Does the saline load test still have a role in the orthopaedic world? A systematic review of the literature

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A B S T R A C T

Introduction: The aim of this systematic review was to assess the efficacy of Saline load tests (SLTs) to evaluate extension of periarticular wounds into capsule in emergent settings.

Methods: We systematically reviewed the literature to evaluate the accuracy of the SLT in diagnosing penetrating joint injuries in the elbow, wrist, shoulder, knee, or ankle.

Results: The SLT values to determine knee arthrotomies vary from 73.8 mL to 194 mL with sensitivities ranging between 91% and 99% depending on the size of the laceration. A SLT of 30 mL in the ankle yields sensitivities ranging from 95% to 99% in assessing joint penetration. A SLT of 45 mL in the elbow yields a sensitivity of 95% in assessing joint penetration. The addition of methylene blue does not change the sensitivity of the SLT.

Conclusion: Several studies have demonstrated the utility of the SLT as a diagnostic modality for penetrating joint injuries. However, the literature analyzed in this study was inconclusive and more studies are required to make definitive recommendations. In addition, more studies will be needed on joints other than the knee, pediatric patients, and the use of methylene blue dye in conjunction with SLT.

Level of evidence: Level II, Diagnostic study.

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Introduction

Ascertaining the integrity of the joint capsule is of high clinical importance in the evaluation of periarticular wounds due to the high possibility of developing a septic arthritis and the potentially catastrophic sequelae. Open knee joint injuries are prevalent amongst young males and commonly result from gunshot wounds, blunt injuries from motor vehicle accidents, falls, and sharp objects. Analysis of these studies found a mean periarticular wound size of approximately 4 cm, an incidence of concurrent fracture ranging from 24% to 55%, and an infection rate which ranged from 0% to 11.8%.

Currently, the gold standard diagnosis for a penetrating joint injury is intraoperative inspection of the joint capsule. However, this approach exposes patients to the risks associated with surgery, is time consuming, and is associated to overall higher costs.

Konda et al recently demonstrated the usefulness of computed tomography scans (CT) in diagnosing traumatic arthrotomies based on the ability to visualize intra-articular air. They reported sensitivity and specificity of 100% utilizing 2 mm slices. Although promising, CT scans may be expensive, time consuming, and sometimes unavailable in an emergency setting. Therefore, other diagnostic modalities, such as saline load test (SLT), are utilized in clinical practice. The SLT consists of injecting sterile saline into a joint where a penetrating joint injury is suspected. The site of injection is carefully chosen to avoid the periarticular wound. Extravasation of saline from the joint constitutes a positive test. Failure of extravasation is defined as a negative SLT and implies an intact joint capsule.

Although the SLT has been shown to be useful in the diagnosis of open joint injuries, there is a lack of consistency in the literature regarding the volume of saline required to generate a reliable test. Although sixty milliliters of saline had been the standard volume of injection in the knee, recent studies have disputed the reliability of
this volume. Studies by Nord et al and Keese et al have suggested load volumes of 155 mL and 194 mL respectively to achieve a sensitivity of 95%.7,8 To the best of our knowledge there has not been a study that has systematically evaluated the ability of the SLT to detect open wounds within different joints. Furthermore, most of the literature focused on the SLT is limited to the knee joint. The purposes of our study were 1) to determine the utility of SLT with different volumes and dyes within the knee joint, and 2) to determine the utility within other joints as reported in the literature to date.

Methods

A systematic review of the literature regarding the SLT was performed utilizing the preferred reporting items for systematic review and meta-analysis protocols (PRISMA guidelines).9 We evaluated the EMBASE, Medline, and Ovid libraries, identifying all studies published until September 2015. Utilizing the search strings “saline load test”, “saline load test wrist”, “saline load test shoulder”, “saline load test knee”, “saline load test hip”, “saline load test elbow” and “saline load test ankle”, 656 studies were retrieved. Limiting the search to studies written only in English yielded 618 studies which were then carefully reviewed.

A specific set of inclusion and exclusion criteria were applied to these 618 studies. Specifically, we included studies evaluating the accuracy of the SLT in diagnosing penetrating joint injuries in the elbow, wrist, shoulder, knee, or ankle. Single case reports, literature reviews, and the SLT involving the gastrointestinal system were excluded from our study but used for cross-referencing, which revealed no additional sources. After applying these criteria, 10 relevant studies were included in our analysis (Fig. 1). Six of these studies reported data from the SLT of the adult knee,4,5,7,8,10,11 one study reported data from SLT of the pediatric knee,12 one study reported data from the wrist,13 one study reported on data from cadaveric elbows,14 and one study reported data from several different joints.15 Additional cross-referencing of these studies yielded no further studies. There were no studies evaluating SLT of the hip or shoulder joints.

Results

There were 10 studies in our analysis which evaluated a total of 467 patients and 505 joints: 438 knees, 23 ankles, 40 elbows, 2 wrists, and 2 proximal interphalangeal joints (PIPs) (Table 1). All of these were in living patients except for 36 elbows, which were performed in cadavers. Within the knee joint, the most common indication was performed during an arthroscopy without providing detailed information of the primary diagnosis. The most common indications which were performed in a non-arthroscopic setting for a SLT of the knee included gunshot wounds, falls, and motor vehicle accidents (Table 2). Saline load test indications for joints other than the knee were either performed during arthroscopy or not provided. In terms of the correlation of between injected volume and...
sensitivity for detecting traumatic arthrotomy of the knee, Nord et al reported that a volume of 50 mL generated a sensitivity of 39.3% while a volume of 175 mL generated a 99% sensitivity7 (Table 3).

**Discussion**

The diagnosis of penetrating joint injuries will continue to remain as a challenge for orthopedic surgeons and emergency personnel. While the SLT is used to aid in the diagnosis of open joint injuries, there is no consensus on the amount of saline to inject to achieve the highest sensitivity and specificity within a joint. This may be due to many factors, including the potential addition of certain dyes,11,14 whether the researcher utilized dynamic motions of the joint following injection, and the fact that SLTs are operator dependent. Different volume considerations must also be made for pediatric patients versus adult patients.13 Furthermore, the available data on the use of SLTs in joints other than the knee is limited. After performing our comprehensive analysis, we found inconclusive data regarding the volume of saline that constitutes a reliable test for penetrating joint injuries of the knee joint and other joints. However, within the knee joint volumes ranging from 155 to 194 mL can provide a sensitivity of 95%,7 while a volume of 175 mL has been shown to provide a sensitivity of 99%.7

In support of the SLT, studies by Nord, Keese, and Konda on the knee have found SLT sensitivities ranging from 92% to 99% utilizing volumes ranging from 73.8 mL to 194 mL.4,5,7 One possible reason for the wide range of volumes is the size of the periarticular laceration. Nord utilized 10 mm lacerations, Keese utilized 5.8 mm diameter lacerations, and Konda used mean perforation sizes of 39 mm and 31 mm. The modality of penetrating joint injury may play a role in how accurate a particular volume of SLT in diagnosing periarticular wounds. While Konda performed the SLT on patients with traumatic arthrotomies of the knee, Nord and Keese performed their work during knee arthroscopy. While SLT is indeed operator-dependent, all of these studies support the use of SLT in diagnosing knee arthrotomies.

In regards to other joints, Bariteau et al performed simulated SLTs in 21 patients undergoing elective ankle arthroscopy and found a sensitivity ranging from 95% to 99% utilizing 30 mL of saline through a mean perforation size of 4 mm.13 Feathers et al reported good results with human cadaveric elbow joints, finding a 95% sensitivity of SLTs utilizing 40 mL of saline mixed with methylene blue dye.14 In their study, cadaveric elbows were loaded with an initial volume of 20 mL saline, and if the SLT was negative, they performed range of motion testing on the joint and added 2 ml/s until the SLT was positive.

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There are several reasons that advocate against performing an SLT to assess joint integrity. In a study conducted by Konda et al that compared the accuracy of SLTs and CT scans in detecting traumatic arthrotomy, CT was found to have a sensitivity and specificity of 100% while SLT was found to have a sensitivity of 92%, suggesting there may be better modalities for diagnosing open joint injuries.3 Although the studies included in our analysis did not report

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**Table 2**

Indications or primary diagnosis for saline load test.

| Author              | Arthroscopy | GSW | Fall | Sharp object | Circular saw | Stab | MCC or MVC | Other |
|---------------------|-------------|-----|------|--------------|--------------|------|------------|-------|
| Bariteau et al., 2013 | 21          | 0   | 0    | 0            | 0            | 0    | 0          | 0     |
| Feathers et al., 2011 | 36          | 0   | 0    | 0            | 0            | 0    | 0          | 0     |
| Haller et al., 2015  | 87          | 0   | 0    | 0            | 0            | 0    | 0          | 0     |
| Keese et al., 2007  | 30          | 0   | 0    | 0            | 0            | 0    | 0          | 0     |
| Konda et al., 2013  | N/A         | 9   | 11   | 6            | 2            | 0    | 8          | 1     |
| Konda et al., 2013  | N/A         | 14  | 14   | 3            | 3            | 4    | 9          | 3     |
| Metzger et al., 2012 | 58          | 0   | 0    | 0            | 0            | 0    | 0          | 0     |
| Nord et al., 2007   | 56          | 0   | 0    | 0            | 0            | 0    | 0          | 0     |
| Tornetta et al., 2007 | 80         | 0   | 0    | 0            | 0            | 0    | 0          | 0     |
| Voit et al., 1996   | N/A         | 1   | 7    | 1            | 0            | 0    | 41         | 0     |

**Table 3**

Volumes of saline and corresponding sensitivities.

| Author               | Joint        | Mean volume load (mL) | Range (mL) | Size of joint perforation in mm (range) | Sensitivity | Specificity |
|----------------------|--------------|-----------------------|------------|----------------------------------------|-------------|-------------|
| Bariteau et al., 2013 | Ankle       | Mean volume needed to diagnose arthrotomy: 10.3 | Range of volumes required to diagnose: (0–5) to (26–30) (4–6) to (45–67) | 10 (NR) | 20 mL static: 72% 20 mL dynamic: 86% 40 mL: 95% | NR |
| Feathers et al., 2011 | Elbow       | Mean volume (mL)     | Mean volume (mL) | 10 (NR) | 94% | 91% |
| Haller et al., 2015  | Knee        | 28.9                  | 7.0–78.0   | 5 (NR) | 47 mL: 90% | NR |
| Keese et al., 2007  | Knee        | 71.0                  | 10–240 mL  | 5.8 (NR) | 50 mL: 46% 194 mL: 95% | NR |
| Konda et al., 2013  | Knee        | 73.8                  | 40–180     | 31 (10–130) | 92% | 92% |
| Konda et al., 2013  | Knee        | 74.9                  | 40–180     | 39 (10–250) | 94% | 91% |
| Metzger et al., 2012 | Knee        | 105 NS: 95 (in patients with + test) | MB: 42–160 NS: 30–160 | 6–7 (NR) | MB: 31% NS: 34% | NR |
| Nord et al., 2007   | Knee        | Mean volume for pos. result perforation (range) | NR | 10 (NR) | 50 mL diagnosed 39.3% of arthrotomies, 75 mL: 50% 110 mL: 75% 145 mL: 95% 175 mL: 99% | NR |
| Tornetta et al., 2007 | Knee        | Mean volume (mL)     | Mean volume (mL) | 7.5 (4–12) | Static test: 36% Dynamic test: 43% | NR |
| Voit et al., 1996   | Multiple    | Mean volume (mL)     | Mean volume (mL) | 7.5 (4–12) | Static test: 36% Dynamic test: 43% | NR |

MB: Methylene Blue, NS: Normal Saline.
complications, the SLT increases the pressure within the joint. Increased intraarticular pressure has been associated with increased pain and decreased blood flow in the joint, potentially exposing the joint to iatrogenic injury.\textsuperscript{6,17} Another potential disadvantage of the SLT is that the surgeon may be disrupting an intact joint.\textsuperscript{18} The risk of violating an intact joint may outweigh the risk associated with the radiation exposure when utilizing CT scans.

The SLT does have some advantages over CT scans. The test can be easily performed in various clinical settings and does not need specialized equipment. The test also does not expose the patient to radiation, which is of particular importance in pediatric patients. Furthermore, the SLT does not expose the patient to risks inherently associated with an operative procedure and a negative test can potentially save valuable operating room time resources.

Of the studies analyzed, two utilized methylene blue during SLT. Feathers et al used the dye strictly to aid in the confirmation of fluid extravasation from cadaveric elbows, and was not examining whether addition of the dye improved the reliability of SLT. Although it is intuitive to think that the addition of dye would aid in detecting extravasation of fluid from the joint, the only study that actually compared whether the addition of dye increased the efficacy for this diagnostic test was conducted by Metzger et al. His group found a sensitivity of 33% of SLT regardless of the addition of methylene blue\textsuperscript{10} and they concluded that the addition of methylene blue did not improve the diagnostic value of SLT nor did it decrease the volume needed for a positive test. However, dye may be added to the saline based on surgeon preference as it does not precipitate any deleterious effects.\textsuperscript{14,19}

Our study has several limitations. There is an insufficient amount of data on saline volumes and resultant sensitivities to determine a volume that results in the most accurate test. Furthermore, there is a predominance of literature describing the usage of the SLT on the knee joint and a paucity of literature regarding its utilization on other joints. The studies that reported sufficient data often had small cohorts. Study heterogeneity was significant and included size of wound, dynamic motion of the joint tested, and whether a dye was used. This rendered it difficult to compare sensitivities or perform receiver operator characteristic (ROC) curves between studies. The size of the periarticular wounds was not constant between studies which may have influenced how much volume was necessary for a positive SLT. It must also be taken into account that one study utilized cadaveric joints which may react differently to the SLT compared to the joints of live patients.

Conclusion

Penetrating joint injuries require a prompt diagnosis to avoid the development of serious deleterious sequelae. Among the multiple diagnostic modalities, several groups have demonstrated the utility of SLT for such injuries. Within the many joints, SLT was most commonly utilized within the knee, and a volume ranging from 155 to 175 mL achieved sensitivities greater than 95% when detecting these injuries. However, all literature analyzed in this study was inconclusive and more studies are required to make definitive recommendations; especially in relation to other methods of diagnosing an open joint injury, such as intraoperative inspection or CT scans. Additionally, the size of the injury plays an important role in the accuracy of this diagnostic test. Overall, the utility of SLT should be assessed in joints other than the knee and in pediatric patients. Potentially, the addition of dyes such as methylene blue can be evaluated to determine if a lower volume can be used with higher accuracy in detecting these injuries.

References

1. Terry Canale S. Campbell's Operative Orthopaedics. 10th ed. Boston, MA: CV Mosby; 2003.
2. Patzakis MJ, Dorr LD, Ivler D, Moore TM, Harvey JF, JP. The early management of open joint injuries. A prospective study of one hundred and forty patients. J Bone Jt Surg Am Vol. 1975;57(8):1065–1070.
3. Collins DN, Temple SD. Open joint injuries. Classification and treatment. Clin Orthop Relat Res. 1989;243(1):48–56.
4. Konda SR, Howard D, Davidovitch RI, Egol KA. The saline load test of the knee redefined: a test to detect traumatic arthromities and rule out periarticular wounds not requiring surgical intervention. J Orthop Trauma. 2013;27(9):491–497.
5. Konda SR, Davidovitch RI, Egol KA. Computed tomography scan to detect traumatic arthromities and identify periarticular wounds not requiring surgical intervention: an improvement over the saline load test. J Orthop Trauma. 2013;27(9):498–504.
6. Konda SR, Davidovitch RI, Egol KA. Open knee joint injuries—an evidence-based approach to management. Bull Hosp Jt Dis. 2014;72(1):61–69.
7. Nord RM, Quach T, Walsh M, Pereira D, Tejwani NC. Detection of traumatic arthrotomy of the knee using the saline solution load test. J Bone Jt Surg Am Vol. 2009;91(1):66–70.
8. Reese GR, Boody AR, Wongworawat MD, Jobe CM. The accuracy of the saline load test in the diagnosis of traumatic knee arthromities. J Orthop Trauma. 2007;21(7):442–443.
9. Shamseer L, Moher D, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ. 2015;349:g7647.
10. Metzger P, Carney J, Kuhn K, Booher K, Mazurek M. Sensitivity of the saline arthrogram for wounds around the knee? J Orthop Trauma. 2008;22(6):345–349.
11. Torretta 3rd P, Boes MT, Scheepsis AA, Foster TE, Bhandari M, Garcia E. How effective is a saline arthrogram for wounds around the knee? Clin Orthop Relat Res. 2008;466(2):432–435.
12. Haller JM, Beckmann JT, Kapron AL, Aoki SK. Detection of a traumatic arthrotomy in the pediatric knee using the saline solution load test. J Bone Jt Surg Am Vol. 2015;97(10):846–849.
13. Bariteau JT, Blanlenhorn BD, Digiovanni CW. Evaluation of saline load test for simulated traumatic arthromities of the ankle. Injury. 2013;44(11):1498–1501.
14. Feathers T, Stinner D, Kirk K, et al. Effectiveness of the saline load test in diagnosis of traumatic elbow arthromities. J Trauma. 2011;71(5):E110–E113.
15. Voot GA, Irvine G, Beals RK. Saline load test for penetration of periarticular lacerations. J Bone Jt Surg Br Vol. 1996;78(5):732–733.
16. Goddard NJ, Gosling PT. Intra-articular fluid pressure and pain in osteoarthritis of the hip. J Bone Jt Surg Br Vol. 1988;70(1):52–55.
17. Beck M, Siebensrock KA, Affolter B, Notzli H, Parvizi J, Ganz R. Increased intra-articular pressure reduces blood flow to the femoral head. Clin Orthop Relat Res. 2004(424):149–152.
18. Ninomiya JT, Dean JC, Goldberg VM. Injury to the popliteal artery and its anatomic location in total knee arthroplasty. J Arthroplast. 1999;14(7):803–805.
19. Raskind JR, Marder RA. Arthroscopic versus open debridment of penetrating knee joint injuries. Iowa Orthop J. 1993;13:121–123.