# Special Article

# A Review of the Efficacy of the Saline Load Test to the Traumatic Arthrotomy of the Knee

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***Objective:*** *Saline load test of the knee could have benefit in the evaluation of the patient with traumatic arthrotomy. The aim of this study was to find out the efficacy in aspect of the volume to be used, the position to be done, the sensitivity and clinical efficacy of the test.*

***Material and Method:*** *The articles published after 1995 about the saline load test focusing on the knee joint which were written in English language were reviewed. The universal database including Medline and Google Scholar were used. The searched terms were "saline load test knee" and "saline arthrogram knee".*

***Results:*** *Ten articles were reviewed for relevancy. They consisted of four articles with level I of evidence and six articles with level III of evidence. There were eight articles with prospective design and two articles with retrospective design. The mean volume of the fluid was 69.8 ml. (ranged from 7.0 ml to 240 ml). The sensitivity ranged from 31% to 99%. Seven articles suggest to use the test but two articles were opposed. One article did not give its recommendation.*

***Conclusion:*** *The saline load test of the knee is a reasonable option to detect a traumatic arthrotomy of the knee. The maximum amount of volume tolerated must be injected to gain the highest sensitivity. However, the negative test could not rule out the potential of joint injury. There should be a discussion about the potential benefits and disadvantages with the patient and the relatives before making a definitive treatment.*

***Keywords:*** *Open knee injury, Traumatic knee arthrotomy, Saline load test, Saline arthrogram*

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Traumatic arthrotomy of the joint is important to diagnose because of the risk of septic arthritis. The most common site of this injury is the knee because of its large size and superficial position. In clinical settings, if the simple inspection of the wound shows intra-articular contents, or the x-ray shows a foreign body or air inside the joint, the diagnosis of penetrating joint injury is obvious. However, in other cases, determining the intra-articular penetration is more difficult (Fig. 1). The saline load test has been shown to assist in the diagnosis of a traumatic arthrotomy of the knee joint[1]. The sterile saline is injected into a joint with a periarticular wound suspected for a traumatic arthrotomy. If there is an extravasation of fluid from the open wound, the diagnosis of traumatic arthrotomy is done. Detecting the connection between the periarticular wound to the intra-articular space is crucial in the aspect of treatment. If such wound has no

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**Fig. 1** Periarticular wound of left knee with an intra-articular extension. Note that determining the depth of the wound could be difficult in this case based on physical examination.

connection to the intra-articular space, the primary wound closure can be done in the emergency department. However, if there is any connection, the standard treatment nowadays is forward the patient to the operating room for systematic debridement, to avoid the chance of septic arthritis.

Although there is the benefit of saline load test, the standard protocol is controversial. Some articles even recommend against using this test to rule out the traumatic arthrotomy of the knee[2,3]. To the best of knowledge, there is no review article of the efficacy of saline loading test that focus only in the knee joint. The purpose of this study was to review the published research articles related to the saline load test of the knee in the aspect of the volume of the fluid, the position of the joint, the wound size, and also the result with recommendation.

## Material and Method

The universal database including Medline and Google Scholar were used. The searched terms included "saline load test knee" and "Saline arthrogram knee". All type of scientific papers with reference to the saline load test to the traumatic arthrotomy of the knee were included in the study. The search was then narrowed to include only studies published after 1995 and written in the English language. Relevant articles' bibliographies were also reviewed to expand the search. The search and the analysis was done by an orthopedic surgeon.

## Results

The initial results of the search were 42 articles from Medline. After screening, only eight articles fully met the eligibility criteria. The additional results from Google Scholar gave 2 more articles (Table 1). After reviewing these ten articles in details, they consisted of four articles with level I of evidence and six articles with level III of evidence. There were eight articles with prospective design and two articles with retrospective design. Four articles were from traumatic cause and six articles were from arthroscopy. All of these articles described living patients. Two articles reported the result from multiple joints including ankle, elbow and wrist. In these cases, only the results from knee joint would be included in an analysis.

The total number of the knee in the reviewed articles was 546, which consisted of 195 knees from traumatic cause. The most common cause in the traumatic injury was the motor vehicle accident. In the non-traumatic setting, there was 87 pediatric knees involved from one article[4]. Other modifications included the use of methylene blue in 58 knees and the additional direct compression in 40 knees.

The volume of the fluid injected through the knee ranged from 7.0 ml to 240 ml. There were 5 articles that used the dynamic test that brought the knee through a range of motion during or after the injection. The other 5 articles used only static test. For the sensitivity, it ranged from 31% to 99%, depending on the volume of fluid injected to the joint. Seven articles recommended to use the saline load test. Two articles were against this test and 1 article did not give its recommendation (Table 2).

## Discussion

Penetrating injuries of the joints are potentially serious. Carefully diagnosis and management is essential to achieve good outcomes. Patzakis et al[5] first described the saline load test in 1975, but they did not mention about the efficacy of the procedure. After that, there have been multiple studies to determine the validity of this test. However, different techniques and protocols have been used. Up until now, the data

**Table 1.** Details of the study design with level of evidence

| Author | Year | N | Cause | Design | Level of evidence |
|---|---|---|---|---|---|
| Haller [4] | 2015 | 87 | Arthroscopy | Prospective | III |
| Konda [9] | 2013 | 50 | Trauma | Retrospective | III |
| Konda [11] | 2013 | 37 | Trauma | Retrospective | III |
| Phonglaohaphan[10] | 2013 | 40 | Arthroscopy | Prospective | III |
| Metzger[8] | 2012 | 58 | Arthroscopy | Prospective | I |
| Nord[7] | 2009 | 56 | Arthroscopy | Prospective | I |
| Solooki[6] | 2008 | 68 | Trauma | Prospective | III |
| Tornetta[3] | 2008 | 80 | Arthroscopy | Prospective | I |
| Keese[2] | 2007 | 30 | Arthroscopy | Prospective | I |
| Voit[1] | 1996 | 40 | Trauma | Prospective | III |

**Table 2.** Characteristics of the study and each study recommendation

| Author | Mean volume(ml) | Range (ml) | Position | Wound size (mm) | Result | Recommendation |
|---|---|---|---|---|---|---|
| Haller[4] | 28.9 | 7.0-78.0 | Static | 5 | Sensitivity 50% (With 27 ml)<br>Sensitivity 75% (With 37 ml)<br>Sensitivity 90% (With 47 ml)<br>Sensitivity 95% (With 58 ml) | Yes |
| Konda[9] | 74.9 | 40-180 | Dynamic | 39±43 | Sensitivity 94%, Specificity 91% | Yes |
| )Konda[11] | 73.8 | 40-180 | Dynamic | 36±39 | Sensitivity 92%, Specificity 92%<br>CT scan Sensitivity 100%, Specificity 100% | Yes but CT is better |
| Phonglaohaphan[10] | 50 | NR | Static | 7 to 8 | Sensitivity 32.5%<br>Sensitivity with direct compression 77.5% | Yes with compression |
| Metzger[8] (In positive test) | Methylene blue 105<br>NSS 95 | 42-160<br>30-160 | Static | 6 to 7 | Sensitivity 31% (with Methylene blue)<br>Sensitivity 34% (only saline) | Yes |
| Nord[7] (In positive test) | Inferomedial 64<br>Superomedial 95.2 | NR | Static | 10 | Sensitivity 39.3% (with 50 ml)<br>Sensitivity 50% (with 75 ml)<br>Sensitivity 75% (with 110 ml)<br>Sensitivity 90% (with 145 ml)<br>Sensitivity 95% (with 155 ml)<br>Sensitivity 99% (with 175 ml) | No recommendation |
| Solooki[6] (Compare with clinical examination) | 60 | NR | Dynamic | NR | 38% error in positive case<br>28% error in negative case<br>Changed the treatment 33% | Yes |
| Tornetta[3] | 60 | NR | Dynamic | 4 to 12 | Static test sensitivity 36%<br>Dynamic test sensitivity 43% | No |
| Keese[2] | 71.0 | 10-240 | Static | 5.8 | Sensitivity 46% (with 50 ml)<br>Sensitivity 95% (with 194 ml) | No |
| Voit[1] (Compare with clinical examination) | 60 | NR | Dynamic | NR | 43% error in positive case<br>39% error in negative case<br>Changed the treatment 40% | Yes |

regarding the volume of the fluid, the position of the joint, the sensitivity, and the clinical efficacy are inconclusive. The results from analysis are as followings:

***Volume***

The volume of normal saline varied in the articles. The first published article by Voit et al [1] used only 60 ml of saline to show the clinical benefit. Keese et al[2] showed that the volume of saline need to be up to 194 ml to give the sensitivity at 95%. However, the mean volume of saline in his paper was 71 ml. Tornetta[3] and Solooki[6] also used the volume at 60 ml in their paper and stated that this volume was the commonly agree-on amount at that time. After that, the trend of the volume of saline used in the test was higher. As confirmed by Nord et al[7], the sensitivity would be higher if more amount of saline was injected. They also noted that the position of the wound is one of the factor altering the result. The inferomedial positon (64 ml) of the wound used the less amount of fluid than the superomedial position (95.2 ml). The result of Metzger et al[8] and Konda et al[9] also showed that the maximum volume of the fluid tolerated by the patient would increase the sensitivity which may be up to 180 ml. Recently, Haller et al[4] also confirmed this result in the pediatric population which require the mean volume at 28.9 ml and the maximum volume at 78 ml. On the other hand, the article of Phonglaohaphan et al[10] used only 50 ml of saline. They only found low sensitivity of the test with this volume.

***Position***

Half of the studies supported the used of dynamic test. The rational of the dynamic test was to force the saline through the arthrotomy site to increase the detection rate. The other half believed that this test should be done in static mode because it may be more clinically applicable in an injured awake patient who may not tolerate a painful range of motion. Both of these methods had their own rational. The recommendation was that if the patient could move the knee through a range of motion without pain, this would give a higher sensitivity. If the patient could not move his knee, the article by Phonglaohaphan et al[10] recommended subsequent direct compression to increase of capsular distention by pressure.

***Sensitivity and clinical application***

This is an area with the most controversy. Voit et al[1], who first recommended to use this test, stated that the treatment was changed after the test for 40% of the patient, compared to clinical judgement alone. Solooki et al[6] also confirmed this result by stating that 33% of the patients had changed the treatment plan on the basis of clinical examination. However, Keese et al[2] showed that a volume of fluid less than 194 mL was less sensitive for small lacerations around the knee and discouraged the use of the test alone to rule out open knee injuries. Tornetta et al[3] also confirmed that this test did not provide a diagnosis, even when the knee had been brought through range of motion. However, most of the papers published after that seems to believe that this test has some clinical benefit, even though it could not be a diagnostic test. Metzger et al[8] noted that, although they found the low sensitivity at 34%, they still used this test as an adjunct procedure when evaluating traumatic arthrotomy of the knee. They also noted that the dye added to the fluid did not lead to any complication, anyway it did not improve the sensitivity of the test either. Phonglaohaphan et al[10] found the similar result with 32.5% sensitivity. This could be increased to 77.5% with direct compression. Two articles from Konda et al in 2013[9,11] had more interesting point. The first one[9] found a 94% sensitivity and 91% specificity with the injection volume administered up to the maximum tolerance of the patient or until fluid begins to extravasate. The second one [11], although they recommend that CT scan were better than the SLT in detecting and ruling out this injury, they also found the sensitivity 92% and specificity 92% from saline load test, compared with 100% sensitivity and specificity from CT scan. Compared to the saline load test, CT scan had some benefits because it is quick, easy to perform, does not cause additional pain to the patient, and can be done if the patient had polytrauma injury that need CT scan of other parts of the body. Therefore, CT scan is an optional investigation in the available trauma center. However, the cost of the test and the extent of radiation exposure, especially in a pediatrics should be kept in mind. Both articles by Konda had an interesting point. The wound size were fairly large (39$\pm$43 mm). If the periarticular wound is large, one can assume that the traumatic arthrotomy is also large, which may overestimate the diagnostic accuracy of the saline load test. The specificity and sensitivity may be high due to larger opening in the joint capsule. A recent article from Haller et al[4] also recommended the use the saline load test in a pediatric knee with volume of 47 ml to detect 90% of 5-mm superolateral arthrotomies.

The latest article on this topic was the systematic review from Browning et al. in 2016[12]. This diagnostic study focused on the utility of the saline load test on different joint. They found that this test was most commonly utilized within the knee. However, they did not make any definitive recommendation. From the author's viewpoint, the saline load test serves as a first adjunct procedure to detect the traumatic knee arthrotomy. The surgeon should inject the maximum volume of fluid to the knee joint until fluid began to extravasate. If the patient develops pain before the fluid extravasation, the direct compression can increase capsular pressure and give higher sensitivity. If the test is positive, the doctors will have a strong evidence of traumatic knee arthrotomy and the patient would require operative systematic debridement. However, when the result of the saline load test is negative, if the patient needs a CT scan of other part, in a center with available CT scan, then the CT scan is an optional investigation to detect the traumatic arthrotomy. In the case of all negative test, from the evidence up until now, the potential of joint involvement could not be effectively excluded. This is a point that should be discussed with the patient and the relatives. If the clinical suspicion is high based on history, mechanism, physical examination, the systematic debridement in the operating room is still the gold standard. Nonetheless, after the discussion, if they decide not to operate, close follow-up is mandatory to check for the development of septic arthritis.

This study had some limitations due to the heterogeneity of the population, the setting of cause of the wound, the volume of fluid, the position of the joint, and the wound size. This makes it difficult to compare between the articles using statistical methods. Future research with standardized protocol to control these variables is necessary to elucidate the efficacy of the saline load test are required to make a definitive recommendation. The second issue is the part that was focused on the saline load test was the knee joint. The author believes that the results from other joints such as ankle, elbow, or wrist, which are also very different in nature, will make the readers more confused. As the knee joint is the most common injury site of traumatic arthrotomy, the recommendation in this joint should be first established, before the consideration of this test in other joints.

**Conclusion**

The saline load test of the knee is a reasonable option to detect a traumatic arthrotomy of the knee. The maximum amount of volume tolerated must be injected to gain the highest sensitivity. However, the negative test could not rule out the potential of joint injury. There should be a discussion about the potential benefits and disadvantages with the patient and the relatives before making a definitive treatment.

**What is already known on this topic?**

The clinical diagnosis of traumatic arthrotomy of the knee may be difficult in some situations. Saline load test has been proposed to determine the intra-articular penetration of the wound. However, there is no universal protocol of the test in terms of the volume to be used, the position to be done, the sensitivity and clinical efficacy of the test.

**What this study adds?**

The saline load test assists the physician as a first adjunct procedure in emergency room of any hospital to detect the traumatic knee arthrotomy. There is no special instrument to be used. The maximum volume of fluid that the patients can tolerate without pain should be injected. The direct compression gives the higher sensitivity. If the test is positive, there is a strong evidence of traumatic knee arthrotomy which requires operative systematic debridement. However, if the result is negative, CT scan is an optional investigation. In the case of all negative test, the potential of joint involvement could not be effectively excluded. There should be a discussion about the potential benefits and disadvantages with the patient and the relatives before making a definitive treatment.

**Potential conflicts of interest**

None.

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## *การใช้ saline load test เพื่อวินิจฉัยการเชื่อมต่อของบาดแผลภายนอกสู่ภายในข้อเข่า*

*พิงควรรศ คงมาลัย*

***วัตถุประสงค์:*** *ในผู้ป่วยที่มีการบาดเจ็บและมีแผลเปิดบริเวณเข่านั้น การตรวจวินิจฉัยว่าบาดแผลนั้นมีช่องทางเชื่อม ต่อสู่ในข้อเข่าหรือไม่ อาจใช้ saline load test หรือ ฉีดน้ำเกลือเข้าไปในเข่าช่วยได้ บทความนี้จะอธิบายถึงแง่มุมต่าง ๆ ของการตรวจวินิจฉัยด้วยวิธีนี้ คือประสิทธิภาพ, ปริมาตรน้ำเกลือที่ใช้ฉีด, ท่าของเข่าขณะฉีด รวมไปถึงข้อสรุป จากงานวิจัยต่าง ๆ*

***วัสดุและวิธีการ:*** *ทำการรวบรวมงานวิจัยที่มีทั้งหมดในปัจจุบันโดยใช้คำค้นหาคือ "saline load test knee" and "saline arthrogram knee"*

***ผลการศึกษา:*** *งานวิจัยที่มีความเกี่ยวข้องกับคำค้นหามีทั้งสิ้น 10 งานวิจัย โดยจัดเป็นความน่าเชื่อถือระดับที่หนึ่ง 4 งานวิจัย และระดับที่สาม 6 งานวิจัย, มี 8 งานวิจัยความที่ทำการศึกษาแบบไปข้างหน้า และ 2 งานวิจัยเป็นการศึกษาแบบย้อนหลัง ปริมาตรของน้ำเกลือที่ใช้เฉลี่ย 69.8 มิลลิลิตร (ตั้งแต่ 7 ถึง 240 มิลลิลิตร) ความไวของการตรวจสอบอยู่ที่ 31 ถึง 99% มี 7 งานวิจัยที่แนะนำให้ใช้ 2 งานวิจัยที่ไม่แนะนำและ 1 งานวิจัยไม่ได้ให้คำแนะนำนี้*

***สรุป:*** *การใช้ saline load test ถือเป็นตัวเลือกหนึ่งในการตรวจวินิจฉัยว่าบาดแผลบริเวณเข่านั้นมีช่องทางเชื่อม ต่อสู่ในข้อเข่าหรือไม่เพื่อให้ได้ความไวที่ดีที่สุดนั้น ปริมาณของน้ำเกลือที่ใช้ฉีดควรฉีดให้มากที่สุดที่ผู้ป่วยจะทนได้โดยที่ยังไม่เกิดอาการผิดปกติ อย่างไรก็ตามหากผลตรวจพบว่าไม่มีน้ำเกลือไหลออกมาจากแผล อาจยังไม่สามารถ สรุปผลได้ ต้องมีการอธิบายถึงข้อดีและข้อเสียของแนวทางการรักษาให้กับผู้ป่วยและญาติเข้าใจอีกครั้งก่อนส่งผู้ป่วยไปห้องผ่าตัด*