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Detection of traumatic elbow arthrotomies: computed tomography scan vs. saline load test

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Background: Traumatic elbow arthrotomies are common injuries evaluated for by orthopedic services; however, failed identification of a traumatic arthrotomy leads to a high risk of developing septic arthritis. Currently these injuries are evaluated by either a saline load test or a computed tomography (CT) scan, yet there is little published evidence regarding detection of traumatic elbow arthrotomies.
Hypothesis: In our study, we hypothesized better sensitivity and specificity of detecting a traumatic elbow arthrotomy with a CT scan over a saline load test.
Study Design: Descriptive cadaveric laboratory study.
Methods: Ten fresh-frozen cadaveric transhumeral upper extremity amputation specimens were thawed for trial. Specimens were brought through CT scan prior to arthrotomy, arthrotomy was made, and then post arthrotomy a repeat CT scan was performed. A saline load test was then performed after all CT scans were completed.
Results: Zero CT scans before (0/10) and after (0/10) the arthrotomies were positive for intra-articular air in the elbow joint with a 0% sensitivity and specificity. The saline load test had an average positive test at 19 mL with a 100% sensitivity and 100% specificity.
Conclusion: After our study and based on the recommendations of the brief literature on this topic, we advise evaluating for traumatic elbow arthrotomies with a saline load test as the primary method of detection.
Level of evidence: Basic Science Study; Cadaver Dissection

Keywords: Traumatic elbow arthrotomy; saline load test

Traumas and lacerations are among the leading reasons for emergency room visits in the United States. Elbow injuries are frequently evaluated by orthopedic services secondary to open fractures, motor vehicle accidents, gunshot or stab wounds, etc.[8,12,19] There were an estimated 150,000 elbow surgeries in the United States during 2006, with 9650 involving open elbow injuries.[12] Although not all periarticular lacerations are arthrotomies (violation of the joint capsule), the possibility of a traumatic elbow arthrotomy (TEA) must be on the differential diagnosis. A thorough physical examination of the extremity is a necessity; however, it may not be enough to determine the integrity of the joint capsule. The location, depth, and complexity of a wound often dictates the treatment plan. Because the elbow joint has areas with little connective tissue separating it from the skin, a superficial laceration can penetrate through the joint capsule.[5,15,21] The concern then is bacteria can be inoculated into the joint, leading to the development of septic arthritis. The infection rate after a missed diagnosis of knee arthrotomy is up to 11.8%.[7,13] Bacteria make chondrolytic enzymes along with local infiltration of inflammatory cells and cytokines that cause cartilage

Institutional review board approval was not required for this basic science study.

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destruction in as little as 4-6 days.[1,19] Progression of the chondrolysis will lead to irreversible degradation and potentially osteomyelitis requiring salvage procedures or arthroplasty. Therefore, the standard of care for traumatic arthrotomies is open or arthroscopic irrigation and debridement with intravenous antibiotics.[1,4,8,19] If the joint capsule is not compromised, a much less invasive treatment plan of bedside irrigation, wound repair, and short course of oral antibiotics is sufficient.[1,4,19]

Today, TEAs are most commonly evaluated by a saline load test (SLT) and/or a computed tomography (CT) scan, yet there is little evidence in the literature for either tests. Prior investigations have mostly studied traumatic knee arthrotomies. Hence, there remains an incomplete understanding of detecting TEAs and subsequent septic arthritis of the elbow. Increasing our knowledge in detecting TEA with high sensitivity and specificity may improve treatment in patients with periarticular lacerations by expediting surgical intervention and prevent unnecessary surgeries. Furthermore, to our knowledge, there are no studies documented regarding CT scan, or other radiographic testing, for the detection of TEA. Our hypothesis is an improved sensitivity and specificity of TEA detection with CT scan over SLT.

Figure 1 Direct posterior 1-cm elbow arthrotomy incision with intra-articular access to the olecranon fossa.

Saline load test

An SLT is a diagnostic procedure where sterile saline is injected into a joint suspected of a traumatic arthrotomy. Extravasation or leakage of fluid from the wound is a positive test, indicating the wound has penetrated the joint capsule.[4] The SLT is the most common nonsurgical diagnostic tool and widely accepted as the test of choice to diagnose traumatic arthrotomy,[9,14,17,18,22] as first documented by Patzakis.[20] However, there is inconsistent and little data to rely on for sensitivity/specificity of an elbow SLT as well as the amount of saline injected.

CT scans

CT scans have the capability to evaluate osseous structures and soft tissue in 3 dimensions. Noncontrasted CT scans with different viewing windows can be used to better evaluate subcutaneous and intra-articular air, as opposed to contrasted CT scan's enhanced ability to detect vascular injury or fluid collections. In today's modern medical practice, CT scans are much more readily available. Because of their increased abundance, in addition to level I or II trauma centers, facilities such as Urgent Cares or rural community hospitals can perform CT scans on extremity wounds in minutes. They now can potentially identify a traumatic arthrotomy and transfer the patient to an institution with a higher level of care where appropriate treatment can be performed.[9] A CT scan does not afflict any more pain on the patient, in comparison to the SLT—a painful procedure—thus tempting the clinician to forgo the SLT. One concern with CT scans is the patient being exposed to potentially harmful radiation. Radiography and magnetic resonance imaging are also good modalities to evaluate for fracture and soft tissue injury; however, identification of subcutaneous and intra-articular air is not as predictable as CT. Additionally magnetic resonance imaging is not typically performed as quickly as a CT scan, thus, delaying appropriate diagnosis and treatment.

Materials and methods

We performed a cadaveric study using 10 fresh-frozen upper extremity transhumeral amputations that were thawed before use. We included cadaveric specimens with an intact elbow joint and capsule with no known prior elbow surgery or pathology. Exclusion criteria were cadaveric specimens with a history of previous elbow surgery.

A 0.6-mm-per-slice noncontrast CT scan (Siemens 128 CT scanner; Siemens Healthineers, Erlangen Germany) was performed on all specimens to detect intra-articular air prior to the elbow arthrotomy. An orthopedic surgery resident then made a 1-cm elbow arthrotomy in the direct posterior arthroscopic portal site[6] with a no. 15 blade scalpel while holding the elbow flexed at 90° in neutral rotation, allowing intra-articular access to the olecranon fossa

Figure 2 Elbow specimen brought through flexion, extension, pronation, and supination range of motion after arthrotomy. Specimen in extension.

Figure 3 Elbow specimen brought through flexion, extension, pronation, and supination range of motion after arthrotomy. Specimen in flexion.

(Fig. 1). The elbows were then placed through flexion-extension and pronation-supination range of motion maneuvers, 10 times each (Figs. 2 and 3) to optimize air entry into the wound. Again a 0.6-mm-per-slice noncontrast CT scan was then performed on all specimens to detect intra-articular air compared to pre-arthrotomy CT scan images (Figs. 4-6). The CT scan images were examined twice by 3 orthopedic surgery residents, while using the lung viewing window on Philips IntelliSpace Picture Archiving and Communication System (PACS) Enterprise software (Centricity; GE, Waukeshau, WI, USA). SLTs were then performed on all specimens with an 18-gauge needle and a mixture of normal saline with methylene blue dye (1 mg/300 mL), similar to Feathers et al.[8] The needle was inserted into the direct lateral "soft spot" elbow arthroscopy portal as described by Camp et al,[6] in between the radial head, olecranon, and lateral epicondyle. The arthrotomy site was then observed as the fluid was injected, and any leakage from the arthrotomy site resulted in a positive static test. Data were collected as positive and negative intra-articular air on CT scan (+IACT, –IACT) as well as positive and negative SLT after the number of injected milliliters (+SLT, –SLT).

Results

All elbow CT scans, before (0/10) and after (0/10) the arthrotomies, were negative for intra-articular air in the elbow joint or evidence of traumatic arthrotomy. CT scans demonstrated a 0% sensitivity with a 95% confidence interval (69%-100%). The SLT of the specimens 1-10 were positive at 15, 15, 12, 12, 15, 18, 40 + 5, 20, 20, and 15 mL, respectively (Fig. 7). The SLT demonstrated a 100% sensitivity and 100% specificity compared with the 0% sensitivity and specificity of the CT scans. To reach 60% sensitivity of the SLT, 15 mL need to be injected. To obtain 90% sensitivity, 20 mL need to be injected (Fig. 8). On specimen number 7, 40 mL was injected into the soft spot at the direct lateral elbow arthroscopy portal; however, no dye leakage was noted. The needle was then redirected into the joint, and within 5 mL of injection, the dye was seen from the traumatic arthrotomy incision site. The average milliliters injected for a positive SLT is 19 mL. Excluding specimen number 7, producing a 45-mL +SLT, where the needle was likely extra-articular, the average +SLT is 16 mL.

Discussion

Injuries and lacerations around the elbow can range from minor to very complicated injuries, but a traumatic elbow arthrotomy must always be evaluated. We have been forced to apply literature based on the knee for traumatic arthrotomies. This should not be the case, as the elbow and

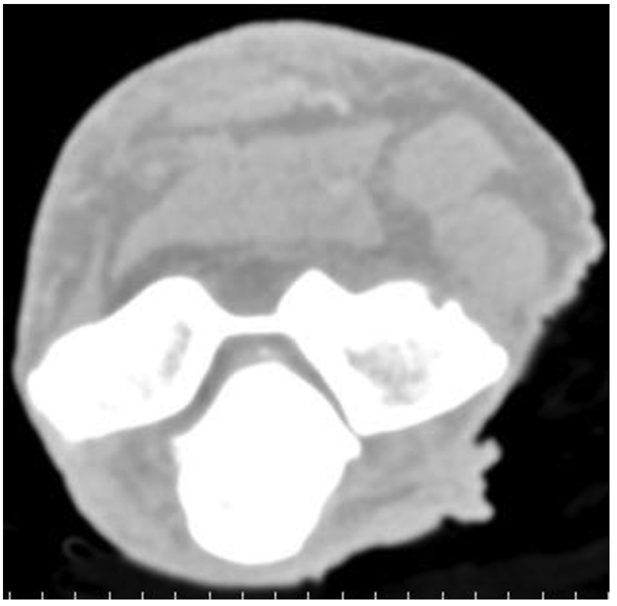

Figure 4 Axial CT cut of the Ulnohumeral joint with the lung viewing window. No intra-articular air is noted. *CT*, computed tomography.

knee anatomic structures are vastly different. Knees are superficial large joints, making it easier to sustain a traumatic arthrotomy.[21] The elbow is a deeper joint with many more overlying layers of muscle and subcutaneous tissue, making an arthrotomy more difficult. In this study, we hypothesized better sensitivity and specificity of detecting a traumatic elbow arthrotomy with a CT scan over an SLT. After the data collection, the SLT proved to be more sensitive (100% vs. 0% with CT) in detecting a TEA.

Voit et al[18] were among the first to apply the SLT to their clinical practice. They studied 50 patients with periarticular lacerations and compared their clinical diagnosis vs. SLT for traumatic arthrotomies. They determined the SLT was superior with an estimated 40% clinical diagnosis error, thus changing their treatment plan based on the SLT outcomes.

Nord et al[17] and Keese et al[11] both produced studies demonstrating SLT in knee joints, with sensitivities of 95% reached after 155 and 194 mL normal saline was injected, respectively.[11,17,21] However, a false-negative rate of 67% and a false-positive rate of 9% were reported in prior knee SLT studies.[14,16] Tornetta et al[21] also performed sensitivity and specificity testing for knee SLTs under a controlled operative setting. They calculated a 36%-43% static/dynamic knee SLT sensitivity after injecting 60 mL of normal saline during a knee arthroscopy portal.[21]

A systematic review of SLT was performed by Browning et al,[4] yielding 10 relevant studies. They determined there is no consensus on the amount of saline needed to achieve the highest sensitivity. Additionally, the use of methylene blue dye did not improve the sensitivity of the SLT.[4,16] Limitations such as operator dependency, cadaveric specimens,

Figure 5 Sagittal CT cut of an elbow specimen with the lung viewing window. No intra-articular is air noted. *CT*, computed tomography.

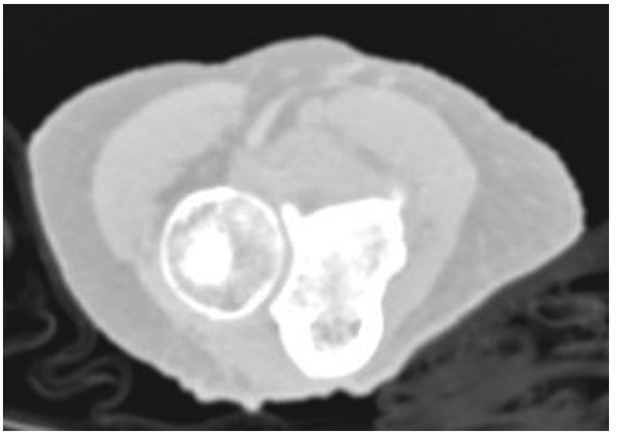

Figure 6 Axial CT cut of the proximal radioulnar joint with the lung viewing window. No intra-articular air is noted. *CT*, computed tomography.

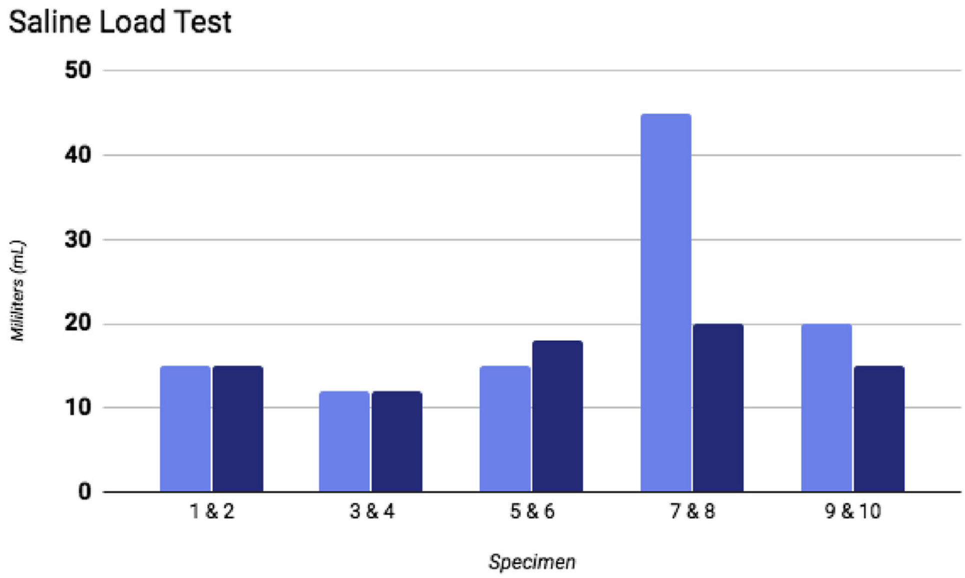

Figure 7 SLT results charted per specimen. An average of 19 mL is needed for a positive SLT. Excluding specimen 7, the average inject is 16 mL for a positive SLT. *SLT*, saline load test.

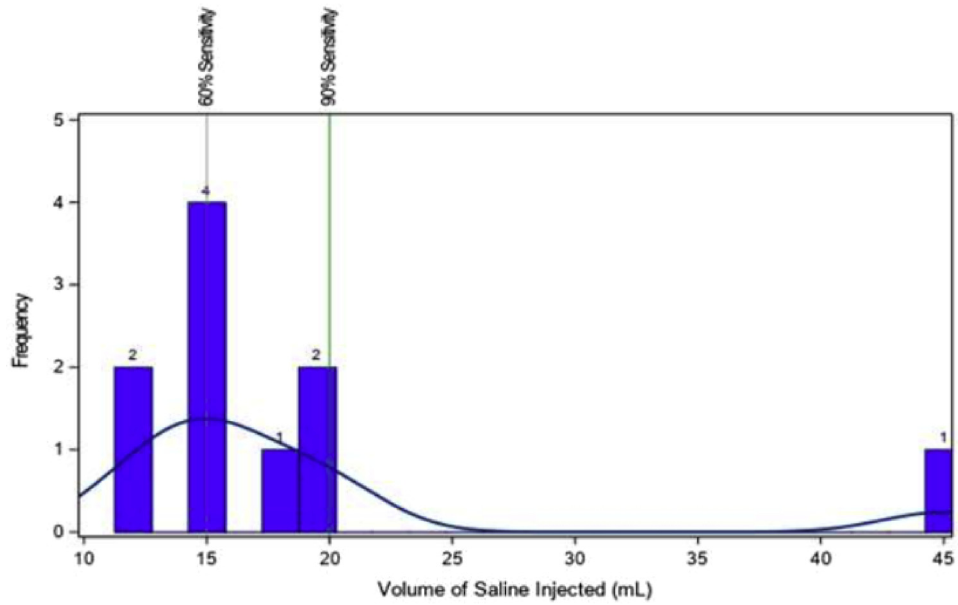

Figure 8 Sensitivity of the SLT: 15 mL injected to reach 60% sensitivity, and 20 mL injected to reach 90% sensitivity. *SLT*, saline load test.

arthrotomy sizes, and modalities were discussed, concluding more evidence is needed.[4]

All prior SLT studies in the literature were based on the knee, until Feathers et al[8] performed SLTs on 40 cadaveric elbows. According to the maximum capsular capacity of the elbow reproduced by O'Driscoll et al,[18] the specimens were initially injected with 20 mL of saline. Only 72% of their specimens had initial extravasation of fluid at the 1-cm posterior arthrotomy site. A total of 40 mL were needed for a sensitivity of 95%. Their study demonstrated a static sensitivity of 58%-87%, and a dynamic sensitivity of 75%-97% in traumatic elbow arthrotomies. The sensitivity of arthrotomy detection changes, however, with different volumes injected into the joint and may be misleading. Using fresh-frozen cadaveric specimens, O'Driscoll et al[18] as well as Hudson[9] and Johansson[10] reported estimated normal elbow volumes to be 10-15 mL with a maximum capsular capacity of approximately 20-25 mL.[8] O'Driscoll et al also found capsular rupture or leakage at low injection pressures, ranging 32-170 mmHg, and a 95% confidence interval of 54-108 mmHg. Thus, once the maximum capsular capacity was reached, there was a high likelihood of leakage/capsular rupture causing extravasation of fluid and potentially inaccurate results.

The use of CT scans are convenient and more accessible; however, they do have their pitfalls. CT scans of the elbow and knee have an estimated radiation exposure of 0.14 and 0.16 mSv, respectively. These have much less radiation exposure than of the chest (5.27 mSv) or abdomen/pelvis (4.9 mSv) CT scans.[3] The cost of CT scans is also a concern. Of course, all facilities are different and insurance coverage also may change the price for the patients. At our institution, the cost of an upper extremity CT scan without contrast is $418.75.[2] In comparison, the SLT using an 18-gauge needle, syringe, and a 100-mL bottle of normal saline is pennies on the dollar compared with a CT scan.

To date there are no known studies in the literature testing the sensitivity of CT scans of the elbow for TEA. There is, however, a CT study by Konda et al[13] evaluating evaluating traumatic knee arthrotomies performed over 3 years, collecting data from 63 periarticular knee wounds. CT scans were obtained to identify intra-articular air with the lung viewing window, and positive tests were taken for confirmation in the operating room with irrigation and débridement. They found that 51% (32/63) of the wounds were traumatic knee arthrotomies based on CT, with all 32 having operating room arthrotomy confirmation. Additionally, none of the patients with negative CT scans developed septic arthritis at their 2-week follow-up, meeting their negative arthrotomy criterion. Thus, Konda et al concluded an improved sensitivity and specificity of detecting traumatic knee arthrotomy to 100% with use of CT scan.

Our study, however, had its limitations; thus, we recommend that additional research is warranted. First, our specimens were thawed fresh-frozen cadaveric arms where tissue consistency may be altered in comparison to living tissue. The SLT is a procedure with variable intrauser reliability, as not all injections may be intra-articular, as seen with our specimen 7. Next, our arthrotomy location and size may not imitate typical elbow wounds. Although it is impossible to re-create all injury patterns, the smaller wounds are more likely to warrant an SLT to rule out an occult TEA. Even with the specimens being brought through range of motion, it is possible the size of the arthrotomy did not introduce air into the joint, resulting in zero positive CT scans. Additionally, CT scans only show the structures at one point in time, rather than dynamic or serial testing. Bunyasaranand et al[5] published a case report of a patient with a 6-cm elbow laceration sustained from a motorcycle accident. Examination showed mild pain with passive range of motion and the wound extended deep to the muscular fascia. A CT scan was negative for intra-articular air, so the patient received bedside irrigation and wound repair. No SLT was performed. On his 1-week follow-up examination in office, the patient presented with signs and symptoms of a septic elbow with purulent drainage from the wound. He was then taken for 2 separate irrigation and débridements in the operating room, finding a 3-cm laceration through the joint capsule. This case demonstrates clinically that even a larger laceration to the elbow may not show intra-articular air on CT.

Conclusion

Based on this study, we would recommend that all potential traumatic elbow arthrotomies be preferentially evaluated by a saline-load test. Although CT scans are non-invasive, this cadaveric study did not show them to be reliable for detecting traumatic elbow arthrotomies, in addition to their added cost and increased radiation exposure to the patient.

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