of what must be learned, proficiency is essential to the performance of safe and effective interventional spine procedures. These "hands-on" skills are typically learned through residency and fellowship training programs, individual proctoring using live patients, or cadaver courses. Disadvantages of learning beginner skills using the apprenticeship method include high monetary cost, high time commitment of students and teaching staff, increased operating room usage times, increased medicolegal liability, patient discomfort, and patient dissatisfaction (1-3).

Inanimate simulators have been shown to be effective in surgical and medical training (3-10). Simulated procedures allow students to inexpensively practice surgical skills without affecting patient safety or discomfort. They may also permit standardization of training and provide an objective measurement of proficiency (3,5). Using simulators, the acquisition of basic technical skills can be accomplished without direct patient contact and can be performed by residents or fellows during the off-duty period (1,3).

As an alternative to live patient needle injection training, an inanimate simulator using a cut of beef as the injection model was developed. Our objective was to determine if inexpensive and efficient individual practice sessions using this simulator would facilitate mastery of basic needle injection skills.

Methods

An injection model was constructed using an inexpensive cut of beef rump roast. The beef muscle was approximately 16 cm x 16 cm x 7-8 cm thick and weighed 3-4 lbs. The muscle (e.g. pelvic group muslce, gluteus) was wrapped in flexible cellophane and then secured to a plexiglass base (Fig. 1).

The plexiglass base contained 2 circular patterns of 2 mm diameter holes; an inner circle of "lineup" holes and an outer circle of "target" holes (Fig. 2). These holes were drilled at specific angles with respect to a perpendicular line through the center of the base. The angles were chosen so as to make the holes clearly visible when viewed end-on radiographically from angles similar to those commonly used for C-arm guided spinal injection procedures (Fig. 3).

Two 1.5-inch X 0.25-inch threaded pointed plastic spikes were mounted within the plexiglass base. These 2 spikes served to secure the beef to the base and prevent sliding or rotational movement during the mock procedures described below.

A single 2-inch X 0.25-inch spike was mounted in the center of the model. This taller spike contained a 1.5 cm length of 30g metal rod embedded within its distal tip. This metallic tip was used as a radio-opaque reference point to align the C-arm in step 1 of the mock procedure as described. When the C-arm angle was adjusted to superimpose the shadow of the distal tip of this rod over a lineup hole, the axis of the x-ray was aligned exactly with the axis of the hole, making

Fig. 1. *Beef muscle attached to the plexiglass base*

Fig. 2. *The plexiglass base viewed from 2 angles*

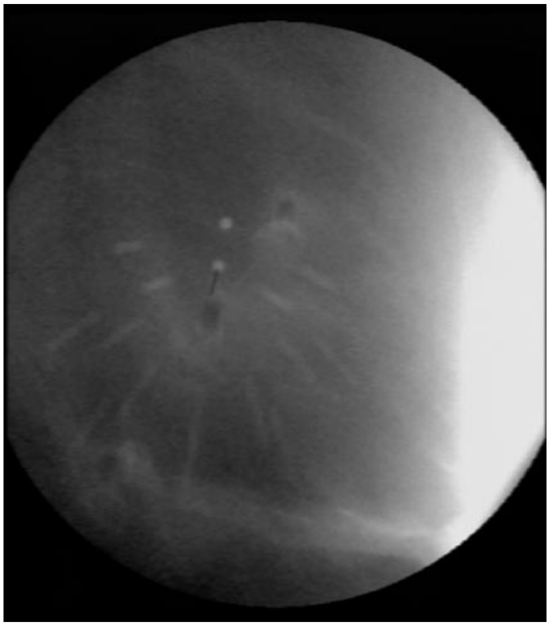


Fig. 3. *Fluoroscopic image of the plexiglass base. The C-arm has been tilted approximately 15 degrees to superimpose the distal shadow of the center metal rod over a lineup hole. When positioned in this way, the axis of the x-ray is exactly aligned with the axis of the corresponding hole, making it clearly visible.*

Fig. 4. *Sticks have been inserted to illustrate the axes of the lineup and target holes with respect to the tip of the center spike. The axes of the paired lineup and target holes are parallel. The axis of the lineup hole intersects the metallic tip of the center spike.*

it clearly visible (Fig. 3 & 4).

Two subjects were chosen. Both were beginning fellows in an interventional spine pain training program. Prior to participating, the subjects completed a course in radiation safety, received instruction in operation of the C-arm machine, and instruction in basic needle handling technique.

A mock procedure was designed to:

1. Facilitate practice with C-arm operation and target alignment
2. Facilitate practice with fluoroscopic x-ray guided needle placement, and
3. Permit an objective measurement of improvement of these skills with practice over time.

The specific procedures to be performed were introduced to the subject and demonstrated by a senior ISIS (International Spine Intervention Society) instructor. The subjects performed 5 supervised practice attempts to verify that the procedure instructions were understood.

Our goal was to determine if the subject's speed, needle accuracy, and fluoroscopy time would improve with practice. The mock procedure chosen for this study consisted of 2 steps.

STEP 1.

To begin, the C-arm was placed in the neutral position and centered over the model (Fig. 5).

A timer was started and the subject was required to adjust the tilt angle, oblique angle, and position of the C-arm so as to superimpose the x-ray image of the distal end of the metallic reference marker over one of the 2 mm inner circle "lineup" holes within the plexiglass base (Fig. 6).

When successful, the timer was stopped. The total procedure time and fluoroscopy time necessary to accomplish step 1 was recorded.

STEP 2.

The timer was restarted and the subject was required insert a 25g 3.5 inch spinal needle into the beef, then use fluoroscopy to help guide the needle tip into the corresponding outer circle target hole within the plexiglass base. A metal pointer was used to locate the site of needle insertion (Figs. 7& 8).

When successful, the timer was again stopped.

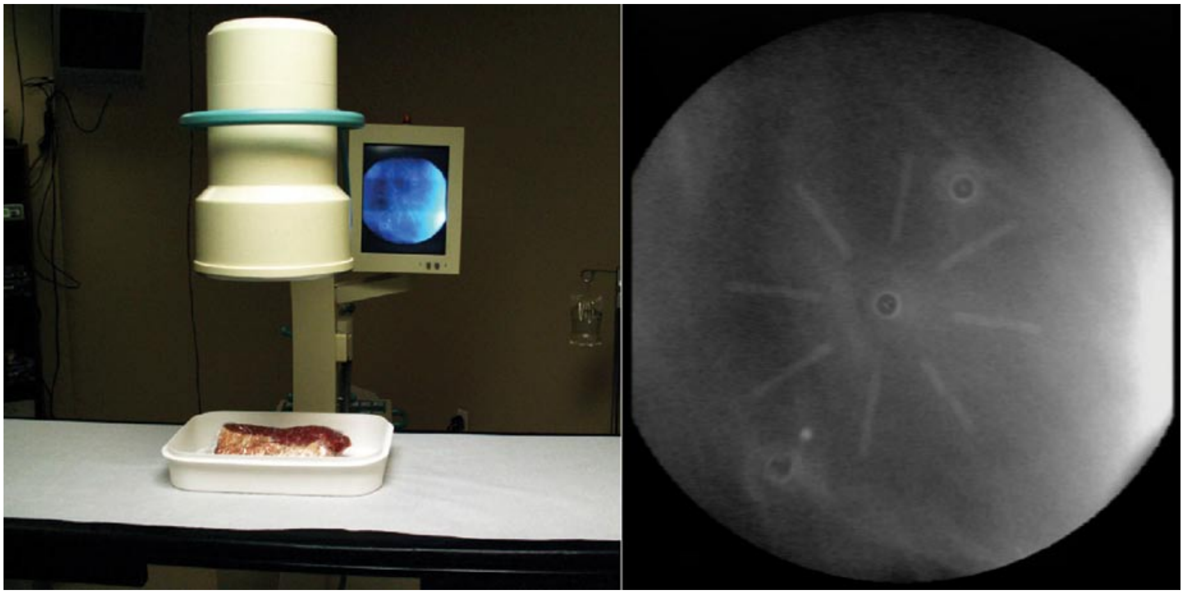


Fig. 5. *The plexiglass base with meat attached. The C-arm is centered over the model at 0 tilt and 0 oblique. The model is kept within a plastic storage container to protect the operating room table from damage or contamination.*

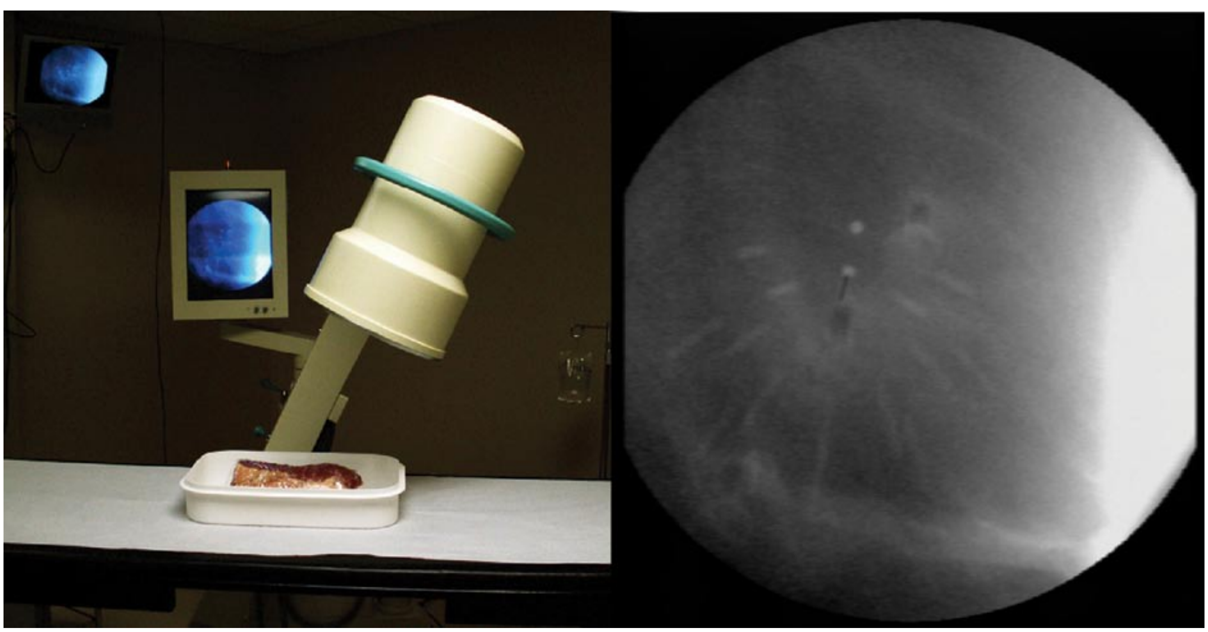


Fig. 6. *The C-arm is tilted to superimpose the shadow of the metal rod tip over the "12 o'clock" lineup hole. Both the lineup hole and corresponding target hole are now visible.*

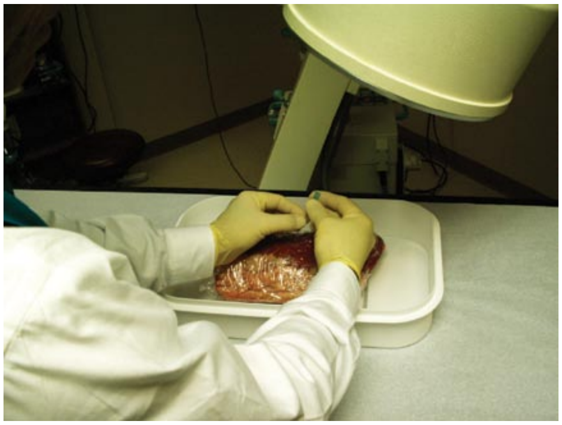


Fig. 7. *The needle is inserted into the beef.*

The total needle passage time, total fluoroscopy time (step 1 plus step 2), and total number of needle redirects were recorded.

An observer was present to record elapsed times and number of needle redirections. The subject was required to perform all C-arm operations without assistance. A "redirect" was defined as any withdrawal of the needle no matter how slight.

The subjects started with the lineup and target holes at the "12 o'clock" position, then progressed clockwise for each additional mock procedure. Progressing in this way, the angles and positions of the holes were such as to force the subjects to use the C-arm and pass the needle from a variety of different commonly used angles and orientations.

Rest periods were permitted between procedures. Unlimited untimed practice sessions were allowed. These unmeasured practice sessions were not recorded. Data were entered into Origin Pro 7.5 statistical software for analysis.

Data were collected from the 2 subjects. Subject #1 performed a total of approximately 1,000 mock procedures of which 151 were measured and recorded for this study. Subject #2 performed approximately 600 mock procedures of which 66 were recorded.

Results

Both subjects showed improvement over time in all parameters. Comparing the first 20 measured procedures with the final 20 measured procedures, the average total procedure time, target lineup time, total fluoroscopy time, and lineup fluoroscopy time all decreased ($P<0.005$). The results are presented in the graphs (Figs. 9 & 10).

After practice using the simulator, both subjects were able to independently align the C-arm so as to superimpose the metallic marker over a 2mm diameter target hole in less than 10 seconds with an average fluoroscopy time of less than 4 seconds. Both subjects were able to align the C-arm over the target then insert and direct a needle through 7-8 cm of soft tissue into a 2mm diameter target in an average of less than 46 seconds total time and with a total fluoroscopy

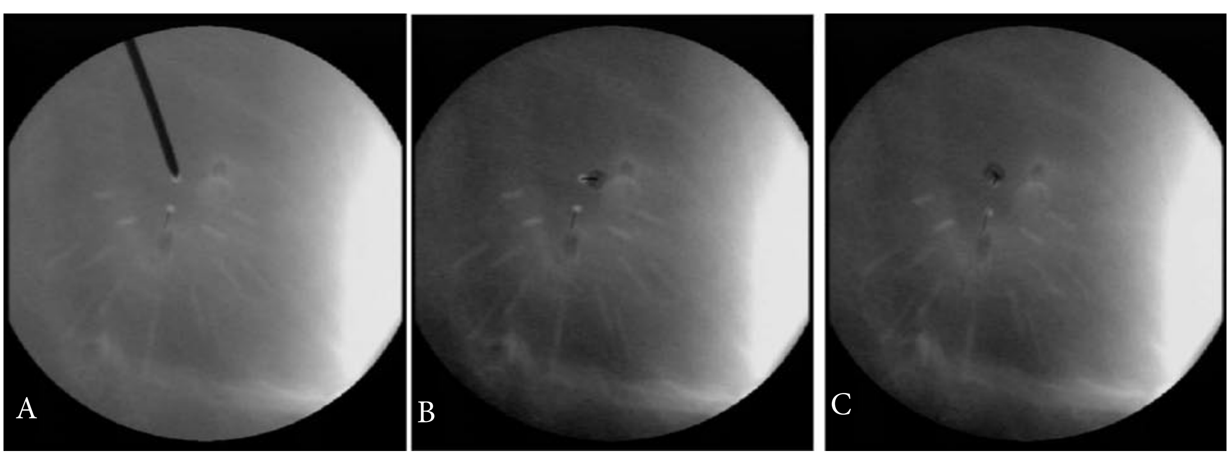
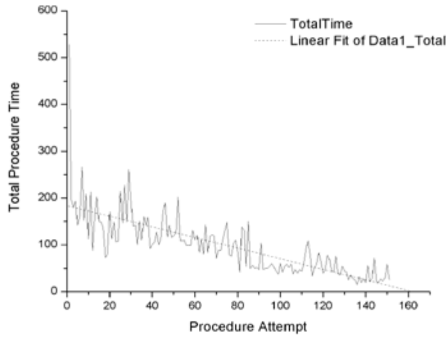
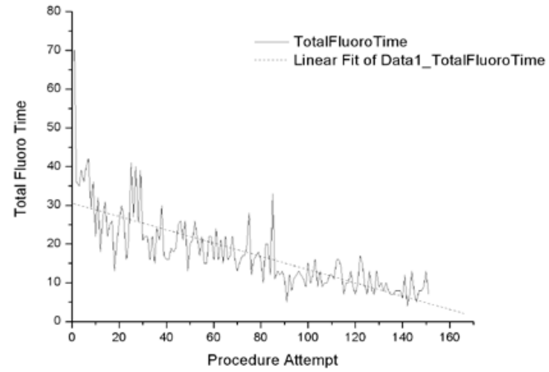


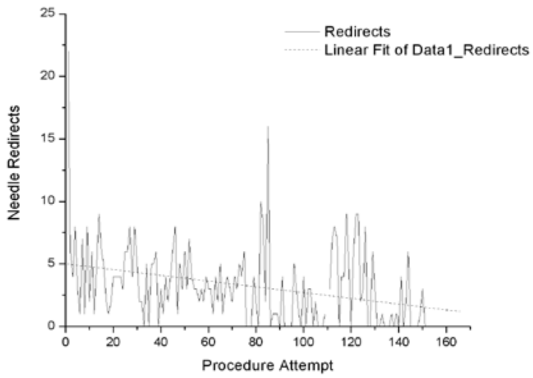
Fig. 8. *A. The C-arm is aligned for the 12 o'clock procedure with the pointer tip overlying the target hole. The reference marker tip is overlying the 12 o'clock lineup hole. B. The needle has been inserted over the target hole in a nearly end-on orientation. C. The needle tip has been advanced into the target hole*



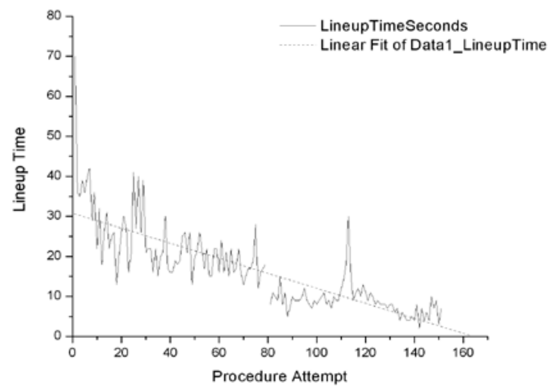
Total procedure time vs procedure attempt



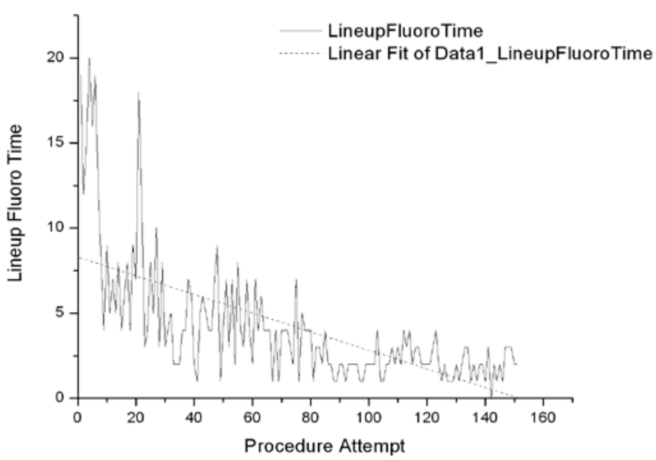
Total fluoro time vs procedure attempt



Number of needle redirects vs procedure attempt

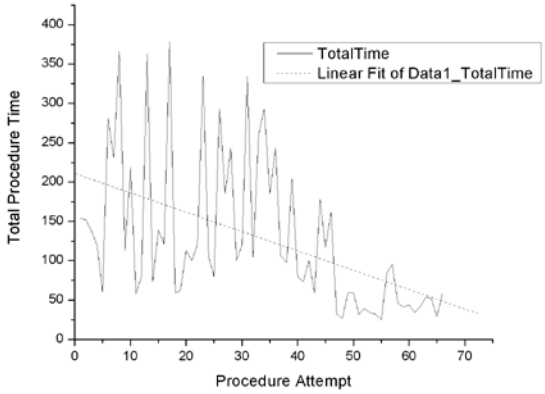


Lineup time vs procedure attempt

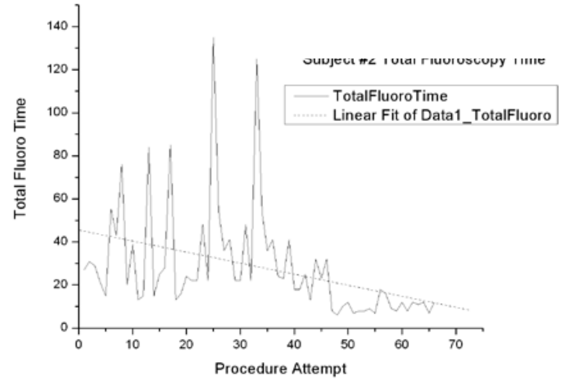


Lineup fluoro time vs procedure attempt

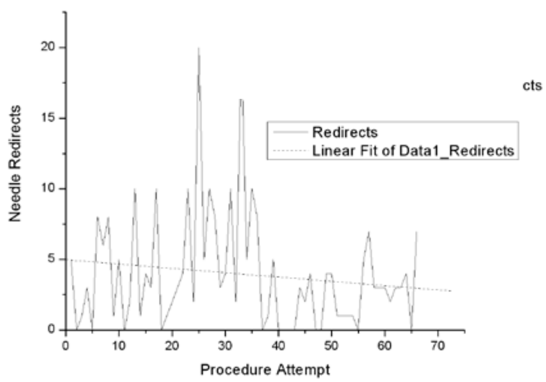
Fig. 9 ***The results of the subject #1.***



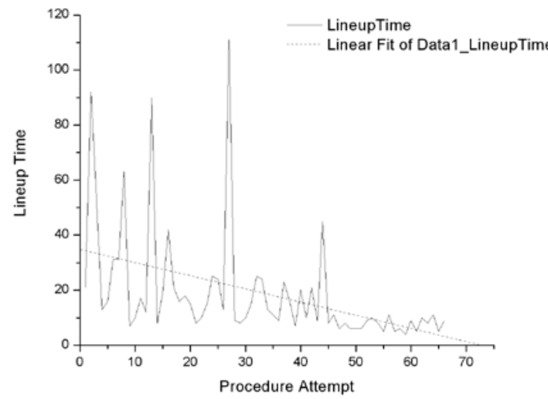
Total procedure time vs procedure attempt



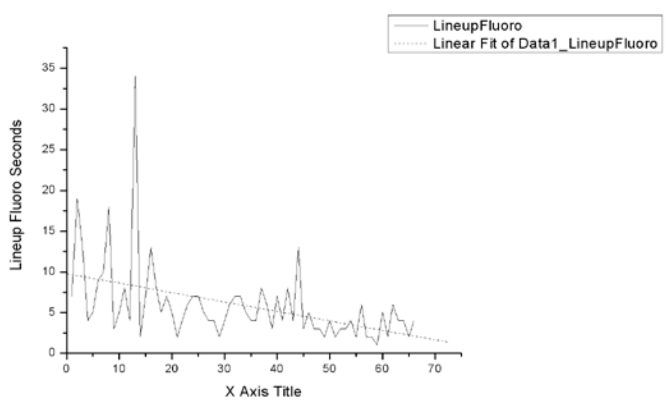
Total fluoro time vs procedure attempt



Number of needle redirects vs procedure attempt



Lineup time vs procedure attempt



Lineup fluoro time vs procedure attempt

Fig. 10 ***The results of the subject #2.***

time of less than 10 seconds.

Discussion

Financial and medicolegal incentives are driving a change from traditional apprenticeship training to training outside the "live patient" operating room when feasible (3,10). Live animals and human cadavers are realistic models but they are expensive and cannot be reused indefinitely. Virtual reality simulators are often prohibitively expensive, unavailable, or lack tactile feedback (1). Inanimate models such as this beef injection simulator are inexpensive, reasonably realistic, and can be reused indefinitely.

Using this simulator allowed the subjects to practice directing a needle through muscle tissue under fluoroscopic x-ray guidance in a relaxed environment without the monetary and time constraints associated with a live patient and full OR staff. Practice sessions were conducted during evenings and weekends when the OR and C-arm were not normally in use. A hundred or more of these mock procedures could be performed in a single day leading to rapid proficiency with needle control. Familiarity with the control, positioning, and operation of the C-arm fluoroscope was also rapidly acquired.

After several hundred practice procedures using the simulator, the subjects were able to make adjustments in C-arm orientation, needle orientation, and needle rotation somewhat "automatically" and thus were able to more easily focus conscious attention upon other aspects of subsequent live patient procedures.

Instructor time was utilized more efficiently. A student or group of students could be taught C-arm operation and needle handling technique in a single short session, then left to practice unlimited repetitions alone with only intermittent instructor supervision thereafter.

The subjects felt more confident and better prepared to perform live patient procedures after training with this simulator. Both felt that using the simulator to learn basic needle handling skills in this way was superior to receiving short periods of individual proctoring during live patient procedures, or cadaver sessions alone. The subjects and instructor felt the beef model provided a realistic tactile approximation of human tissues for spinal injection procedures.

This model is meant to simulate the soft tissue texture of live patients for the purpose of learning needle control. It does not simulate "live patient" injections with regards to the challenges of varied anatomy and pathology.

The use of a beef injection model in this way appears to be a valid, reliable, and feasible component of a structured comprehensive sequential training program for interventional spine pain procedures.(2)

This simulator has been implemented within our Interventional Spine Pain Fellowship program. Before performing independent live patient procedures, beginning fellows are required to practice using the simulator, then demonstrate technical proficiency by aligning the C-arm correctly and passing a needle from surface to the target holes without exceeding a specified maximum of total procedure time, fluoroscopy time, or number of needle redirections.

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