Saline Load Test for Detecting Traumatic Arthrotomy in the Wrist

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Abstract

Background Open injuries communicating with the wrist joint are essential to detect to facilitate timely, appropriate treatment. While the saline load test to detect traumatic arthrotomy has been well studied in the knee and ankle, it has not been studied in the wrist, and therefore the appropriate volume of saline infusion to detect traumatic arthrotomy is not known.

Purpose The purpose of this study was to utilize wrist arthroscopy to determine the saline infusion volume necessary to achieve 99% sensitivity in detecting traumatic arthrotomy.

Methods Twenty consecutive patients undergoing elective wrist arthroscopy were prospectively enrolled. A 5-mm arthrotomy was established between the third and fourth dorsal extensor compartments. An 18-gauge needle was inserted into the 6R portal on the radial side of the extensor carpi ulnaris. Sterile normal saline was injected into the wrist joint through the needle at a rate of 0.1 mL per second until extravasation from the 3–4 portal was visualized. Saline volumes required for extravasation were analyzed.

Results The mean saline volume required for extravasation was 0.8 mL. The volume of saline needed to achieve sensitivities of 50, 90, 95, and 99% were 0.4, 2.2, 2.3, and 2.5 mL respectively.

Conclusions The saline infusion volume required to detect a dorsal radiocarpal arthrotomy with 99% sensitivity was 2.5 mL. We recommend using at least 2.5 mL when performing the saline load test to rule out a potential arthrotomy to the wrist in the traumatic setting.

Level of Evidence: This is a Level II, diagnostic study.

Keywords

- ▶ arthrotomy
- ▶ saline load test
- ▶ wrist

Open injuries communicating with the wrist joint are essential to detect on presentation to facilitate timely, appropriate treatment and avoid the morbidity of a subsequent septic joint.¹ In patients with penetrating injuries or lacerations concerning for violation of the wrist joint, the integrity of the joint capsule should be assessed. The saline load test consists of an injection of a certain volume of sterile saline into a given

joint separate from the site of injury, whereby extravasation of saline from the injury site is a positive result that indicates a capsular breach.¹ This test has been studied in the knee,^{2,3} ankle,^{4,5} and elbow⁶ with the recommended infusion volumes reported as 155 to 194 mL, 30 to 60 mL, and 40 mL, respectively. Some studies have used the saline load detecting traumatic arthrotomy with 95% sensitivity

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as the suggested threshold,^{2-4,6} while others suggested using the 99% sensitivity level as the threshold.^{4,5} Computed tomography (CT) scan demonstrating intra-articular air has also shown to be a validated tool to diagnose traumatic knee arthrotomy,⁷ though there is one report of CT not adequately diagnosing traumatic elbow arthrotomy.⁸

Despite the well-documented use of the saline load test in the knee, ankle, and elbow, there is insufficient characterization of the test for diagnosing traumatic wrist arthrotomy. Voit et al performed the saline load test on 50 consecutive patients with periarticular lacerations, two of which involved the wrist joint.⁹ The authors used 5 mL as an infusion volume for the wrist; however, this volume was determined theoretically based on the relative size of the wrist joint. The saline load test has not yet been studied specifically in the wrist, and therefore the appropriate volume of saline infusion to detect traumatic arthrotomy is not known. Arthroscopy models have been utilized in several prior studies to characterize the saline load test in the knee and ankle,²⁻⁵ yet no similar study has been performed in the wrist.

Our purpose was to utilize wrist arthroscopy to determine the saline infusion volume necessary to achieve 99% sensitivity in detecting traumatic arthrotomy of the radiocarpal joint. We opted to use the 99% sensitivity level as the threshold to maximize the ability to rule out an open wrist injury.

Methods

This study was approved by our institutional review board. Over a 6-month period, we prospectively enrolled consecutive patients undergoing elective wrist arthroscopy (►Table 1). Inclusion criteria consisted of any adult patient undergoing elective wrist arthroscopy. We did not exclude any patients who had previous surgery on the involved wrist joint, with the goal of identifying any factors that could alter the saline load amount from normal and minimize the chance of a false negative when performing the saline load test. Exclusion criteria consisted of refusal or lack of capacity to provide consent. As discussed in a previous study characterizing the saline load test in the ankle, a power analysis was not performed as it cannot be applied in this type of study determining the sensitivity of the saline load test among a single cohort in which the disease prevalence (iatrogenic arthrotomy) is 100%.⁵

Table 1 Patient characteristics (n = 20)

Characteristic	Summary statistics
Age (y; mean ± SD)	41.2 ± 12.8
Male sex (n [%])	11 (55.0%)
Height (cm; mean ± SD)	170.3 ± 11.8
Weight (kg; mean ± SD)	79.9 ± 19.6
Body mass index (kg/m ² ; mean ± SD)	27.2 ± 4.5

Abbreviation: SD, standard deviation.

For each patient, the operative wrist was prepped and draped in the usual fashion in the operative room. The limb was exsanguinated and tourniquet inflated to 250 mm Hg to limit any bleeding that would make visualization of saline extravasation difficult. The extremity was positioned in the arthroscopy tower with initially 10 to 15 pounds of traction across the middle and ring finger. A 5 mm arthrotomy was made with an 11-blade scalpel through skin and capsule between the third and fourth dorsal extensor compartments. A blunt trocar and arthroscope were inserted and clear visualization of the radiocarpal joint was confirmed without any joint insufflation or irrigation fluid. A diagnostic arthroscopy was performed to evaluate for any high-grade interosseous ligament injuries. An 18-gauge needle was inserted into the 6R portal on the radial side of the extensor carpi ulnaris and directly visualized under dry arthroscopy. The arthroscope and trocar were then removed and traction was taken down for 2 minutes. Sterile normal saline was injected into the wrist joint through the needle in the 6R portal at a rate of 0.1 mL per second until extravasation from the 3-4 portal was visualized and this volume was recorded.

Statistical analysis was performed using Stata 10 Statistical Software (StataCorp, 2007. Stata Statistical Software: Release 10. College Station, TX: StataCorp LP). The sensitivity of the saline load test was calculated. Linear regression and Student's *t*-tests were performed to determine if any correlations exist between saline volume required for extravasation and age, gender, height, weight, or body mass index. Mann-Whitney U tests were performed to compare saline volume required for extravasation between patients with and without prior wrist surgery given nonparametric distributions. Alpha was set at a two-tailed level of 0.05.

Results

Twenty consecutive patients were enrolled during the study period. This included 11 males and 9 females. The mean age was 41.2 years (range: 23-64 years). The primary diagnoses/reasons for arthroscopy included ulnocarpal impaction (11 patients), triangular fibrocartilage complex (TFCC) tears without impaction (4 patients), scapholunate ligament tears (4 patients), and dorsal wrist syndrome/impingement (1 patient). Diagnostic arthroscopy did not reveal any high-grade TFCC or interosseous ligament tears requiring repair or reconstruction in any of the 20 patients.

The mean saline volume required for extravasation was 0.8 mL, with minimum of 0.2 mL and maximum of 2.5 mL (►Fig. 1). The volume of saline needed to achieve sensitivities of 50, 90, 95, and 99% were 0.4, 2.2, 2.3, and 2.5 mL, respectively (►Table 2, ►Fig. 2).

Saline volume required for extravasation was significantly higher in males compared with females (1.2 vs. 0.5 mL; *p* = 0.030). There was a positive association between saline volume and height (β = 0.03, 95% confidence interval = 0.004-0.06; *p* = 0.027). There was no statistically significant association between saline volume required for extravasation and age, weight, and body mass index (*p* > 0.05 for each; ►Fig. 3).

Fig. 1 Distribution of saline load volume required for extravasation in the wrist. SD, standard deviation.

Four patients had prior wrist surgery, including (1) carpal tunnel release; (2) wrist arthroscopy with ulnar styloid debridement, carpal tunnel release, and distal radius open reduction internal fixation; (3) wrist arthroscopy with unknown associated procedures; and (4) volar ganglion cyst excision. These patients' saline load volumes measured 1, 1.2, 2.2, and 2.3 mL, respectively. When compared with the 16 patients who had not undergone previous wrist surgery, the saline volume required for extravasation was significantly higher in the previous surgery group (median 1.7 [interquartile range 1.1–2.25] vs. median 0.4 [interquartile range 0.3–0.6]; $p = 0.020$). In a subgroup analysis of patients without any prior wrist surgery, the saline volume needed to achieve sensitivities of 50, 90, 95, and 99% were 0.4, 1.6, 2.5, and 2.5 mL respectively. Thus, the threshold for 99% sensitivity was no different whether or not there had been previous surgery.

Discussion

Open wrist injuries have the potential to cause significant morbidity if not identified and treated urgently.¹ The saline

Table 2 Lowest saline volumes to achieve sensitivities of 50, 75, 90, 95, and 99%

Sensitivity	Lowest saline volume to achieve sensitivity	Actual sensitivity at saline volume
50%	0.4 mL	50.0%
75%	1.2 mL	80.0%
90%	2.2 mL	90.0%
95%	2.3 mL	95.0%
99%	2.5 mL	100.0%

Abbreviation: SD, standard deviation.

Fig. 2 Sensitivity of saline load test for the wrist at incremental volumes.

load test for open arthrotomy, while well studied in various joints,^{2–6} has not been studied in the wrist. In our study, we utilized wrist arthroscopy to simulate an arthrotomy and characterize the saline load test within the wrist.

We found that the saline infusion volume required to achieve 99% sensitivity within our sample was 2.5 mL. Given the morbidity of missing a potential open injury, we recommend maximizing sensitivity and therefore using 2.5 mL to load the wrist when performing this test in practice. The saline infusion volume determined in this study was similar, though less than the theoretical volume of 5 mL used by Voit et al in their prospective study saline loading 50 joints, 2 of which were wrists.⁹ The above authors reported an overall analysis of false positive and false negative rates; however, they did not stratify by joint involved and therefore no ideal saline volume for the wrist can be gleaned from their study.

A higher saline volume required for extravasation was associated with male gender, and increasing height. This finding is contradictory to reported results for the knee, elbow, and ankle, where saline load volume showed no such correlation.^{2,3,5,6} However, Bariteau et al did find saline volumes required for extravasation in the ankle to be 14.5 mL in males and 7.3 mL in females with a p -value of 0.071. Crisco et al analyzed CT reconstructions to show that carpal bones are significantly larger in males.¹⁰ It is possible that due to relatively small size of the wrist joint, small changes in capsular volume due to gender and height are significant.

The four patients in this study who had prior wrist surgery all had saline infusion volumes greater than the mean of 0.8 mL, and collectively had statistically higher values than those who did not have prior surgery. The reason for this is not clear and no other study has commented on the influence of prior surgery on the saline load test. One would expect that violation of the joint capsule and subsequent scarring would lead to a less extensible capsule that would leak fluid sooner, which is to the contrary of what was seen here. Regardless of whether patients with prior surgery were included, the

Fig. 3 Saline load required for extravasation versus patient demographics.

saline volume needed to achieve 99% sensitivity was 2.5 mL; thus, it appears that at least in this cohort having had a previous surgery did not change the key data point. One should be aware, however, that a previous operation may have a tendency to increase the effective volume of the wrist, so consideration should be given to erring on the side of a higher dose of saline load to assure sufficient insufflation.

The limitations of this study involve the use of wrist arthroscopy to simulate wrist arthrotomy and thus characterize the saline load test. The most widely accepted infusion thresholds for the saline load test in the knee stem from studies using knee arthroscopy models to simulate traumatic arthrotomy.^{2,3} This study has similar limitations to prior studies that have utilized arthroscopy models to characterize the saline load test.²⁻⁵ All of the wrist arthrotomies were made at the 3-4 portal through 5 mm incisions. It is possible that a penetrating injury of a different size may require a

different volume of saline infusion for extravasation. We intentionally chose a relatively small laceration size in an attempt to err on the side of a high value for the saline load, which hopefully creates a low false negative rate using the values in this study. One would expect that a larger laceration would lead to earlier egress of fluid and a lower data point for the saline load. Thus, our infusion value of 2.5 mL hopefully creates a high sensitivity regardless of laceration size. A limitation of exclusively using the 3-4 arthroscopy portal sites to detect extravasation is that lacerations at different locations could have different saline load values. For example, a volar laceration concerning for arthrotomy could require significantly more fluid as it would need to track through the contents of the carpal tunnel or Guyon's canal before reaching the level of visible extravasation. Thankfully this is a rare circumstance given the numerous soft tissue structures between the skin and the wrist joint volarly.

Therefore, the results of this study are best applied to traumatic with soft tissues similar to those at the 3–4 arthroscopy portal. The majority of the span from the radial wrist across dorsally to the extensor carpi ulnaris has a relatively consistent soft tissue thickness and tendon distribution, hopefully making our data relevant over that broad anatomic area.

Another limitation is that a wrist undergoing elective wrist arthroscopy may not mirror the acutely traumatized patient. The soft tissue swelling that almost immediately accompanies an open injury may have multiple effects. A system with increased pressure from soft tissue swelling could make it more difficult for fluid to extravasate from the joint. Conversely, if the soft tissues are swollen, they would be expected to make any laceration gap open more, which could lead to fluid extravasating more readily. Any true effect is not known.

Lastly, the wrist is somewhat unique in that it is comprised of three distinct joints: the radiocarpal, midcarpal, and distal radioulnar joints which do not necessarily always communicate with each other. This study included patients with TFCC and interosseous ligament tears (though none were high grade) in which fluid could potentially leak into the distal radioulnar joint or midcarpal joints, respectively. If this indeed occurred, it would theoretically increase the quantity of saline load needed to detect traumatic arthrotomy of the radiocarpal joint. Therefore, the suggested volume of 2.5 mL if anything may be high but still maximizes sensitivity in detecting an open wrist injury. While it is theoretically possible that a penetrating injury could violate only the midcarpal and distal radioulnar joints and be missed by only loading the radiocarpal joint, in our experience this is not a common scenario and we did not have a reliable model to test for such an arthrotomy. We do recommend, however, that if there is very high suspicion for a traumatic arthrotomy, for example, a strong sense for visible cartilage or a very deep wound, consideration should be given for surgical irrigation and debridement even in the setting of a negative saline load test.

In conclusion, the present study suggests that the saline infusion volume required to detect a dorsal radiocarpal arthrotomy with 99% sensitivity is 2.5 mL. We recommend

using at least 2.5 mL when performing the saline load test to rule out a potential arthrotomy to the wrist in the traumatic setting. Further study should characterize the saline load test in the wrist used in the awake, traumatized patient.

Note

This study was approved by our institutional IRB and the approval letter is attached.

Conflict of Interest

None declared.

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