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Ultrasound-guided versus landmark in knee arthrocentesis: A systematic review

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ABSTRACT

Objectives: The objective was to assess the efficacy of ultrasound-guided (USG) versus landmark (LM) knee arthrocentesis in adults with knee pain or effusion.
Methods: A systematic review of the literature was performed until August 2015. All controlled trials reporting the accuracy or clinical efficacy between USG and LM knee joint arthrocentesis were selected. Pooled weighted mean difference (WMD) using the D–L fixed models for continuous outcomes and the risk ratio (RR) for dichotomous outcomes were assessed by meta-analysis. Heterogeneity between studies was estimated by I^2 statistic.
Results: Nine studies including 715 adult patients (725 knee joints) were eligible for this review versus LM group; there was a statistically significant difference in favor of USG for knee arthrocentesis accuracy rate (risk ratio = 1.21; 95% CI: 1.13–1.29; $P < 0.001$; $I^2 = 37\%$), lower procedural pain scores (WMD = −2.24; 95% CI: −2.92 to −1.56; $P < 0.001$; $I^2 = 4\%$), more aspiration volume (WMD = 17.06; 95% CI: 5.98–28.13; $P = 0.003$; $I^2 = 57\%$), and decreased pain score 2 weeks after injection (WMD = 0.84; 95% CI: 0.42–1.27; $P < 0.001$; $I^2 = 0$). There was no statistically significant difference in procedural duration between two groups (WMD = −0.8; 95% CI: −2.24 to 0.74; $P = 0.31$; $I^2 = 0$).
Conclusions: Ultrasound-guided knee joint arthrocentesis offer a significantly greater accuracy and clinical improvement over landmark technique in adults with knee pain or joint effusion.

The aspiration of joint effusion and injection are routine diagnostic and therapeutic procedure in clinical practices. Intra-articular knee injections are commonly performed by orthopedic surgeons, rheumatologists, physiatrists, and primary care physicians, and have become widely accepted as a therapy for pain accompanying knee osteoarthritis (OA) [1]. Intra-articular injections are traditionally performed "blind" which is guided by palpation, relying on common anatomic landmarks (LM). However, incorrect placement of an extra-articular arthrocentesis causes discomfort and a reduced effect of corticosteroids, hyaluronic acid, or other agents [2,3]. Intra-articular injections are often inaccurate and surprisingly, accuracy at knee and shoulder, the two most commonly injected joints was also poor [4]. A small volume (2–3 mL) of injectant may not be expelled as easily as a larger volume, which may dissipate into the joint through the soft tissues (fat pad) secondary to the injection pressure of the syringe [5].

In 1988, Christensen et al. [6] published the first overview of ultrasound-guided (USG) musculoskeletal intervention. In the last 2 decades, a number of radiologists have described the success of several techniques of USG joint and soft tissue injection. Several clinical studies suggested that sonography could be used as an adjuvant tool for intra-articular injections in the knee joint via the suprapatellar bursa [7–9]. Although several systematic review have been shown the improved accuracy of knee and shoulder joint injections by image-guided approach [10–12], there are no previous review evaluated the efficacy of the knee arthrocentesis between USG and LM. Also it is more controversial whether accuracy of needle placement has a significant impact on long fellow-up clinical outcome in knee injection. To assess the efficacy of this procedure, multiple clinical trials with heterogeneous design have reported conflicting outcomes.

Therefore, we conducted this systematic review to summarize the current evidence and evaluate the clinical efficacy of USG knee joint arthrocentesis. Our study aimed to assess the effectiveness of USG versus clinical landmark (LM)-guided knee arthrocentesis in adults with knee pain or effusion.

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Methods

This systematic review was performed according to the current recommendations of the Cochrane Collaboration [13] and reported using the criteria of the PRISMA statement [14].

Search strategy

The searches were performed on PubMed, Ovid MEDLINE, Ovid EMBASE, and Web of Science from database inception through on August 10th, 2015. Key search terms were image-guided, ultrasound, sonography, injection, aspiration, knee, and clinical trial. Each concept used a combination of controlled vocabulary (MeSH and EMTREE) combined with text words for each database which uses subject heading (PubMed, MEDLINE, and EMBASE). Web of Science depended primarily on text words alone.

Inclusion and exclusion criteria

We included randomized or non-randomized controlled trials (RCTs and N-RCTs) comparing the accuracy or clinical efficacy between USG and LM knee joint arthrocentesis. We did not restrict the clinical diagnosis of patients and the drug utilized. We also did not restrict language or study country. Outcomes of interest included accuracy rate, pain during treatment, aspirated fluid volume, decreased pain score after treatment, and mean procedure duration. Exclusion criteria were case reports, case serials, and technical reports without control group (LM), pilot studies with no data analysis and/or power analysis.

Study selection

Once all relevant full-text articles had been gathered, the reference lists of each eligible article were scrutinized by two reviewers (T.W. and Y.D.) for any omitted studies. Each search was imported into an EndNote (Thomson Reuters Research Soft), a bibliographic database manager, and duplicates removed. All conflicts were discussed and resolved with a third author (J.H.). The reference sections of all articles were used to identify additional relevant articles.

Data collection process and outcome measures

Following selection of all relevant articles, two authors (T.W. and Y.D.) extracted all data into a pre-constructed data table. The following data was extracted: author, year published, population, intervention, sample size, route of arthrocentesis, study design, and outcomes. The outcome measures collected were the accuracy rate, pain score during treatment (procedure pain), aspirated fluid volume, decreased pain score after treatment, and mean procedure duration.

Statistical analysis

All analyses were performed using the generic inverse variance method (Rev Man 5.3, The Cochrane Library). Statistical heterogeneity was quantified using the I^2 statistic and the chi-square-based test. For continuous outcomes using the same measurement (pain score during treatment, aspirated fluid volume, decreased pain score after treatment, and mean procedure duration), we pooled weighted mean difference (WMD) using the D–L fixed models. For summarizing the accuracy rate (successful frequency of total number), the risk ratio (RR) was used. We used the Cochrane Risk of bias tool to assess the methodological quality of the included trails in terms of sequence generation, allocation concealment, blinding, incomplete outcome data, selective outcome reporting, and other sources of bias [13]. The significance level was defined as $P < 0.05$.

Fig. 1. Flow of participants through trial.

Results

We screened 1050 records, nine studies [15–23] were eligible for this article (Fig. 1), with a total of 715 adult patients (725 knee joints). Characteristics of the enrolled studies are described in the Table.

Clinical outcomes

Knee arthrocentesis accuracy of USG versus LM

Eight studies [15–19,21–23] assessed successful rate of knee arthrocentesis after injection. More successful rate was reported with USG group and the difference was statistically significant (risk ratio = 1.21; 95% CI: 1.13–1.29; $P < 0.001$; $I^2 = 37\%$; Fig. 2).

Procedural pain score (visual analog scale, VAS, 0–10) of USG versus LM

Three studies [17,20,22] assessed pain score during treatment (injection or aspiration). This analysis indicated a statistically significant difference between the groups, with greater lower pain scores in the USG group (WMD = −2.24; 95% CI: −2.92 to −1.56; $P < 0.001$; $I^2 = 4\%$; Fig. 3). The reduction of pain by 2.24 on the VAS pain scale (USG group reduced pain by an average of 2.24 more on the VAS scale than the LM group) as indicated by the

Table
The characteristics of the enrolled studies

Study	Population	Intervention	Sample size	Route of arthrocentesis USG/LM	Study design	Main evaluation index
Balint et al. [15]	Patients with rheumatoid arthritis, osteoarthritis, or seronegative arthritis	Joint fluid aspiration	51	Superolateral OR lateral midline OR medial midline OR posterior approach into enlarged Baker's cysts/medial midline OR superolateral approach OR lateral midline approach	N-RCT	Accuracy rate of aspiration
Im et al. [16]	Patients with radiographically confirmed knee OA	Intra-articular injections of hyaluronic acid	89	Medial patellar portal: needle was advanced under direct sonographic guidance/mid-horizontal line of the patella met the medial border of the patella	RCT	Accuracy rate of injection
Wiler et al.[17]	Patients need knee arthrocentesis	Joint fluid aspiration	76	Sonographic localized the area of greatest fluid accumulation/superior-medial OR superior-lateral placement adjacent to the patella	RCT	Accuracy rate of injection, pain during treatment, average amount fluid collected
Cunnington et al.[18]	Patients with inflammatory arthritis	Joint corticosteroid injections	88	Not mention	RCT	Accuracy rate of injection, mean procedure duration
Curtiss et al. [19]	Cadaveric study	Joint injection	40	Suprapatellar recess approach/The junction of the superior and middle thirds of the patella and the lateral patellofemoral joint	N-RCT	Accuracy rate of injection
Sibbitt et al. [20]	Patients with knee osteoarthritis	Joint triamcinolone acetonide injection	92	Superior-medial approach	RCT	Pain score during treatment, decreased pain score 2 weeks after injection
Yong Bum Park (2011) [21]	Patients with knee osteoarthritis	Joint hyaluronic acid injection	89	Suprapatellar bursa approach	RCT	Accuracy rate of injection
Sibbitt et al. [22]	Patients with rheumatoid arthritis OR osteoarthritis	Joint corticosteroid injection	64	The straight leg lateral suprapatellar bursa (superiolateral) approach	RCT	Accuracy rate of injection, pain during treatment, average amount fluid collected, decreased pain score 2 weeks after injection
Jang et al. [23]	Patients with knee osteoarthritis	Joint corticosteroid injection	126	Medial midline approach/Mid-horizontal line of the patella met the medial border of the patella	RCT	Accuracy rate of injection, mean procedure duration

weighted mean difference for the USG group accomplishes the minimal clinically important difference (MCID $>$ 1.4) [24].

Aspiration volume of USG versus LM

Two studies [17,22] assessed the difference of aspiration volume between USG and LM. More fluid volume was reported in USG group and the difference was statistically significant (WMD = 17.06; 95% CI: 5.98–28.13; $P = 0.003$; $I^2 = 57\%$; Fig. 4).

Decreased pain scores (visual analog scale, VAS, 0–10) at 2 weeks after injection

Two studies [20,22] assessed decreased pain score 2 weeks after injection. This indicated a statistically significant difference between the groups, with greater improvement reported of decreased pain scores in the USG group (WMD = 0.84; 95% CI: 0.42–1.27; $P < 0.001$; $I^2 = 0$; Fig. 5).

Mean procedure duration of USG versus LM

Two studies [18,23] assessed the difference of mean procedure duration (min) between USG and LM groups. This indicated no statistically significant difference of procedure duration between two groups (WMD = −0.8; 95% CI: −2.24 to 0.74; $P = 0.31$; $I^2 = 0$)

Quality of included studies

We utilized the Cochrane Risk of bias tool to assess the methodological quality of the included trails in terms of sequence generation, allocation concealment, blinding, incomplete outcome data, selective outcome reporting, and other sources of bias. The studies reported low risk of bias in terms of incomplete outcome data and selective outcome reporting. However, the patients were not blind to the treatment in seven studies (7/9) [15–17,20–23]. Only in Joanna's study [18], sham ultrasound was performed in the control group so all the patients were blind to the treatment. In Jennifer's study [17], the assessors were not blind to the treatment so the detection bias is high. Patients not blinded to

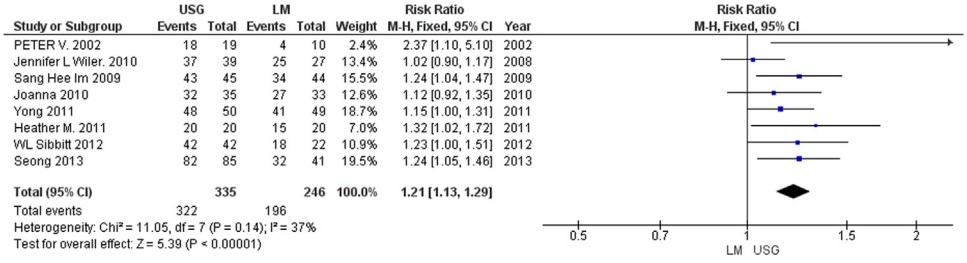

Fig. 2. Accuracy rate of USG versus LM—Forest plot.

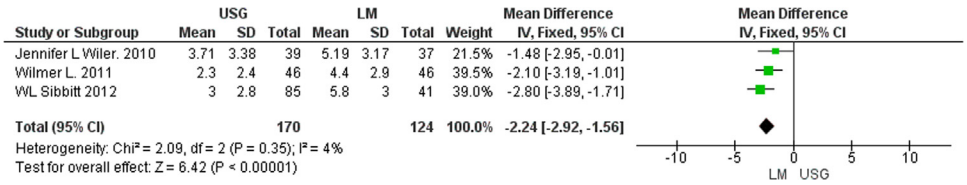

Fig. 3. Procedural pain of USG versus LM—Forest plot.

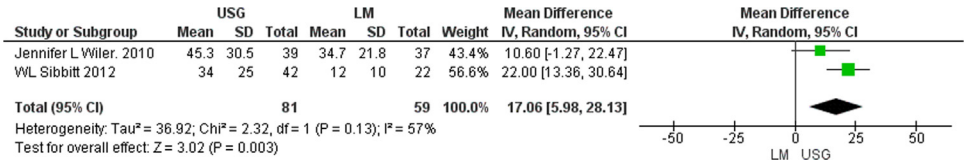

Fig. 4. Mean aspirated synovial fluid volume of USG versus LM—Forest plot.

the injection technique may have resulted in some bias particularly for purely subjective assessments such as VAS. In summary, the risk of bias within the studies was medium due to potential publication bias and unknown quality (Fig. 6).

Discussion

The primary purpose of this systematic review was to provide information related to the accuracy rates of needle placement in varying anatomic portals with and without USG assistance in adults. A total of seven RCTs and two N-RCTs were included in our Meta-analysis. The results showed that USG knee arthrocentesis were more efficient than the LM. USG knee joint injections significantly decreased the procedure and post-treatment pain score, and increased Knee arthrocentesis accuracy rate and aspiration volume.

Most joint arthrocentesis in clinical practice are delivered using the landmark to guide the injection, but a number of studies have demonstrated that the accuracy of LM-guided injections is poor (with 29–63% inaccurate), and this may contribute to the lack of clinical benefit observed in some patients [4,25]. LM-guided aspiration may be unsuccessful due to the use of an inappropriate needle diameter for viscous joint fluid. During ultrasound examination, the depth of the fluid collection from the ultrasound probe and the viscosity of the effusion influenced the selection of the appropriate needle size (diameter and length) for arthrocentesis [15]. So USG arthrocentesis and intra-articular injection of the knee improved outcomes such as accuracy rates of needle placement, decreased the procedure and post-treatment pain score and aspiration volume compared to the conventional anatomic landmark palpation-guided technique. Numerous imaging modalities could be used in identifying the correct trajectory for intra-articular diagnostic and/or therapeutic injections including ultrasound, fluoroscopy, computed tomography, etc.. However, ultrasound represents one of the most practical options because it is safe, quick, comparatively inexpensive than fluoroscopy, and emits no radiation [26].

Arthritis involving the knee joint is a common cause for pain and disability. The knee joint is one of the commonest target joints for intra-articular injection and aspiration therapy [27]. There are a number of possible anatomic injection sites. Clinicians' choice of technique is often influenced by their experience and training [10]. The accuracies of landmark versus ultrasound guidance techniques were also significantly different [11]. Although the presence of an effusion greatly enhances the accuracy of landmark-based injection in the knee [28], loss of resistance is not indicative of an intra-articular location. The failure of the landmark-based injection, with most of the inaccuracies due to the injection into the Hoffa's fat pad (81%) [29].

Experience can be an important contributor to the accuracy. Study of Curtiss et al. [19] demonstrated a huge difference in success rate, 55% versus 100% for the trainee and staff physician, respectively. However, another important finding from the study of Cunnington [18] showed that both trainee and staff achieved 100% accuracy with ultrasound-guided technique. Meanwhile, different USG approach routes are utilizable with high success rates, yet the approach route should be considered depending on the experience of the performer, anatomic conditions of the patient's osteoarthritic knee joint [23]. The levels of experience with ultrasound imaging guidance were 10 months and 3 years for the trainee and staff physician, respectively.

Landmark-based knee injection technique generally has six approaches: superolateral (SL) [15,17], superomedial (SM) [17,20], medial mid-patellar (MMP) [15,16], lateral mid-patellar (LMP) [15,19,23], anteromedial (AM), and anterolateral (AL). The knee was put in extension for SL, SM, LMP, and MMP approaches. The AM and AL approaches are performed with knee in 90° flexion with or without the modification of degree of flexion [30]. Better experience of the practitioner improves the accuracy of landmark-based technique, but the use of ultrasound guidance can improve the accuracy of the less experienced. Superolateral approach is the most reliable approach for both the ultrasound-guided or landmark-based techniques [19,21,22,31]. In the normal joint, the suprapatellar bursa communicates with the knee joint and appears on the United States as a thin hypoechoic line no more than 2 mm

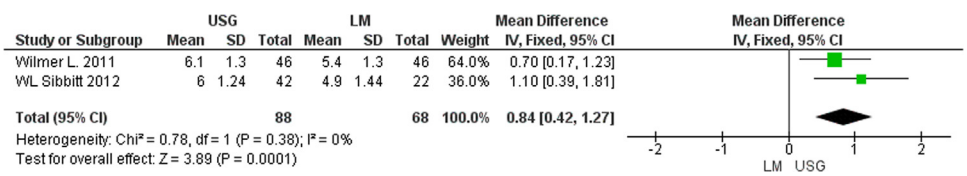

Fig. 5. Decreased pain score after injection of USG versus LM—Forest plot.

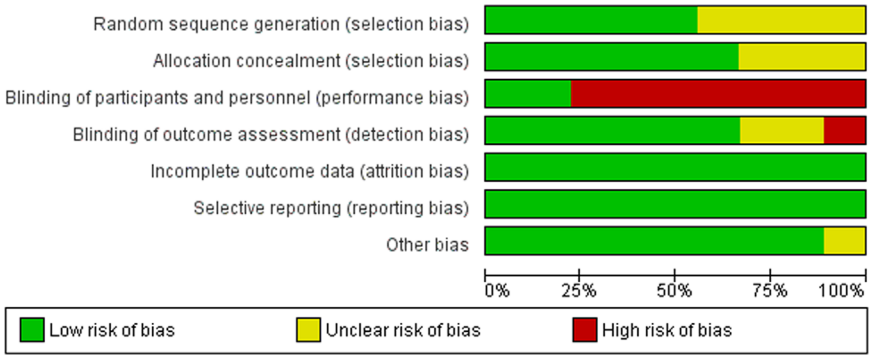

Fig. 6. Risk of bias graph.

wide extending approximately 6 cm above the patella, inferior to the quadriceps tendon [32]. Interestingly, only one study [33] compared the accuracies of different ultrasound-guided approaches and the results showed that the SL (accuracy rates 100%) and LMP (accuracy rates 95%) approaches were significantly more accurate than MMP approach (accuracy rates 75%).

To our knowledge, this is the first Meta-analysis to assess outcome of knee joint arthrocentesis guided by ultrasound versus landmark. The limitation of this study is the relatively small sample size in each group. The results should be interpreted with some caution due to the limited number of studies and small sample sizes available for review. Second, we included one study investigating the accuracy of intra-articular injection performed on cadavers [19] where it may be argued that altered tissue properties could affect the outcome. Third, the different included studies may have reflected the experience of different practitioner and approach routes which may have limited generalization of the study findings. So more adequately powered and well executed RCTs are required to develop a set of technical parameters of USG arthrocentesis in knee joint.

Conclusions

The meta-analysis in this study provides evidence that ultrasound-guided knee joint arthrocentesis offer a significantly greater accuracy and clinical improvement over landmark technique in adults with knee pain or joint effusion. Therefore, we believe that accurate USG intra-articular knee injections improve clinical outcomes, lower health care costs and overall clinical utility of these injections.

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We declare that the article has not been and will not be submitted elsewhere for publication. All authors declare no conflicts of interest. All authors have participated sufficiently to take public responsibility for this work.

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