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Ultrasound in Emergency Medicine

CAN ULTRASOUND IDENTIFY TRAUMATIC KNEE ARTHROTOMY IN A CADAVERIC MODEL?

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☐ **Abstract—Background: Traumatic arthrotomy of the knee (TAK) involves the violation of the knee capsule. TAK differs from simple lacerations because it requires operative management to prevent resultant septic arthritis. The diagnostic test of choice in the emergency department is the saline load test (SLT). SLT sensitivity ranges from 34% to 99%, depending on volume used. Computed tomography (CT) is a possible alternative, using intra-articular air as a diagnostic marker. Ultrasound can identify air in various tissues, given its highly echogenic nature. Objective: We sought to determine the sensitivity and specificity of ultrasound for detecting intra-articular air in cadaveric knee joints. Methods: Soft embalmed cadavers were utilized. The knees were block randomized to having 1 mL of air injected into the joint or sham skin injection. Two blinded, expert operators scanned the knees with a high-frequency linear transducer. The sensitivity and specificity were calculated. Results: Twenty knees were included. Knees that had any prior dissection were excluded from analysis. Ten knees were randomized for air injection. The pooled sensitivity was 0.65 (95% confidence interval [CI] 0.41–0.85) with a specificity of 0.75 (95% CI 0.48–0.93). Mean time taken was 143 s. Conclusions: Ultrasound may have utility in evaluation of TAK. There were limitations. Some knees had effusions with echogenic material present, which could have led to false-positive results. It is also unknown how much air is typical of TAK. One milliliter was used based on previous work with CT. The use of ultrasound for diagnosis of TAK warrants further study.**

☐ **Keywords—traumatic arthrotomy; musculoskeletal ultrasound; pneumarthrosis**

INTRODUCTION

Traumatic arthrotomy involves violation of the capsule of a joint. Traumatic arthrotomies most commonly occur in the knee joint. Fractures are associated with traumatic arthrotomy of the knee (TAK) between 24% and 61% of the time (1). TAK should be on the differential for soft tissue injuries around the knee because it can result in septic arthritis. Definitive management of traumatic arthrotomy includes i.v. antibiotics and operative irrigation and debridement (2). Injection of saline into the joint space, known as the saline load test (SLT), is the standard approach for diagnosing TAK. The reported sensitivity of the SLT for TAK ranges from 34% to 99%, with larger volumes (eg, 150–200 mL) yielding better sensitivity (3). Unfortunately, the SLT can be painful for the patient and time-consuming for the clinician; moreover, this procedure risks iatrogenic infection of a joint space that may not have been violated by the incident trauma.

Recently, computed tomography (CT) has been proposed as an alternative to the SLT for identifying TAK. In a cohort series of 62 patients, Konda et al.

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demonstrated that CT was able to diagnose TAK with 100% sensitivity and specificity based on the presence of intra-articular air (4). While the diagnostic performance of CT appears promising, this modality has the disadvantages of cost, ionizing radiation, and removal of the patient from the treatment area. The ideal test for identifying TAK would be cost effective, time efficient, highly sensitive, and low risk for the patient. Point-of-care ultrasonography meets all of these criteria. Air within the fluid-filled tissues has a characteristic appearance of a hyperechoic signal with "dirty shadowing" posteriorly. One can also commonly see reverberation artifact (5). Because ultrasound can detect gas–fluid interfaces in soft tissue and the finding of intra-articular air has been shown to be diagnostic of TAK, we sought to determine the sensitivity and specificity of a point-of-care ultrasound examination of the knee joint for intra-articular air.

MATERIALS AND METHODS

We utilized the knee joints of soft embalmed cadavers for this study. Because no living human subjects were scanned, the study was exempt from Institutional Review Board review. The knees were excluded from analysis if the knee or the soft tissue surrounding the knee had been violated by dissection or by other procedures evident by skin incisions. The knees were randomized to intra-articular injection of 1 mL of air using a 19-gauge needle or to sham skin puncture with 19-gauge needle. An online program (https://www.randomizer.org) was used for block randomization of knees as cadavers became available. Prior to any skin puncture, the knees were surveyed with ultrasound to evaluate for the presence of fluid or pre-existing air.

In the supine position, the knees were scanned by two physicians using a Sonosite M-turbo (FujiFilm Sonosite Inc, Bothell, WA) machine with a high-frequency linear transducer. Both of the physician operators are certified registered diagnostic medical sonographers. One of the physicians completed an ultrasound fellowship. The other physician became an expert through individual study before formal fellowship training programs were formed. The physicians were blinded to the status of the knees. The joint was scanned in a cranial to caudal fashion from the quadriceps tendon to the tibial plateau. The joint was scanned both medial and lateral to the patella, visualizing the joint capsule and bone cortices. The physicians scanned the knees within 2 h of air instillation.

These two physicians also interpreted the scans after finishing the examinations. They were blinded to interpretations as well. A scan was considered positive if hyperechoic foci with reverberation artifact were visualized within the joint capsule. A scan without these findings was considered negative. The sonographers also noted whether an effusion was present. Each cadaver knee was utilized only once and representative clips of each scan were saved. Statistical analysis was composed of 2×2 tables to calculate the sensitivity and specificity of ultrasound to detect intra-articular air. The κ-statistic was also calculated.

RESULTS

Twenty knees were screened for inclusion in the study, two were excluded due to prior dissection. A total of 10

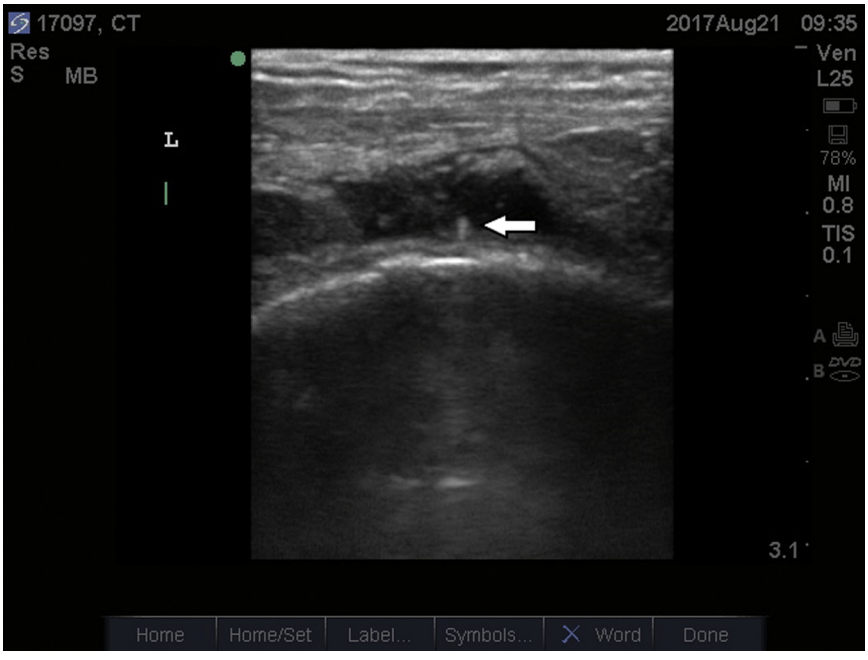

Figure 1. An example of a false-positive result, note the anechoic effusion with echogenic debris (white arrow).

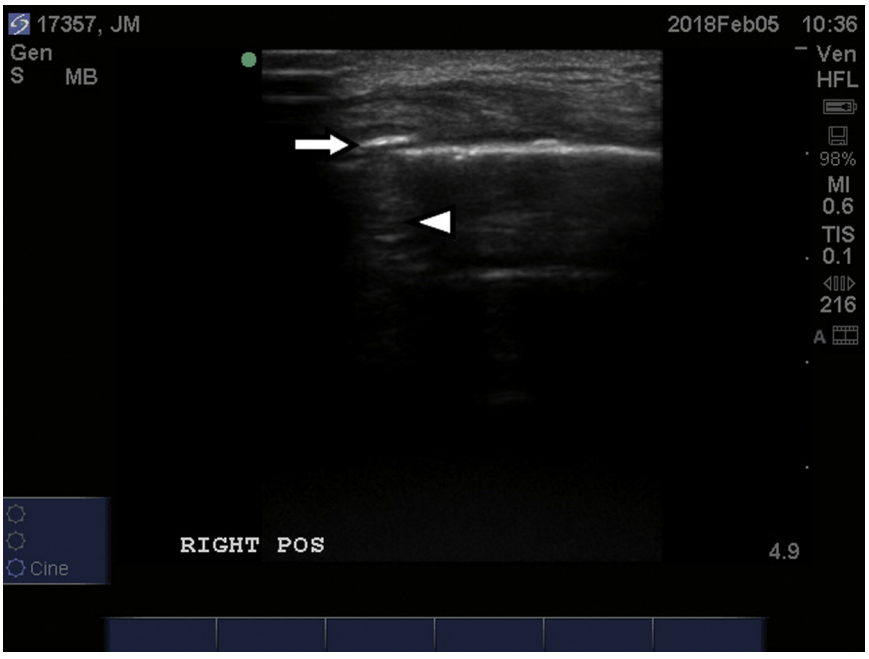

Figure 2. An example of a true-positive result with air appearing as a hyperechoic line (white arrow) with posterior shadowing and reverberation artifact (white arrowhead).

knees were randomized to have air injected into the joint space. Each knee was scanned by the two operators, yielding 36 data points. Effusions with echogenic material were noted in 9 of the 36 knee scans analyzed (for an example, see Video 1). The appearance of the echogenic material (Figure 1) in these knees differed from those of true-positive knees in that the echogenic material lacked the posterior shadowing typical of air (Figure 2, Video 2). True-negative results lacked these findings (Figure 3). The average time per scan was 143 s, with the longest scan taking 243 s. Out of 36 data points, there were 13 true-positive results and 12 true-negative results. Table 1 summarizes the test characteristics of ultrasound for TAK. The sensitivity of ultrasound for intra-articular air in this series was 0.65 (95% confidence interval [CI] 0.41–0.85) with a specificity of 0.75 (95% CI 0.48–0.93). The positive predictive value was 0.76 (95% CI 0.57–0.89) and the negative predictive value was 0.63

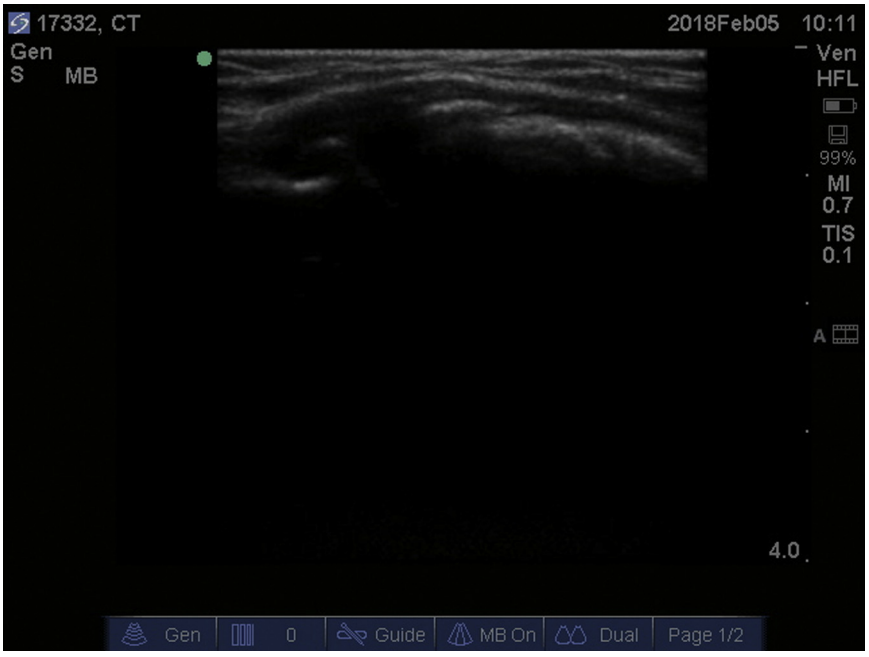

Figure 3. An example of a true-negative result.

Table 1. Pooled Sensitivity and Specificity of Ultrasound for Detecting Intra-articular Air

Variable	Air in the Joint	No Air in the Joint
Positive ultrasound	13	4
Negative ultrasound	7	12
Sensitivity	0.65	
Specificity	0.75	

(95% CI 0.47–77). There was fair agreement between sonographers, with a κ-statistic of 0.44 (95% CI 0.031–0.86).

DISCUSSION

Traumatic knee arthrotomy injuries require operative debridement and irrigation to prevent resultant septic arthritis. Standard diagnosis of TAK involves utilizing the SLT to evaluate for extravasation of any saline from a laceration adjacent to or overlying the structures of the knee. However, this procedure is invasive and has varying reported degrees of diagnostic sensitivity (3). Ultrasonography is capable of demonstrating fracture, tendon injury, as well as air within the tissues, the presence of which is diagnostic of some pathologic states, such as emphysematous cholecystitis and necrotizing soft tissue infections (5–7). If the presence of air is diagnostic of TAK, which the Konda et al. study suggests, then ultrasound is an attractive modality, as it lacks ionizing radiation and is non-invasive (4).

In this cadaver study, the sensitivity of ultrasound for intra-articular air was 65%. Specificity was better, however, this was likely confounded by the echogenic debris material seen in some of our cadaver knees with effusions. The sensitivity of ultrasound in this study was better than some reported sensitivities of the SLT, making it a promising prospect for future research (3).

Limitations

There are several limitations to this series. Our model is cadaveric and may not adequately replicate the clinical and sonographic features of an examination on a live patient. We chose a cadaver model because we believed that intentionally violating the knee joints of healthy volunteers would expose them to unacceptable risk and we are unaware of a suitable non-human inanimate model. We standardized the amount of air instilled to 1 mL to limit confounding, but it is unknown how much intra-articular air is typical for a traumatic arthrotomy. The Konda et al. study demonstrated that CT could identify as little as 0.1 mL of intra-articular air (4). It is possible that compression of the joint space by the ultrasound probe caused the air to migrate to other parts of the joint, eluding discovery. Occasionally, compressing the superior aspect of the joint caused air to migrate into view of the probe. It is possible that if this maneuver had been incorporated into the protocol initially, our sensitivity would have increased.

CONCLUSIONS

This study describes a novel protocol to use non-invasive bedside ultrasound to evaluate for intra-articular air as a proxy for traumatic arthrotomy. To our knowledge, this is the first study to investigate this. The sensitivity and specificity of ultrasound in this study does not support its use as a screening test for TAK at this time. However, additional study into the accuracy of this modality for TAK is warranted.

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SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jemermed.2019.06.012.

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ARTICLE SUMMARY

1. Why is this topic important?

Traumatic arthrotomy of the knee, like other traumatic joint arthrotomies, can lead to septic arthritis. Currently, diagnosis of this condition is dependent on an invasive procedure.

2. What does this study attempt to show?

This study attempts to demonstrate the diagnostic capability of point-of-care ultrasound for traumatic arthrotomy by identifying intra-articular air.

3. What are the key findings?

Air is identifiable in the knee joints of cadavers. The sensitivity and specificity of ultrasound for intra-articular air is fair.

4. How is patient care impacted?

With additional study, this modality could become an easily available, non-invasive alternative to the saline load test.