Original Article

A novel fresh cadaver model for education and assessment of joint aspiration

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ABSTRACT

Objectives: The objective of this study was to describe a novel cadaver model and to determine the utility of this model for teaching and assessing students in performing knee, elbow, and wrist arthrocentesis. **Methods:** Third year medical students were evaluated while performing arthrocentesis during a fresh cadaver training sessions.

Results: Sixty-three participants were included in this analysis. There was statistically significant improvement between the pre- and post-test analysis in all aspects assessed in our study of elbow, knee and wrist arthrocentesis.

Conclusions: The use of fresh cadavers for the education and assessment of arthrocenteses is an effective training model.

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1. Introduction

Joint aspiration, or arthrocentesis, is a commonly performed procedure used to diagnose and treat numerous joint diseases. The procedure has broad utility and is performed by numerous specialties. Despite the broad utility of this and other technical skills, over the past decade, there has been a reduction in the opportunities for medical students to learn and perform these crucial procedures.^{1,2} The reasons for this are complex, but as a consequence, medical students are entering residency with a lack of experience in performing routine but critical procedural skills.^{3,4}

This lack of experience has created a demand in the medical education curriculum for discovering alternative approaches,

including simulation-based training, which allow students to learn procedural skills in a safe, low stress environment prior to direct patient encounters.^{5,6} Although simulation-based instruction can provide high quality training, there are significant differences in the tactile and anatomic features of the human body when compared to the manikin and phantom models that are commonly used.^{7,8}

In response to the need for more life-like simulation models, cadaver-based labs are becoming increasingly favored by medical educators.^{9–14} This model provides more realistic tissue handling, haptic feedback, preserved tissue planes, and anatomic variation.^{9,12} In addition, confidence in performing procedures is heightened as a result of creating more life-like situations, as one would see in clinical practice.¹⁴ Various studies have evaluated the effectiveness of cadaver-based arthrocentesis teaching models.^{10,14,15} However, one notable omission in these studies is the lack of pre- and post-testing to evaluate long-term procedural skills and knowledge retention. The objective of this study was to describe a novel cadaver model and to determine the utility of this model for teaching and assessing students in performing knee, elbow, and wrist arthrocentesis.

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2. Methods

2.1. Study design and setting

This was a cross-sectional study at an urban academic medical center. The study was reviewed by the Institutional Review Board and determined to be exempt. The study participants were third year medical students with no joint arthrocentesis experience. The population had an average age of 26 of which 52% were men and 48% were female. The hands-on cadaver procedure-lab was conducted during the surgical clerkship and data was gathered from July 2015 until January 2016.

2.2. Cadaver preparation

In order to ensure accurate assessment of successful arthrocentesis, preparation of the joints involved injecting red fluid into the above joints with a 25 gauge needle for the wrist and elbow and a 22 gauge needle for the knee. An anatomic dissection was performed on the opposite extremity of the cadaver by an experienced surgeon in such a manner as to demonstrate the relevant anatomy of the selected joint space and identify the correct boundaries for the procedure (Images A and B).

2.3. Educational curriculum

Students were taught how to appropriately identify the landmarks for each joint on the dissected side of the cadaver.

Image A. Elbow and wrist arthrocentesis. Top: image of a fresh cadaver elbow with labels. Blue: lateral epicondyle. Red: radial head. Green: olecranon. Black: soft spot of triangle formed by the above landmarks. Bottom: image of a fresh cadaver wrist. Blue line: extensor pollicis longus. Red dot: Lister tubercle. Black dot: site of aspiration (distal to Lister tubercle and ulnar to extensor pollicis longus tendon). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Image B. Knee arthrocentesis (supralateral approach). Image of a fresh cadaver knee. Top: skin flap present. Bottom: skin flap exposed. Blue line outlines patella. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Once they learned the proper location of each landmark they identified the same landmarks on the non-dissected limb. Aspiration of each joint was then demonstrated by a physician on the non-dissected limb with the dissected limb serving as a visual aid. Students were then allowed to practice aspiration on the dissected limb before moving on to the non-dissected limb with the goal of successfully aspirating the red fluid.

2.4. Assessment

During orientation for their clerkship, and prior to the education session, the students were asked to list the indications, contraindications, and complications of joint aspiration. In addition, they were asked to identify the anatomical landmarks required for performing each of the three chosen joint aspirations. A pre-test questionnaire was given to assess student comfort levels prior to the educational session (Table 1). Lastly, students were asked to perform the aspirations without guidance.

Prior to leaving the educational session of the lab each student was capable of listing the indications, contraindications, and complications of joint aspiration. They could also identify the appropriate landmarks and independently perform joint aspirations of the elbow, wrist, and knee. At 5 weeks the lab was repeated and the performance of the students was evaluated, this time with no instruction. A post-test questionnaire was also given to assess student comfort levels and the general utility of the educational session (Table 1).

In addition to the technical aspect of the procedure, knowledge of the indications, contraindications, complications, and anatomic

Table 1

Mean (SD) of pre- and post-test questionnaire responses on a 5-point Likert-type scale (N=63).

Item	Pre-test ^a	Post-test ^a	p-Value
I feel comfortable performing...			
Elbow arthrocentesis	1.06 (0.25)	3.35 (0.85)	<.0001
Knee arthrocentesis	1.46 (0.64)	4.00 (0.78)	<.0001
Wrist arthrocentesis	1.11 (0.32)	2.83 (0.75)	<.0001
Was the lab helpful in understanding technical aspects of knee joint aspiration		4.17 (0.64)	
Was the lab helpful in understanding the indications, contraindications, and complications of joint arthrocentesis?		4.40 (0.64)	
Would you recommend this lab to medical students prior to graduation?		4.37 (0.79)	

^a Likert-type scale responses, where 1 = strongly disagree and 5 = strongly agree.**Table 2**

Mean (range) of pre- and post-test questionnaire responses (N=63).

Item	Pre-test	Post-test	p-Value
Number of times performed...			
Number of indications for arthrocentesis of a joint	0.56 (0–2)	2.54 (1–4)	<.0001
Number of contraindications for arthrocentesis of a joint	0.44 (0–2)	1.97 (1–3)	<.0001
Number of complications for arthrocentesis of a joint	0.79 (0–2)	2.57 (1–4)	<.0001
Student able to list the landmarks for performing elbow arthrocentesis ^a			
Yes	0 (0.0)	44 (69.8)	
No	63 (100)	19 (30.2)	
Student able to list the landmarks for performing knee arthrocentesis ^a			
Yes	17 (27.0)	52 (82.5)	
No	46 (73.0)	11 (17.5)	
Student able to list the landmarks for performing wrist arthrocentesis ^a			
Yes	0 (0.0)	36 (57.1)	
No	63 (100)	27 (42.9)	
Number of correct observed steps when performing...			
Elbow arthrocentesis	0.29 (0–2)	2.98 (1–4)	<.0001
Knee arthrocentesis	0.87 (0–2)	3.42 (2–5)	<.0001
Wrist arthrocentesis	0.54 (0–2)	3.00 (1–5)	<.0001

^a Values are number (%).

landmarks were also tested. The checklist for assessment was developed by researchers at our institution and then reviewed by experts in the field of orthopedic surgery for content, accuracy, and relevance (Appendices A–C).

2.5. Data analysis

Likert-scale responses were compared between pre- and post-test responses. Wilcoxon ranked-sum testing for non-parametric samples was used to assess differences in population means.

3. Results

Sixty-three medical students participated in the fresh cadaver lab and were included in this analysis. Based on the 5-point Likert-type scale, there was statistically significant improvement in comfort level for performing elbow, knee, and wrist arthrocentesis (Table 1). Post-test surveys also showed that students found the lab to be beneficial and would recommend it for future medical students prior to graduation. There was a statistically significant improvement in knowledge related to arthrocentesis when comparing pre- and post-tests (Table 2). This component included knowledge of indications, contraindications, and complications of arthrocentesis, in addition to knowledge of the landmarks related to elbow, knee, and wrist arthrocentesis. Additionally, when comparing pre- and post-tests, there was a statistically significant improvement in the number of correctly performed steps for elbow, knee, and wrist arthrocentesis (Table 2).

4. Discussion

Despite the decline in the opportunities for students to perform many technical procedures during the clinical years of medical school, the expectations that medical staff have of recent medical graduates to perform them remains high.^{13,16,17} Many junior residents are expected to be competent in technical skills despite limited training. This creates added stress for the resident and ethical concerns regarding practicing procedures on clinical patients.^{13,17}

Traditionally, medical students and residents have learned to perform technical skills via the apprenticeship format of “see one, do one, teach one,” in which demonstration by a skilled physician is followed by performance on a patient.¹⁸ Concerns regarding patient safety have led to a variety of alternative teaching approaches including simulations, animal workshops, and cadaver-based labs.¹⁸ These alternative approaches aim to provide the student with technical experience in a risk-free environment, prior to performing the procedure on a patient. A growing body of literature suggests that there is significant benefit to receiving formal, documented, procedural instruction compared to the traditional apprenticeship model.¹¹

Although arthrocentesis varies in difficulty, hand-eye coordination and confidence must be developed to gain the appropriate level of mastery for clinical practice. Vogelgesang et al. supplemented their teaching of arthrocentesis with a didactic lecture and a hands-on workshop using a synthetic model.¹⁸ In their study, students and residents on a rheumatology rotation that participated in the technical skills workshop performed better on a post-rotation practical examination than those who only received the lecture, while those that learned solely via the traditional approach had the worst performance.¹⁸

There have been numerous reports of institutions utilizing cadaver-based models to teach arthrocentesis.^{10,14,15} Berman et al. was the first to evaluate the relative merits of different alternative approaches for instruction of arthrocentesis.¹⁴ They concluded that the cadaver-based teaching model led to a greater increase in trainee comfort level than did synthetic anatomic models.¹⁴ However, their study lacked a long-term follow up of the newly obtained technical skills.

Huang et al. recently published a systematic review and meta-analysis of effective teaching approaches for invasive bedside procedures (including arthrocentesis), and concluded that the use of high-quality simulation that includes repetitive practice and mastery learning, supplemented by visual aids, appears to be the most effective approach.¹¹ We believe that the fresh cadaver represents the high quality simulation that Huang references. Unique to our approach was providing an additional visual aid by using the opposite limb to display relevant anatomy. In our model, the opposite limb was dissected to demonstrate joint anatomy while the untouched joint was used to teach the procedure.

Huang, et al. recommended using the competency-based education model, in which ‘mastery’ of a skill is required by the

student in order to complete their training.¹¹ In practice, this means that a trainee would only be allowed to perform procedures on patients once they have reached predefined simulation-based skill thresholds. This instructional design should be further explored in the teaching of arthrocenteses.⁹

Our study on the education and assessment of arthrocenteses examined the long-term knowledge and technical skills retention by executing pre- and post-testing, a study design feature that has been left out of many similar studies.¹⁹ In our study there was statistically significant improvement in identification of landmarks and successful joint aspiration of all three joints. Compared to the pre-test, students also scored significantly higher on the knowledge-based portion, which assessed the knowledge of indications, contraindications, and complications. The results of our 5-week post-tests strengthen the evidence that the cadaver-based approach is an effective model for teaching arthrocentesis.

This study is not without limitations. Since all of the students were taught solely using the cadaver-model, we were unable to test the difference in effectiveness of other teaching modalities such as synthetic anatomic models. In addition, although the checklists for each procedure were reviewed by experts in the field or orthopedic surgery, the checklists were not validated by a standardized process. Furthermore, although the puncture sites were not obvious to subsequent users, after 15–20 punctures, needle markings became visible. Subsequent users may have benefited or suffered from seeing these markings, but accurate

needle angle and depth would still be required for successful aspiration. Additionally, despite the realistic nature of the cadaver model, there is limited evidence to show that the skills learned during the cadaver laboratory could be successfully translated to clinical patients. To address this, a study that examines patient outcomes could be conducted at the resident-level, and may elucidate the true benefits of cadaver-based technical skills training. Lastly, our institution is privileged to be a partner of the Willed Body Program that allows us a constant supply of cadavers. This teaching modality may not be an option at other institutions (i.e., rural medical centers) where there may be limited access to cadavers.

In summary, the decline in traditional procedural teaching opportunities for medical students and the increased patient risk using the apprenticeship-based teaching model has created a demand for new, innovative modalities to teach technical skills. We have demonstrated that the use of a fresh cadaver model can provide medical students with early procedural training and can be an effective model to teach arthrocentesis. In the future, this may provide support for implementing a competency-based teaching model that incorporates the use of fresh cadaver models for teaching arthrocentesis to students and residents.

Conflicts of interest

The authors have none to declare.

Appendix A. Elbow arthrocentesis education and assessment template

Knowledge

Indications:

1. Crystal-induced arthropathy
2. Hemarthrosis
3. Septic arthritis
4. Symptomatic relief of a large effusion
5. Evaluation or drainage of joint effusion
6. Unexplained monoarticular arthritis
7. Injections of medications (steroids)

Contraindications:

1. Cellulitis overlying the joint
2. Skin lesions or dermatitis overlying the joint
3. Known bacteremia
4. Adjacent osteomyelitis
5. Uncontrolled coagulopathy/bleeding diatheses
6. Joint prosthesis (performed by orthopedist)

Complications:

1. Pain
2. Infection
3. Post-injection flare/pain
4. Joint instability from repeated injections
5. Iatrogenic hemarthrosis

Total points ____/18

Technical skill

Procedure:

1. Identifies equipment necessary prior to beginning
2. Places patient in supine position with the elbow flexed to 90° and the hand tucked under the buttock
3. Identifies landmarks (radial head, lateral epicondyle, tip of olecranon). A triangle is made with points at the lateral epicondyle, radial head, and olecranon process
4. Injects local anesthesia
5. Sterile prep of the field and draping
6. Inserts needle in the center of the triangle, perpendicular to the skin and parallel to the radial head, 0.75–1 in. (about 2–2.5 cm) deep
7. Advances needle as the student aspirates

Total points ____/7

Appendix B. Wrist arthrocentesis education and assessment template

Knowledge

Indications:

1. Crystal-induced arthropathy
2. Hemarthrosis
3. Septic arthritis
4. Symptomatic relief of a large effusion
5. Evaluation or drainage of joint effusion
6. Unexplained monoarticular arthritis
7. Injections of medications (steroids)
8. Synovial biopsy

Contraindications:

1. Cellulitis overlying the joint
2. Skin lesions or dermatitis overlying the joint
3. Known bacteremia
4. Adjacent osteomyelitis
5. Uncontrolled coagulopathy/bleeding diatheses
6. Joint prosthesis (performed by orthopedist)

Complications:

1. Pain
2. Infection
3. Post-injection flare/pain
4. Joint instability from repeated injections
5. Iatrogenic hemarthrosis
6. Tendon rupture following steroid injection
7. Nerve damage (median nerve atrophy)

Total points ____/21

Technical skill

Procedure:

1. Identifies equipment necessary prior to beginning
2. Places wrist in neutral position
3. Injects local anesthesia between the navicular bone and radius on the extensor surface of the wrist
4. Locates the distal radius between the tendons of the extensor pollicis longus and the extensor carpi radialis longus of the second finger (this site is just ulnar to the anatomic snuffbox)
5. Directs the needle perpendicular to the site and inserts a 25-gauge needle into the joint space (avoiding radial artery and tendons) as the student aspirates (traction can be applied to the thumb to further open the joint space)

[The wrist space also can be approached from the ulnar side by placement of the needle just distal to the ulnar bone].

Total points ____/5

Appendix C. Supralateral knee arthrocentesis education and assessment template

Knowledge

Indications:

1. Crystal-induced arthropathy
2. Hemarthrosis
3. Septic arthritis
4. Symptomatic relief of a large effusion
5. Evaluation or drainage of joint effusion
6. Unexplained monoarticular arthritis
7. Injections of medications (steroids)

Contraindications:

1. Cellulitis overlying the joint
2. Skin lesions or dermatitis overlying the joint
3. Known bacteremia
4. Adjacent osteomyelitis
5. Uncontrolled coagulopathy
6. Joint prosthesis (performed by orthopedist)

Complications:

1. Pain
2. Infection
3. Post-injection flare/pain
4. Joint instability from repeated injections
5. Iatrogenic hemarthrosis

Total points ____/18

Technical skill

Procedure:

1. Identifies equipment necessary prior to beginning
2. Positions patient in supine position with knee extended (or slightly flexed)
3. Injects local anesthesia
4. Inserts needle through stretched skin 1 cm above and 1 cm lateral to the superior lateral aspect of the patella at a 45° angle
5. Advances needle slightly posteriorly beneath the patella and slightly inferiorly as the student aspirates

Total points ____/5

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