Hydrodilatation for adhesive capsulitis: a systematic review exploring efficacy and optimal technique

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► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bjsports-2025-110539).

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Accepted 21 July 2026
Published Online First
29 July 2026

Check for updates

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To cite: Rhim HC, Shin J, Olson G, *et al*. *Br J Sports Med* 2026;**60**:1495–1509.

ABSTRACT

Objective Patients with adhesive capsulitis are often referred for conservative management, including corticosteroid injection or hydrodilatation of the glenohumeral joint. This systematic review aimed to evaluate the efficacy of hydrodilatation compared with other interventions and summarise reported techniques.

Design Systematic review with meta-analysis.

Data sources PubMed, Embase and Web of Science.

Eligibility criteria for selecting studies Randomised clinical trials (RCTs) and non-RCTs reporting outcomes related to hydrodilatation for idiopathic adhesive capsulitis.

Results A total of 103 studies (9951 patients and 44 RCTs) were included, and the selected RCTs were used to perform meta-analyses. The mean hydrodilatation volume from the included studies was 36.0±26.3 mL, and the median volume was 28 mL (range: 8.3–200). The anterior approach was more common with fluoroscopy guidance (anterior n=31 vs posterior n=5), while the posterior approach was more common with ultrasound guidance (anterior n=9 vs posterior n=40). At 12 weeks, hydrodilatation resulted in greater external rotation (standardised mean difference (SMD) 0.61, 95% CI 0.14 to 1.08, I^2 81.6%) than corticosteroid injection alone (low certainty of evidence), but without significant differences in pain Visual Analog Scores (VAS), shoulder pain and disability index (SPADI), abduction and forward flexion. When combined with physical therapy or exercise, at 12 weeks, hydrodilatation resulted in better pain VAS scores (low certainty of evidence) (SMD 0.288, 95% CI 0.01 to 0.57, I^2 20.7%) and SPADI scores (very low certainty of evidence) (SMD 0.52, 95% CI 0.08 to 0.96, I^2 52.3%) compared with physical therapy alone, but no additional gains in range of motion. The reported incidence of infection associated with hydrodilatation was 0.02% (two cases among 8754 patients).

Conclusion Significant variability exists in hydrodilatation techniques. Current evidence, combining these various techniques, does not support meaningful clinical improvements from hydrodilatation compared with corticosteroid injection alone or as an adjunct to physical therapy in patients with adhesive capsulitis. The ideal injection volume, capsular status, and number of injections remain inconclusive.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Some systematic reviews have suggested hydrodilatation may be superior to corticosteroid injection or physical therapy, and in a few network meta-analyses, it has been identified as one of the most effective conservative management options. However, conflicting evidence remains, with prior reviews providing limited analyses of technical factors, such as injection volume and approach.

⇒ Hydrodilatation employs several different techniques, including differences in injection volume, imaging guidance, types of injectates, injection approaches, capsular rupture versus preservation, number of injections, use of nerve blocks and postprocedural physical therapy recommendations.

WHAT THIS STUDY ADDS

⇒ Low certainty of evidence suggests that hydrodilatation using various techniques was associated with marginally greater external rotation at 12 weeks without significant differences in Visual Analog Scale score, Shoulder Pain and Disability Index score, shoulder abduction and shoulder forward flexion compared with corticosteroid injection.

⇒ The benefit of adding hydrodilatation for pain and function in patients already undergoing physical therapy or exercise appears to be minimal, given the clinically insignificant improvements observed.

⇒ With respect to technique, the anterior approach may offer a small clinically insignificant advantage in pain reduction and shoulder abduction, with volumes greater than 20 mL providing a benefit in pain reduction.

⇒ The ideal injection volume, capsular status and number of injections remain inconclusive.

INTRODUCTION

Adhesive capsulitis, commonly known as 'frozen shoulder', is a debilitating and painful condition with a reported incidence of 5% in a single shoulder clinic,[1] a prevalence of 8.2% in men and 10.1% in women aged 25–64 years with upper limb symptoms in the UK.[2] The incidence appears to be higher in females between the age of 40 and 60 years.[3] The natural history of adhesive capsulitis has been described by four stages based on the arthroscopic appearance of the joint capsule[4] or three stages based on the prognosis.[5] In the four-stage model, stage 1 is characterised by early synovial inflammation causing mild pain and minimal restriction of motion; stage 2 is marked by acute adhesive synovitis and early adhesion formation

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leading to progressive motion loss and increasing pain; stage 3 involves less synovitis and more fibrosis, resulting in significant restriction in motion but with less pain and stage 4 is characterised by painless, limited range of motion (ROM) from fully mature adhesions and fibrosis. The three-stage model progresses through overlapping stages of pain (stage 1 or 'freezing' stage, lasting 2–9 months); stiffness (stage 2 or 'frozen' stage, lasting 4–12 months) and recovery (stage 3 or 'thawing' stage, lasting 5–26 months).[5 6] External rotation is typically the first movement to be affected, as the coracohumeral ligament, which forms the roof of the rotator interval,[7] is often the earliest structure to become thickened and contracted.[8 9]

Although adhesive capsulitis is generally considered a self-limiting condition over 1–4 years, many patients seek treatment during the earlier stages due to significant pain and loss of ROM that interfere with daily activities. Conservative management options include oral steroids or non-steroidal anti-inflammatory drugs, physical therapy and corticosteroid injections.[10] Another such intervention is hydrodilatation, also referred to as hydrodilation, hydrodistension, arthrographic distension, capsular distension or joint distension, which was first introduced by Andren and Lundberg in 1965.[11] This technique aims to expand the joint capsule by exerting hydraulic pressure through the injected solution. Since its introduction, numerous studies have investigated the use of hydrodilatation for adhesive capsulitis, leading to multiple systematic reviews with conflicting findings.[12–17] These discrepancies may be attributed to variations in comparison groups, differences in inclusion criteria and the number of studies reviewed, as well as inconsistencies in meta-analytic methods. Furthermore, variations in hydrodilatation techniques—including differences in injection volume, imaging guidance, types of injectates, injection approaches, capsular rupture versus preservation, number of injections, use of nerve blocks and postprocedural physical therapy recommendations—contribute to significant clinical heterogeneity across studies, limiting the interpretation of how to optimally perform the hydrodilatation procedure.

Therefore, the primary objective of this systematic review was to evaluate the efficacy of hydrodilatation compared with other interventions individually (ie, hydrodilatation vs corticosteroid injection, physical therapy, arthroscopic release and manipulation under anaesthesia (MUA)). The secondary objective was to describe the various hydrodilatation techniques reported in the literature and propose an optimal approach for performing hydrodilatation.

METHODS

Study design

The PERSiST (implementing Prisma in Exercise, Rehabilitation, Sport medicine and SporTs science) guidance 2022 was used to conduct and report this review.[18] The study protocol was registered at The International Database to Register Systematic Reviews (INPLASY2024120088). Our Population, Intervention, Comparison and Outcome (PICO) framework is as follows:

- Participants: adult patients with a clinical diagnosis of adhesive capsulitis.
- Intervention: glenohumeral joint hydrodilatation (hydrodilation, hydrodistension, joint distension and arthrographic distension).
- Comparison: glenohumeral joint hydrodilatation with different imaging guidance, injectate, volume or any other techniques; glenohumeral joint corticosteroid injection, physical therapy, sham, other injections or other interventions.
- Outcome: all clinically relevant outcomes, including patient-reported pain (Visual Analogue Scale (VAS)); functional outcome measures, such as Shoulder Pain and Disability Index (SPADI), Disabilities of the Arm, Shoulder and Hand (DASH), University of California Los Angeles Shoulder Score (UCLA), Oxford Shoulder Score (OSS), Constant-Murley Shoulder Score (CMS), American Shoulder and Elbow Surgeon (ASES) scores and Subjective Shoulder Value (SSV); ROM and complications.

Search strategy

PubMed, Embase and Web of Science were searched from their inception to 21 December 2024 for articles evaluating or using hydrodilatation in patients with adhesive capsulitis (see online supplemental table 1 for full search strategy).

Study selection

The systematic review included RCTs, prospective and retrospective comparative studies and case series that reported outcomes related to hydrodilatation for idiopathic adhesive capsulitis. Reviews, case reports, studies conducted on animals, cadavers or in vitro settings, letters to the editor and technical descriptions without outcomes were not eligible for inclusion. We also excluded studies that did not describe details of hydrodilatation and any studies that included isolated secondary adhesive capsulitis (eg, vaccination-related, traumatic or postsurgical adhesive capsulitis). We limited the included studies to those published in English, as prior research has found no evidence of bias resulting from the exclusion of non-English language studies.[19 20]

Study screening and data extraction

All references were uploaded to Covidence and independently screened by two authors (HCR and XP). Discrepancies between the two authors were resolved through discussion with a third author (JS). A set of two authors (HCR, JS, GO, RF, RCG, DBC, XP and JR) independently reviewed each study and conducted data extraction. Extracted variables included the country where the study was conducted, study design, inclusion and exclusion criteria, patient demographics, hydrodilatation techniques, rehabilitation protocols, follow-up durations and any reported adverse events. Statistical information such as mean and SD was also extracted for meta-analysis. If required data were not available in the published manuscript, corresponding authors were contacted for additional information.

Risk of bias assessment

Two authors (HCR and JS) independently evaluated the risk of bias using the revised Cochrane risk-of-bias tool for randomised controlled trials (ROB 2)[21] and Risk Of Bias In Non-Randomised Studies - of Interventions (ROBINS-I)[22] for non-RCTs. Only interventional studies that included a comparison group were assessed. Any discrepancies between the two authors were resolved through discussion with a third author (XP). Non-comparative studies including case series and comparative studies that investigated factors associated with hydrodilatation outcomes were not formally assessed for risk of bias, as they were included in this review for descriptive purposes, such as characterising procedural variations and outcome predictors.

Data analysis

We conducted random-effects pairwise meta-analyses to account for clinical variability among studies, including differences in

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patient and injection characteristics for RCTs that compared (1) hydrodilatation with corticosteroid injection, (2) hydrodilatation in addition to physical therapy (or an exercise programme) with physical therapy alone and (3) anterior versus posterior approaches in hydrodilatation. Our primary outcomes were pain VAS, SPADI and ROM (external rotation, abduction and forward flexion) at 12 weeks, as these were the most commonly reported outcome measures. One study reporting a 9-week outcome[23] or 4-month outcome[24] was incorporated into the 12-week outcome category. Our secondary outcomes included those reported at 2–4 weeks, 6–8 weeks and beyond 12 weeks.

Standardised mean differences (SMDs) were calculated as the effect size to account for variations in the measurement of VAS scores (0–10 vs 0–100, as well as pain at rest or during activities), ROM assessments (passive vs active) and outcome reporting formats (mean change vs follow-up means). If both active and passive ROM were reported, passive ROM values were used because passive ROM may better reflect true capsular restriction in adhesive capsulitis and is less influenced by patient effort. For studies that reported only group means and 95% CIs, SDs were estimated using the formula: $SD = \sqrt{N} \times (Upper\ limit - Lower\ limit)/3.92$. When only group means and p value were provided, we estimated the SDs for each group by reverse-calculating from the reported p value of an independent two-sample t-test, following guidance from the Cochrane Handbook (Section 6.5.2.3).[25] Because lower VAS and SPADI scores represent better outcomes, these values were multiplied by −1 so that positive SMDs consistently indicate favourable outcomes with hydrodilatation. The pooled effect estimates were back-translated to original scales (VAS, SPADI and ROM) by multiplying the SMD by the control group SD from trials with the highest weight in the meta-analysis to enhance interpretability of measures of treatment effects.[26] Statistical heterogeneity was assessed using Q and I^2 statistics. A sensitivity analysis was conducted using the leave-one-out approach, sequentially refitting the random-effects model after omitting each study to evaluate the robustness of the pooled estimates.

The mean and median volume of hydrodilatation reported across studies were also calculated to plan for subgroup analysis. When the injected volume was not explicitly reported, the 'total possible injection volume' was estimated by summing the reported volumes of each injectate. If the volume of corticosteroid was not specified, it was assumed to be 1 mL. For example, if the authors noted an injection of 40 mg triamcinolone without specifying volume, a volume of 1 mL was assumed based on standard preparation concentrations. A subgroup analysis was also performed based on the number of injections performed. The certainty of evidence was assessed using the Grading of Recommendations, Development and Evaluation (GRADE) framework.[27 28] The certainty of evidence started at 'high' and was downgraded for the following domains: risk of bias (downgraded if studies had some concerns or high risk of bias), inconsistency (downgraded for substantial heterogeneity or opposing directions of effects), indirectness (downgraded if studies deviated from the predefined PICO criteria) and imprecision (downgraded if the CI crossed the line of no effect and spanned from potential benefit to potential harm or if the CI did not cross the line of no effect but the total sample size was less than 400 participants). Publication bias was not assessed because less than 10 studies were included in the meta-analysis.[29] Descriptive analyses were performed using t-tests or Mann-Whitney tests for continuous variables with and without normal distribution, respectively. All analyses were conducted using STATA V.16 (StataCorp, College Station, Texas). P values <0.05 were considered statistically significant. Studies that could not be included in the quantitative synthesis were summarised qualitatively.

Equity, diversity and inclusion statement

The research group consisted of researchers who are of different genders and from varied professional backgrounds, including physical medicine and rehabilitation residents, sports medicine fellows, student researchers and academic sports medicine physiatrists. Our study participants represented both male and female individuals but may not fully represent diverse geographic regions and cultural backgrounds because the review was restricted to English-language literature.

RESULTS

A total of 679 studies were identified. After removing 294 duplicates, 385 studies remained for title and abstract screening. Of these studies, 243 were excluded after screening, and 142 studies were eligible for full-text review. 42 studies were excluded for the following reasons: 12 were abstracts only, 9 were not in English, 6 evaluated unrelated conditions, 5 lacked details on hydrodilatation, 4 full texts were unavailable, 3 evaluated non-relevant interventions and 3 implemented ineligible study designs. This process resulted in 100 studies, and an additional three studies were identified through screening reference lists of relevant articles. A total of 103 studies with 9951 patients (44 RCTs; 8754 patients undergoing hydrodilatation) were included in this review (figure 1). The study design, inclusion and exclusion criteria and patient demographics are summarised in online supplemental table 2. The remaining study characteristics, including outcome measures, follow-up duration, adverse events and summary of main findings, are summarised in online supplemental table 3. Online supplemental table 4 summarises hydrodilatation techniques and postprocedural rehabilitation. Online supplemental figures 1 and 2 display overall risk of bias assessment of interventional RCTs and non-RCTs.

Hydrodilatation versus corticosteroid injection

16 RCTs and one retrospective cohort study compared hydrodilatation using various injectates and techniques to corticosteroid injection. 10 RCTs were deemed to have a high risk of bias, while six RCTs had some concerns, and the cohort study was rated as having a serious risk of bias. Three RCTs[30–32] were excluded from the meta-analysis due to insufficient data, and one retrospective cohort[33] study was excluded to reduce the risk of bias.

At 12 weeks, there were no significant differences in VAS scores (figure 2A, n=565, SMD −0.21, 95% CI −0.93 to 0.50, I^2 93.3%)[34–41] and SPADI scores (figure 2B, n=559, SMD −0.26, 95% CI −0.71 to 0.19, I^2 85.0%)[34–37 39 42–44] between hydrodilatation and corticosteroid injections. At 12 weeks, hydrodilatation resulted in greater external rotation (figure 2C, n=423, SMD 0.61, 95% CI 0.14 to 1.08, I^2 81.6%)[34 37 39–41 44] than corticosteroids without significant differences in abduction (figure 2D, n=366, SMD 0.37, 95% CI −0.19 to 0.93, I^2 85.4%)[34 37 39 40 44] and forward flexion (figure 2E, n=423, SMD 0.31, 95% CI −0.10 to 0.72, I^2 76.5%).[34 37 39–41 44] The GRADE assessments and back-translation of these results to original scales are summarised in table 1. The certainty of evidence was rated 'very low' for VAS, SPADI, abduction and forward flexion and 'low' for external rotation (back-translated MD 7.5, 95% CI 1.7 to 13.2). The results before and after 12 weeks are summarised in the online supplemental table 5.

Sensitivity analyses showed that the omission of the RCT by Reza *et al*[40] rendered the pooled estimate for external rotation

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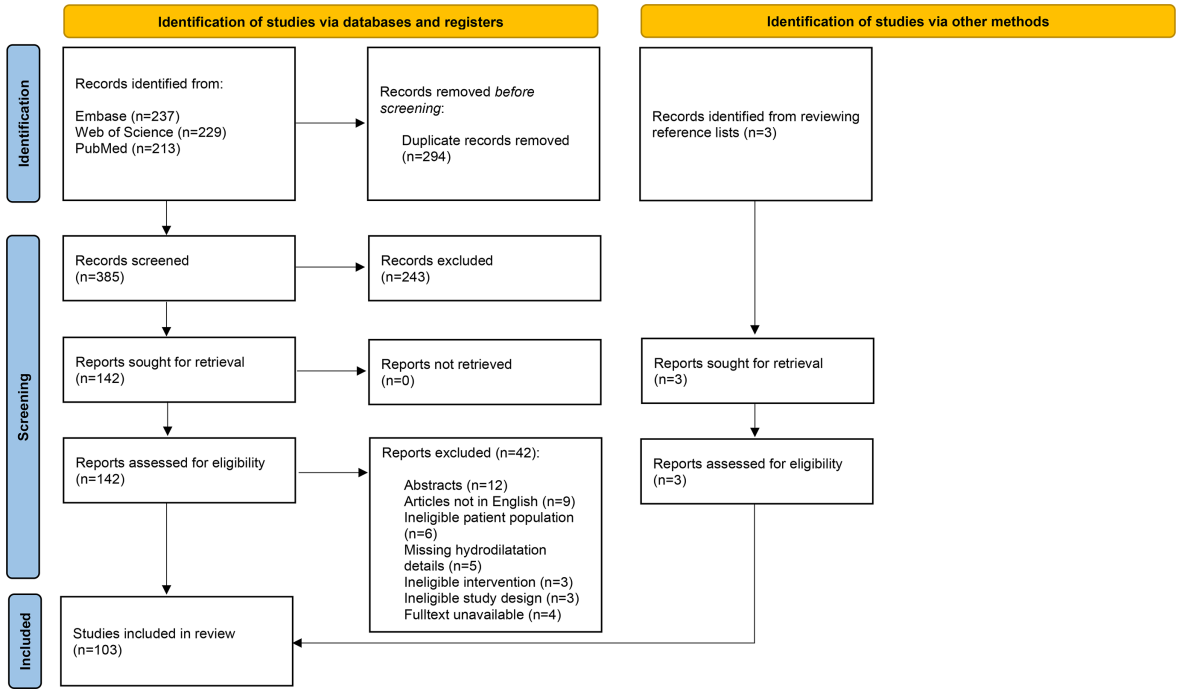

Figure 1 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram showing selection of articles.

non-significant (SMD 0.53, 95% −0.03 to 1.09), whereas exclusion of the RCT by Tveita *et al*[44] resulted in a statistically significant pooled estimate for forward flexion (SMD 0.44, 95% CI 0.05 to 0.83). Apart from these changes, the overall findings remained robust across sensitivity analyses.

One prospective cohort study compared hydrodilatation and steroid injection, which were performed in conjunction with MUA. At each follow-up interval of 4 weeks, 12 weeks and 24 weeks, the MUA combined with hydrodilatation resulted in significantly greater improvement in total VAS, total disability and SPADI scores compared with the MUA combined with steroid injection.[45]

Hydrodilatation with physical therapy versus physical therapy alone

Seven RCTs[24 46–51] compared hydrodilatation using various injectates and techniques in conjunction with physical therapy (or exercise programme) to physical therapy alone. Six RCTs were deemed to have a high risk of bias, and one RCT was rated as having some concerns. One RCT was excluded from the meta-analysis due to missing data.[48]

Meta-analyses revealed that hydrodilatation with physical therapy (or exercise programme) resulted in better VAS (figure 3A, n=249, SMD 0.288, 95% CI 0.01 to 0.57, I^2 20.7%)[24 46 47 49] and SPADI scores (figure 3B, n=173, SMD 0.52, 95% CI 0.08 to 0.96, I^2 52.3%)[24 46 49] at 12 weeks. The back-translated results and certainty of evidence for VAS and SPADI were 0.26 (95% CI 0.01 to 0.51, low certainty) and 9.2 (95% CI 1.3 to 17, very low certainty), respectively. However, there were no additional benefits in external rotation (figure 3C, n=249, SMD 0.40, 95% CI −0.31 to 1.10, I^2 86.5%),[24 46 47 49] abduction (figure 3D, n=249, SMD 0.23, 95% CI −0.55 to 1.018, I^2 89.1%)[24 46 47 49] and forward flexion (figure 3E, n=249, SMD 0.22, 95% CI −0.56 to 1.00, I^2 89%).[24 46 47 49] The GRADE assessments and back-translation of these results to original scales are summarised in table 2. The certainty of evidence was rated 'very low' for external rotation, abduction and forward flexion. The results before and after 12 weeks are summarised in online supplemental table 6. Sensitivity analyses demonstrated that the pooled estimates for VAS and SPADI were not robust, as the omission of three RCTs[24 46 49] and two RCTs,[24 49] respectively, rendered the pooled effects non-significant. No notable changes were observed for external rotation, abduction and forward flexion.

Following the hydrodilatation procedure, manipulation therapy with home exercises appeared to have more benefits in patient-reported outcomes over supervised physical therapy[50 52] and ROM over home exercise alone.[53] Supervised physical therapy composed of stretching, cervical and thoracic spine mobilisation and strengthening exercises resulted in greater active shoulder ROM and patient-perceived improvement up to 24 weeks when compared with sham physical therapy where participants attended the same number of visits but with sham ultrasound, no therapeutic gel, no instruction on exercise and no manual therapy.[54] However, in another RCT, both supervised physical therapy and self-directed exercise led to improvements in OSS, VAS, passive external rotation and EuroQol 5-Dimension during 1 year follow-up without significant differences between the two groups.[55]

One RCT compared the analgesic effects of high- and low-intensity transcutaneous electrical nerve stimulation (TENS), with a control group during the hydrodilatation procedure, and applications of both TENS resulted in significant improvement in VAS compared with the control group, but there was no significant difference between the two intensities.[56]

Hydrodilatation versus arthroscopic release

Two RCTs with high risk of bias compared hydrodilatation with arthroscopic release.[57 58] Dai *et al* found that combining arthroscopic release with hydrodilatation resulted in greater ROM (passive abduction, passive flexion, passive external rotation and passive internal rotation) at 1, 4, 12 and 24 weeks, as well as greater passive flexion and internal rotation at 1 year, compared with hydrodilatation alone. The UCLA and DASH

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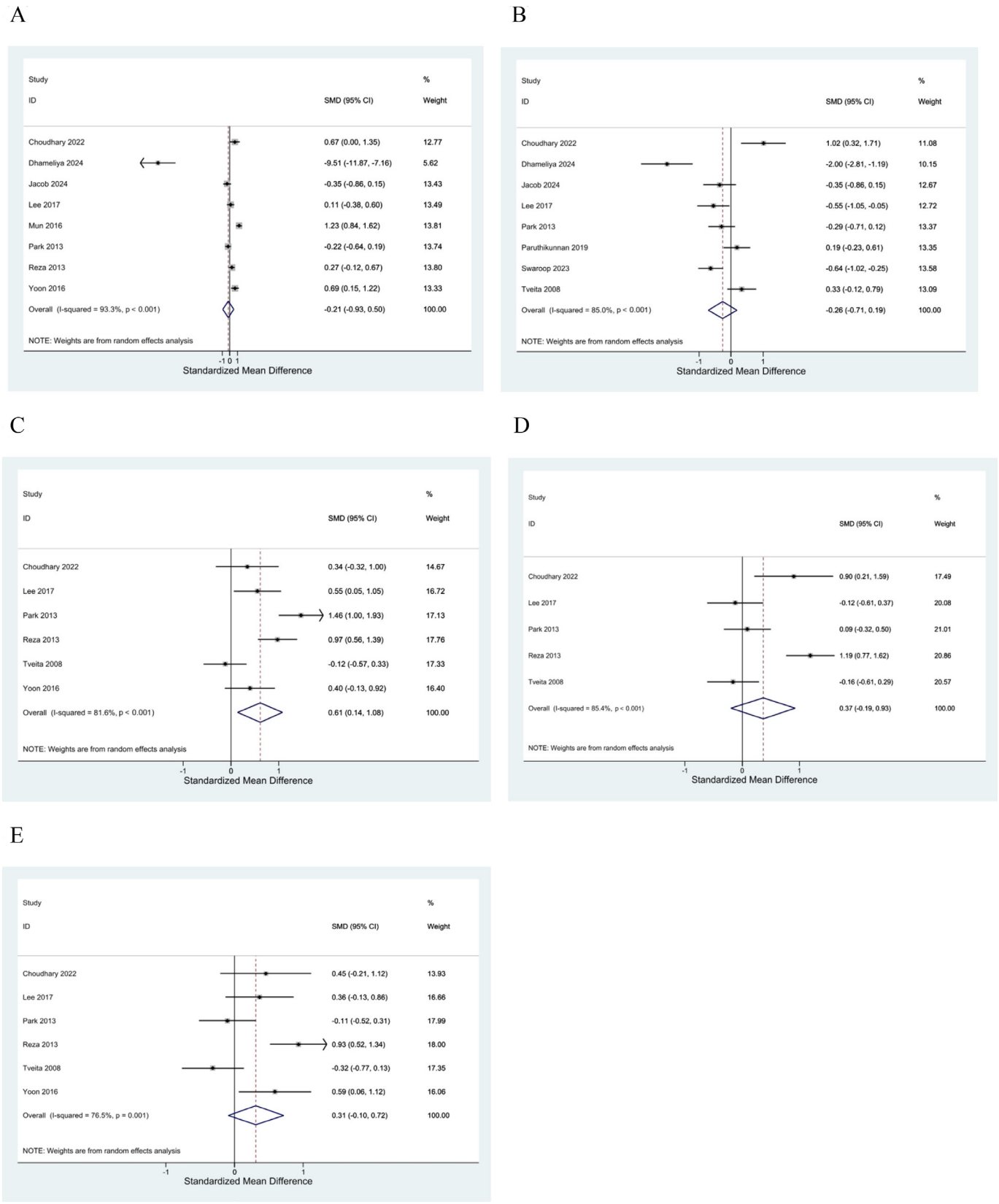

Figure 2 Meta-analysis of hydrodilatation versus corticosteroid injection in adhesive capsulitis at 12 weeks in standardised mean difference (SMD): (A) pain Visual Analog Scale (VAS) scores, (B) Shoulder Pain and Disability Index (SPADI) scores, (C) external rotation (back-translated MD 7.5 degrees, 95% CI 1.7 to 13.2), (D) abduction and (E) forward flexion.

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Table 1 GRADE summary findings for comparison of hydrodilatation (HD) with corticosteroid injection (CSI) at 12 weeks

Outcome	Sample size		Effect size (95% CI)*	Risk of bias†	Inconsistency‡	Indirectness§	Imprecision¶	Quality of evidence
	HD	CSI						
Pain VAS (8 RCTs)	281	284	MD = –0.19 (–0.84 to 0.45)	↓ 1 level	↓ 2 levels	No downgrade	↓ 1 level	Very low
SPADI (8 RCTs)	280	279	MD = –0.79 (–2.15 to 0.58)	↓ 1 level	↓ 2 levels	No downgrade	↓ 1 level	Very low
External rotation (6 RCTs)	212	211	**MD=7.5 (1.7 to 13.2)**	↓ 1 level	↓ 1 level	No downgrade	No downgrade	Low
Abduction (5 RCTs)	184	182	MD=4.8 (–2.5 to 12.0)	↓ 1 level	↓ 2 levels	No downgrade	↓ 1 level	Very low
Forward flexion (6 RCTs)	212	211	MD=6.6 (–2.0 to 15.3)	↓ 1 level	↓ 1 level	No downgrade	↓ 1 level	Very low

Bold values indicate statistically significant results ($p < 0.05$).
*Back-translated to original scale by multiplying the standard mean difference by the SD obtained from the control group of the trial with the highest weight in the meta-analysis.
†Downgraded one level if the included RCTs had 'some concerns' or 'high risk' of bias.
‡Downgraded one level if there were substantial heterogeneity (I^2>50%), but most studies showed effects in the same direction; downgraded two levels if there were substantial heterogeneity (I^2>75%) and opposing directions of effect.
§No downgrade because most studies did not deviate from the predefined PICO criteria.
¶Downgraded one level if the CI crossed the line of no effect and spanned from potential benefit to potential harm.
**Publication bias was not assessed because fewer than 10 trials were included.
CSI, corticosteroid injection; GRADE, Grading of Recommendations, Development and Evaluation; HD, hydrodilatation; MD, mean difference; RCT, randomised controlled trial; SPADI, Shoulder Pain and Disability Index; VAS, Visual Analog Scale.

scores were also better in the combined group at 12 weeks, 24 weeks and 1 year. There was no significant difference in VAS across follow-up periods.[57] Similarly, Gallacher *et al* reported greater improvements in OSS and passive ROM (external rotation and forward elevation) with arthroscopic release at 24 weeks, without a significant difference in pain. No complications were noted in either trial.[58]

Hydrodilatation versus MUA

Three RCTs with different durations of follow-up compared hydrodilatation with MUA. One RCT with high risk of bias showed that at 2 weeks, both hydrodilatation and MUA resulted in improvement in the SPADI scores, with no significant difference between groups.[59] Another RCT with some concerns for risk of bias reported no significant difference in CMS and VAS scores up to 16 weeks between these two treatments.[60] On the other hand, the other RCT with high risk of bias found significantly greater improvements in VAS and CMS over 24 weeks with hydrodilatation (without steroid). Furthermore, at 8 weeks, hydrodilatation led to improvements in all ROMs, whereas MUA showed improvements only in abduction and forward flexion.[61] Similarly, one retrospective cohort study with a serious risk of bias found that average ROM and pain level significantly improved with hydrodilatation compared with MUA.[62] Another retrospective cohort study with serious risk of bias demonstrated that MUA combined with hydrodilatation significantly reduced the need for subsequent MUAs and improved clinical outcomes (CMS and VAS) compared with MUA alone.[63]

Imaging guidance

Excluding the studies that did not report imaging guidance or reported unclearly, a total of 49 procedures used ultrasound guidance, 36 used fluoroscopy guidance, and nine used landmark guidance. Three RCTs[23 64 65] compared the outcomes following hydrodilatation performed under ultrasound guidance versus fluoroscopy guidance. One RCT with some concerns for risk of bias compared the anterior approach using fluoroscopy versus ultrasound.[64] The authors reported that ultrasound-guided hydrodilatation offered greater pain reduction within the first 4 weeks, and ROM improved within the first 8 weeks. Another RCT with high risk of bias compared the posterior approach using fluoroscopy versus ultrasound.[65] The authors performed three injections at 2-week intervals and found improvements in VAS, SPADI and active and passive ROM from 2 weeks after the last injection through 6 weeks, without any differences between groups. However, in this RCT, the ultrasound-guided procedure was preferred by patients, shorter in duration than that guided by fluoroscopy, and more cost-effective. The other RCT with some concerns for risk of bias also compared the anterior approach using fluoroscopic guidance versus the posterior approach using ultrasound guidance.[23] The authors found no significant difference between the two approaches in terms of SPADI, VAS, passive ROM and grip and pinch strengths measured by dynamometers at 1, 5 and 9 weeks following the procedure.

Hydrodilatation approach

The anterior approach with the patient lying supine was more common with fluoroscopy guidance (anterior n=31 vs posterior n=5), while the posterior approach was more common with ultrasound guidance (anterior n=9 vs posterior n=40). The hydrodilatation approaches are summarised in online supplemental table 4.

Three RCTs, one with low risk of bias and two with some concerns, compared the anterior approach targeting rotator interval with the posterior approach targeting glenohumeral joint recess.[23 66 67] One RCT[23] used fluoroscopy guidance for the anterior approach while using ultrasound for the posterior approach. Two RCTs[66 67] used ultrasound guidance for both approaches. Meta-analyses revealed that at 12 weeks, the anterior approach resulted in greater VAS (n=178, SMD 0.42, 95% CI 0.1 to 0.74, I^2 14.7%) and abduction improvement (n=178, SMD 0.317, 95% CI 0.02 to 0.61,

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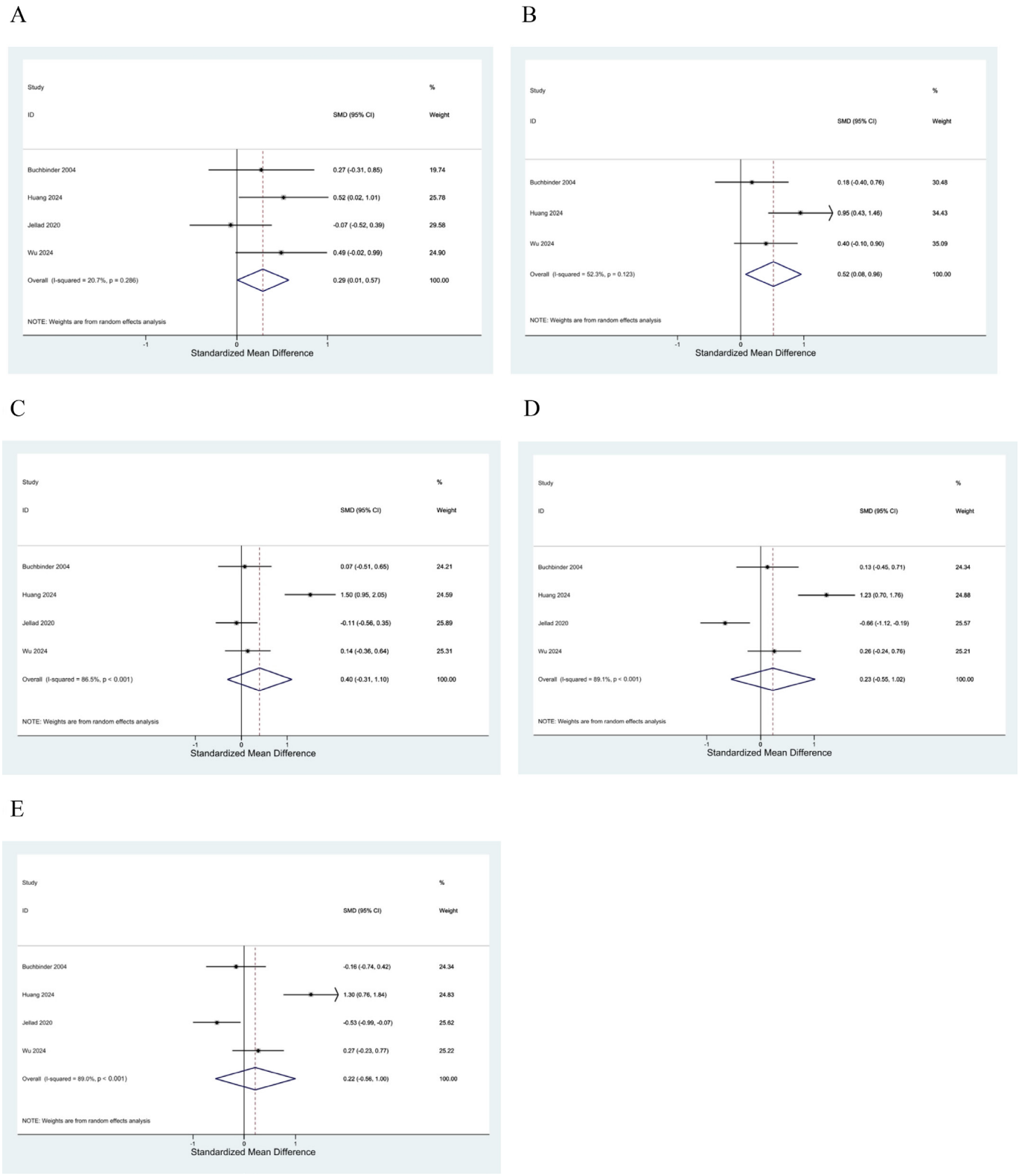

Figure 3 Meta-analysis of hydrodilatation combined with physical therapy versus physical therapy alone in adhesive capsulitis at 12 weeks in SMD: (A) pain VAS scores, (B) SPADI scores, (C) external rotation, (D) abduction and (E) forward flexion. SMD, standardised mean difference; SPADI, Shoulder Pain and Disability Index; VAS, Visual Analog Scale.

I^2 0%) compared with the posterior approach. The back-translated results and certainty of evidence for VAS and abduction were 0.47 (95% CI 0.11 to 0.84, low certainty) and 10.5 (95% CI 0.7 to 20.3, low certainty), respectively. However, no significant difference in improvements were seen in SPADI (n=178, SMD −0.64, 95% CI −1.78 to 0.50, I^2 92.4%), external rotation (n=178, SMD 0.53, 95% CI −0.35 to 1.41, I^2 88.0%) and forward flexion (n=178 SMD

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Table 2 GRADE summary findings for comparison of hydrodilatation (HD) in addition to physical therapy (PT) with PT alone at 12 weeks

Outcome	Sample size		Effect size (95% CI)*	Risk of bias†	Inconsistency‡	Indirectness§	Imprecision¶	Quality of evidence
	HD+PT	PT						
Pain VAS (4 RCTs)	123	126	**MD=0.26 (0.01 to 0.51)**	↓ 1 level	No downgrade	No downgrade	↓ 1 level	Low
SPADI (3 RCTs)	89	84	**MD=9.2 (1.3 to 17.0)**	↓ 1 level	↓ 1 level	No downgrade	↓ 1 level	Very low
External rotation (4 RCTs)	123	126	MD=7.1 (−5.5 to 19.8)	↓ 1 level	↓ 2 level	No downgrade	↓ 1 level	Very low
Abduction (4 RCTs)	123	126	MD=6.8 (−16 to 29.5)	↓ 1 level	↓ 2 level	No downgrade	↓ 1 level	Very low
Forward flexion (4 RCTs)	123	126	MD=5.2 (−13.5 to 24.0)	↓ 1 level	↓ 2 level	No downgrade	↓ 1 level	Very low

Bold values indicate statistically significant results (p < 0.05).
*Back-translated to original scale by multiplying the standard mean difference by the SD obtained from the control group of the trial with the highest weight in the meta-analysis.
†Downgraded one level if the included RCTs had 'some concerns' or 'high risk' of bias.
‡Downgraded one level if there were substantial heterogeneity (I^2>50%), but most studies showed effects in the same direction; downgraded two levels if there were substantial heterogeneity (I^2>75%) and opposing directions of effect.
§No downgrade because most studies did not deviate from the predefined PICO criteria.
¶Downgraded one level if the CI crossed the line of no effect and spanned from potential benefit to potential harm, OR if the CI did not cross the line of no effect but the total sample size was less than 400 participants.
**Publication bias was not assessed because fewer than 10 trials were included.
GRADE, Grading of Recommendations, Development and Evaluation; HD, hydrodilatation; MD, mean difference; PT, physical therapy; RCT, randomised controlled trial; SPADI, Shoulder Pain and Disability Index; VAS, Visual Analog Scale.

0.27, 95% CI −0.06 to 0.60, I^2 19%). The GRADE assessments and back-translation of these results to original scales are summarised in table 3.

Hydrodilatation volume

The mean hydrodilatation volume from all studies included in this review was 36.0±26.3 mL, and the median volume was 28 mL (range: 8.3–200). When studies were categorised by capsular preservation and rupture, the mean volumes were 24.9±11.8 mL and 50.4±23.7 mL, respectively, and the median volumes were 20 mL (range: 8.33–52) and 45 mL (range: 20–115), respectively. The largest volume reported was 200 mL, which was used during the MUA.[45] The mean volume used during the fluoroscopic guide procedure was significantly higher, with 44.4±25 mL (median 38.7 mL, IQR 25.5–52 mL) than that during ultrasound with 26.5±13.4 mL (median 21 mL, IQR 20–30 mL). Previous studies have evaluated the pressure and volume during the hydrodilatation procedure and their association with patient characteristics.[68–70] One of these studies reported an average rupture volume of 20.3±6.4 mL and pressure of 440.87±232.05 mmHg.[69] Based on this study—and given that the median volume reported in studies with capsular preservation was 20 mL and the minimum volume reported in the studies with capsular rupture was also 20 mL—we used this

Table 3 GRADE summary findings for anterior versus posterior approach in hydrodilatation at 12 weeks

Outcome	Sample size		Effect size (95% CI)*	Risk of bias†	Inconsistency‡	Indirectness§	Imprecision¶	Quality of evidence
	Anterior	Posterior						
Pain VAS (3 RCTs)	89	89	**MD=0.47 (0.11 to 0.84)**	↓ 1 level	No downgrade	No downgrade	↓ 1 level	Low
SPADI (3 RCTs)	89	89	MD = −8.8 (−24.4 to 6.9)	↓ 1 level	↓ 2 levels	No downgrade	↓ 1 level	Very low
External rotation (3 RCTs)	89	89	MD=14.5 (−9.7 to 38.6)	↓ 1 level	↓ 2 levels	No downgrade	↓ 1 level	Very low
Abduction (3 RCTs)	89	89	**MD=10.5 (0.7 to 20.3)**	↓ 1 level	No downgrade	No downgrade	↓ 1 level	Low
Forward flexion (3 RCTs)	89	89	MD=5.2 (−1.2 to 11.5)	↓ 1 level	No downgrade	No downgrade	↓ 1 level	Low

Bold values indicate statistically significant results (p < 0.05).
*Back-translated to original scale by multiplying the standard mean difference by the SD obtained from the control group of the trial with the highest weight in the meta-analysis.
†Downgraded one level if the included RCTs had 'some concerns' or 'high risk' of bias.
‡Downgraded one level if there were substantial heterogeneity (I^2>50%), but most studies showed effects in the same direction; downgraded two levels if there were substantial heterogeneity (I^2>75%) and opposing directions of effect.
§No downgrade because most studies did not deviate from the predefined PICO criteria.
¶Downgraded one level if the CI crossed the line of no effect and spanned from potential benefit to potential harm, OR if the CI did not cross the line of no effect but the total sample size was less than 400 participants.
**Publication bias was not assessed because fewer than 10 trials were included.
GRADE, Grading of Recommendations, Development and Evaluation; MD, mean difference; RCT, randomised controlled trial; SPADI, Shoulder Pain and Disability Index; VAS, Visual Analog Scale.

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volume as a cut-off to perform subgroup analyses of our primary outcome measures at 12 weeks.

Subgroup analyses revealed that hydrodilatation volumes greater than 20 mL were associated with lower VAS scores compared with corticosteroid injection alone (n=378, SMD 0.60, 95% CI 0.16 to 1.04, I^2 76.2%) at 12 weeks. In contrast, volumes equal to or less than 20 mL were associated with higher VAS scores than corticosteroid injection alone (n=187, SMD −2.64, 95% CI −4.72 to −0.56, I^2 96.6%). While there were no significant differences in SPADI scores between hydrodilatation volumes greater than 20 mL and corticosteroid injection (n=176, SMD 0.24, 95% CI −0.59 to 1.07, I^2 85.8%), volumes ≤20 mL were associated with worse SPADI scores than corticosteroid injection alone (n=383, SMD −0.54, 95% CI −1.07 to −0.02, I^2 83.5%). There were no significant impacts of volumes in shoulder ROM.

Similarly, while hydrodilatation volume greater than 20 mL added to physical therapy (or exercise programme) resulted in better VAS scores than physical therapy alone (n=111, SMD 0.41, 95% CI 0.04 to 0.79, I^2 0%), there was no additional benefit of hydrodilatation added to physical therapy (or exercise programme) if the hydrodilatation volume was less than 20 mL (n=138, SMD 0.20, 95% CI −0.34 to 0.74, I^2 61.2%). Subgroup analysis for the SPADI scores was not performed due to the limited number of studies, and there were no significant impacts of volumes in shoulder ROM.

Several studies compared different injection volumes or evaluated the impact of hydrodilatation volume on outcome measures. One RCT with some concerns for risk of bias compared hydrodilatation using 10 mL versus 20 mL. The authors reported that both volumes resulted in improvements of VAS and SPADI scores and ROM over 12 weeks, but the group-by-time interactions for any of the outcomes between the two volumes were not significant except for VAS pain in motion, which was attributed to the effect of time.[71] One retrospective review of 2432 hydrodilatation cases with a distension volume of 10 mL, 30 mL or 50 mL revealed that greater volumes of distension were associated with lower rates of need for further intervention independent of capsular rupture.[72] Similarly, one case series demonstrated that patients with an injection of 25 mL had a significantly lower recurrence rate (2/21, 9.5%) than those with 20 mL or less (14/34, 41%).[73] On the other hand, another case series reported that there was a negative correlation between hydrodilatation volume and OSS improvement, with OSS improvement being lowest for the highest volume (≥50 mL).[74]

One study identified that longer symptom duration, greater initial SPADI and decreased ROM were associated with a reduced volume of infused fluid during hydrodilatation.[75] One case series showed that repeat hydrodilatation with 1-month interval over 12 weeks resulted in decreased stiffness and increased maximal volume capacity, accompanied by improved passive ROM and pain relief.[76]

Capsular preservation versus capsular rupture

Not all studies clearly reported the status of capsules during the procedure. Studies were categorised as capsular rupture (n=33) if the primary aim was to rupture the capsule, and the rupture was confirmed in over 50% of patients or indicated by a loss of resistance. Studies were classified as capsular preservation (n=28) if hydrodilatation was performed until syringe resistance increased or maximal distension was visualised on ultrasound, and fewer than 50% of patients experienced rupture. The remaining studies were labelled unclear due to insufficient procedural detail or lack of reporting. Given this inconsistency and the variability in rupture volumes, subgroup analysis based on capsular status following hydrodilatation was not performed.

Two studies[77 78] specifically compared capsular preserving and capsular rupturing techniques of hydrodilatation. One cohort study with moderate risk of bias reported greater improvements in abduction, summed ROM and external/internal rotation at 4 weeks with capsule-preserving hydrodilatation, while there was no significant difference in pain (29.5±8.36 mL vs 23.4±10.33 mL).[77] Similarly, another prospective cohort study with serious risk of bias found that while both capsular preserving and rupturing techniques improved DASH and VAS scores at 4, 12 and 24 weeks, these scores were better in the capsule preservation group compared with the rupture group during all time points (24.8±5 vs 36.2±8 mL).[78]

One large retrospective review reported that capsular rupture was not associated with the need for further intervention.[72] Similarly, in one small case series, capsular rupture was not associated with changes in SPADI scores at 8 weeks.[79] On the other hand, one small study showed that the absence of massive fluid leakage was an independent predictor of good clinical outcomes (≥50% improvement in the VAS score and ≥20 points in the SPADI score) at 4 weeks.[75]

Hydrodilatation with/without steroid

Three RCTs with high risk of bias investigated the effect of adding steroids to hydrodilatation and found superior outcomes compared with hydrodilatation without steroids.[31 80 81] One RCT reported greater improvements in SPADI, SSV and VAS up to 1 year with the use of 11.4 mg betamethasone during hydrodilatation.[80] Another RCT found increased abduction and flexion at 16 weeks when 40 mg triamcinolone was used with hydrodilatation.[31] Similarly, the remaining RCT observed greater pain reduction in patients who received 80 mg methylprednisolone during hydrodilatation compared with those who did not.

One RCT with some concerns for risk of bias compared 40 mg of triamcinolone with 10 mg of triamcinolone, both delivered in a total volume of 20 mL for hydrodilatation targeting the posterior glenohumeral recess under ultrasound guidance.[82] The authors found no significant differences between the two steroid doses in terms of SPADI, VAS and ROM at 12 weeks.

One large retrospective review showed that steroid dose (40 mg vs 80 mg triamcinolone or methylprednisolone) was not associated with the need for further intervention following hydrodilatation.[72]

Types of injectate

While corticosteroid, local anaesthetic such as lidocaine and normal saline were the most common components of hydrodilatation (online supplemental table 4), several studies incorporated different injectates such as ketorolac,[83] hyaluronic acid[39 49] and hypertonic saline,[84] which offered greater benefits than their controls (online supplemental table 3). One retrospective cohort study with a serious risk of bias found that there was no significant difference in clinical outcomes (VAS and improvement 0%–100%) between hydrodilatation with lidocaine and without lidocaine.[85]

Number of injections

68 studies performed only one hydrodilatation, while the remaining studies offered additional procedures if symptoms persisted, with some allowing up to five hydrodilatation procedures as part of their protocol. One large retrospective review

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of 2432 hydrodilatation cases reported that recurrent symptoms were seen in 184 cases, all of whom had repeated hydrodilatation at a median of 9 months. Following the second hydrodilatation, 137 cases did not require further intervention.[72] However, another case series showed that patients with single and repeat hydrodilatation both showed significant improvements in OSS without significant difference between groups.[86]

Subgroup analyses based on the number of hydrodilatation procedures (single vs multiple) demonstrated no significant differences in VAS, SPADI, external rotation and abduction between hydrodilatation and corticosteroid injection at 12 weeks. However, a single hydrodilatation procedure resulted in significantly greater forward flexion (SMD 0.63, 95% CI 0.36 to 0.90, I^2 13.1%) than a single corticosteroid injection, while there was no significant difference between three repeated hydrodilatation procedures and corticosteroid injections (SMD −0.20, 95% CI −0.51 to 0.10, I^2 0%).

When hydrodilatation combined with physical therapy (or exercise programme) was compared with physical therapy alone, multiple hydrodilatation procedures appeared to offer greater pain reduction than physical therapy alone (SMD 0.50, 95% CI 0.15 to 0.86, I^2 0%), whereas a single procedure did not (SMD 0.06, 95% CI −0.30 to 0.42, I^2 0%). On the other hand, physical therapy alone resulted in greater forward flexion improvement compared with a single hydrodilatation procedure (SMD −0.39, 95% CI −0.75 to −0.03, I^2 0%), while multiple procedures showed no significant difference (SMD 0.78, 95% CI −0.22 to 1.79, I^2 86.7%). There were no significant differences in other ROM measures.

Hydrodilatation with nerve block

Suprascapular nerve block (SSNB) was either added to hydrodilatation or compared with it in five studies,[87–91] while one RCT used interscalene nerve block during hydrodilatation procedure.[38] One retrospective cohort study with serious risk of bias reported greater improvements in VAS, ASES and DASH scores at 1 month when combining hydrodilatation with 40 mg triamcinolone with SSNB using 20 mg triamcinolone, compared with hydrodilatation alone. However, no significant differences were observed between groups at 24 weeks.[87] Another retrospective cohort study with serious risk of bias found that combining hydrodilatation with 40 mg triamcinolone and SSNB without steroid had a significantly better SPADI score at 2, 6 and 12 weeks. Intraprocedural VAS and improvements in ROM at 12 weeks were both significantly better in the combined group as well.[88] One prospective cohort study with serious risk of bias compared SSNB using triamcinolone 40 mg with hydrodilatation using triamcinolone 40 mg and found that there was no significant difference between these two treatments over 24 weeks although SSNB offered a faster onset of pain relief at 2 weeks.[91] One RCT with high risk of bias found that combining hydrodilatation without steroid and SSNB without steroid did not provide additional benefit compared with SSNB alone at 4 and 12 weeks in terms of VAS, quick DASH, and passive ROM.[89]

Other procedural variables and techniques

Previous studies have evaluated variations of hydrodilatation, including its combination with acupotomy to release the tissue thickening between the coracohumeral ligament and superior glenohumeral ligament,[92] the use of pumping technique[93] and its administration with subdeltoid subacromial bursa injections.[94 95] These approaches have been associated with greater improvements in clinical outcomes compared with hydrodilatation alone (online supplemental table 3).

Adverse events associated with hydrodilatation

Adverse events associated with hydrodilatation were mild and self-limiting overall. However, two cases of septic arthritis, which required urgent arthroscopic surgeries, were reported after hydrodilatation across the studies, corresponding to an infection incidence of 0.02% (two cases among 8754 patients undergoing hydrodilatation included in this review).[44 96] Also, there was one case of transient suprascapular nerve palsy from anaesthetic leakage to the supraglenoid notch[97] as well as one case of brachial plexus neuropraxia, which occurred after MUA combined with hydrodilatation and lasted 2 weeks.[63] The most commonly reported events include procedural pain, transient facial flushing and dizziness. A few cases of contrast allergy were noted in the fluoroscopy-guided group.[64] Other adverse events are summarised in online supplemental table 3.

Factors associated with hydrodilatation outcomes

Diabetes status: five studies suggested suboptimal outcomes in patients with diabetes mellitus, including less improvement in pain and ROM,[90 98 99] a higher rate of recurrence and a lower time to recurrence[100] and worse VAS and DASH scores,[101] requiring significantly more interventions following hydrodilatation.[102] However, others suggested no influence of diabetes on outcomes following hydrodilatation.[74 96 97 103]

Concomitant rotator cuff tear: while patients without rotator cuff tears demonstrated significant improvement in ROM and symptoms, patients with rotator cuff tears did not show significant change in the ROM.[104]

Stages of adhesive capsulitis: two studies reported better and faster functional recovery and ROM in stage I than stage II (three-stage model).[105 106] One case series showed that stage II patients had significant improvements in the L'Insalata Shoulder Rating Questionnaire and ROM, while none of the stage III patients had significant improvements in these measurements.[107]

Capsular stiffness: one study measured pressure-volume monitoring data during hydrodilatation and found that while shoulder pain in motion or rest did not correlate with capsular stiffness, patients with stiffer capsules tended to have distinct limitations in external rotation and abduction. Females demonstrated significantly stiffer capsules than males, and having diabetes was not associated with capsular stiffness.[108]

Psychosocial: one study identified that kinesiophobia, depression and anxiety at baseline were significantly predictive of VAS and abduction at 12 weeks. Kinesiophobia and depression were also predictive of a lower Constant-Murley Score and forward flexion score, while depression and anxiety predicted a higher residual disability index at 12 weeks.[109]

One study identified that use of analgesic medication prior to hydrodilatation, coracohumeral thickness <3 mm and female sex were associated with good improvement in SPADI at 8 weeks.[79]

Fat replacement and capsular thickness seen on MRI,[110] prehydrodilatation ROM,[111] age,[103] duration of symptoms[97 103] and previous physiotherapy[97] were not associated with outcomes following hydrodilatation.

The remaining 18 case series[11 112–128] not mentioned above but included in this review are summarised in online supplemental table 3.

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DISCUSSION

To the best of our knowledge, this is the most comprehensive and largest systematic review to date evaluating the efficacy of hydrodilatation and characterising variations in hydrodilatation techniques. Our key findings of meta-analyses are as follows: (1) based on low-certainty evidence, compared with corticosteroid injection, hydrodilatation using various techniques was associated with greater external rotation at 12 weeks (MD 7.5, 95% CI 1.7 to 13.2), without significant differences in VAS and SPADI scores, abduction and forward flexion; (2) compared with physical therapy alone, hydrodilatation combined with physical therapy (or exercise programme) was associated with better VAS (MD 0.26, 95% CI 0.01 to 0.51; low-certainty evidence) and SPADI scores (MD 9.2, 95% CI 1.3 to 17; very low-certainty evidence) at 12 weeks, without significant differences in ROM measures; (3) the anterior approach was associated with greater pain reduction (MD 0.47, 95% CI 0.11 to 0.84; low-certainty evidence) and abduction improvement (MD 10.5, 95% CI 0.7 to 20.3) at 12 weeks. The ideal injection volume, capsular status and number of injections remain inconclusive; however, subgroup analyses from a small number of studies suggest that a hydrodilatation volume greater than 20 mL may provide greater pain reduction.

Although adhesive capsulitis is often considered a self-limiting condition resolving over 1–4 years, a previous systematic review found a lack of evidence to support this theory and suggested that without treatment, full recovery is less likely.[129] In its early stage, adhesive capsulitis is characterised by inflammatory hypervascular synovitis, which progressively leads to abnormal fibroblastic proliferation and capsular fibrosis.[130] Intra-articular steroid injection may alleviate pain by reducing inflammation and potentially limiting the progression of fibrosis, a benefit supported by findings from a prior systematic review.[131] Nonetheless, steroid injection alone may not be sufficient to address the loss of ROM caused by reduced capsular volume, which in adhesive capsulitis is estimated to be 5–10 mL compared with 28–35 mL in a healthy shoulder.[132] The addition of hydrodilatation to steroid injection may have a synergistic effect by providing expansion of the contracted capsule and mechanically disrupting adhesions and scar tissues. Despite its theoretical advantages, our meta-analyses found only low-certainty evidence supporting an external rotation improvement with hydrodilatation compared with corticosteroid injection. Although the minimal clinically important differences (MCID) for ROM improvement in adhesive capsulitis have not been established, the observed mean difference of 7.5° is relatively small. Furthermore, the clinical significance of these changes remains questionable, as abduction and flexion are more involved in a broader range of activities of daily living than external rotation.[133]

While corticosteroid injections alone may be sufficient for pain control, based on the subgroup analysis from a limited number of studies, hydrodilatation using volumes greater than 20 mL appears to offer superior pain relief compared with corticosteroid injections alone. Some of the studies included in our review also support this finding, as higher volumes were associated with better outcomes,[72 73] although one study reported that volumes ≥50 mL negatively affected OSS improvement.[74] Despite the potential role of volume, a corticosteroid remains a critical component of hydrodilatation, as outcomes are consistently better when corticosteroids are included in hydrodilatation compared with when they are not.[31 80 81]

Other important considerations when performing the hydrodilatation procedure—besides injection volume—include imaging guidance, injection approach and capsular preservation. Both fluoroscopy and ultrasound were commonly used in the studies included in our review, with the anterior approach more frequently used under fluoroscopy and the posterior approach more common under ultrasound. Given that the primary pathological sites in adhesive capsulitis involve the rotator interval, anterior/axillary joint capsule and coracohumeral ligament, the anterior approach may offer greater therapeutic benefits by directly targeting these areas. This theory is partially supported by our meta-analysis, which found that hydrodilatation using the anterior approach was associated with greater improvements in pain reduction and shoulder abduction, with low certainty of evidence and a mean difference in pain VAS not exceeding the MCID of 1.1 reported in prior literature.[134] These findings are consistent with a recent systematic review,[135] but differ from another review which included studies undergoing either corticosteroid injection or hydrodilatation, which reported a clinically significant improvement in VAS (MD 1.3).[136] While both fluoroscopy and ultrasound can deliver the injectate into the glenohumeral joint with similar accuracy,[135] fluoroscopy has notable disadvantages, including the risk of contrast allergy, which has been reported in some of the studies included in our review, and radiation exposure. In contrast, ultrasound was found to be preferred by patients, have a shorter procedure duration, be more cost-effective,[65] as well as provide real-time visualisation of joint expansion. Interestingly, the injection volume was notably higher in studies that used fluoroscopy (median 38.7 mL) compared with those that used ultrasound (median 21 mL). This larger volume associated with fluoroscopy suggests a greater likelihood of capsular rupture and possible extravasation of the injectate.

When hydrodilatation was first described by Andren and Lunberg in 1965,[11] the intended endpoint of the procedure was capsular rupture, as this was thought to achieve maximal expansion and, consequently, the greatest clinical improvement. However, capsular rupture frequently occurs at the subscapularis recess or along the long head of the biceps tendon sheaths,[112 115 120] areas that may represent the weakest, rather than the tightest, portions of the capsule. More recent studies have instead focused on preserving the capsule, hypothesising that this approach helps retain the injected corticosteroid within the joint, thereby maximising its anti-inflammatory effects and prolonging pain relief. This theory is supported by two cohort studies included in our review,[77 78] which showed superior outcomes with capsular preservation. Nonetheless, findings remain mixed, as other observational studies reported inconsistent associations between capsular status and clinical outcomes.[72 75 79] The studies included in our review also reported a wide range of volumes at which rupture occurred, making it difficult to draw definitive conclusions about how capsular status influences outcomes. Furthermore, these findings underscore the need to individualise injected volumes to perform capsule-preserving techniques.

While hydrodilatation provided benefits in ROM compared with corticosteroid injection, hydrodilatation added to a physical therapy or exercise programme did not provide additional benefit in ROM at 12 weeks. Our meta-analyses found low certainty and very low certainty of evidence for the benefits in VAS as well as SPADI scores, respectively, but these findings were not robust in sensitivity analyses. Furthermore, the mean differences in VAS (0.26) and SPADI (9.2) did not exceed the MCIDs reported in prior literature (1.1 for VAS[134] and 8–13 for SPADI).[137] These findings highlight that the additional benefit of hydrodilatation for pain and function in patients already undergoing physical therapy may be marginal. Although evidence is

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mixed regarding the superiority of supervised physical therapy over home exercise programmes, postprocedural shoulder mobilisation and ROM exercises, regardless of supervision, were components of recovery following hydrodilatation in the literature included in our review.

Clinical implications

To date, numerous systematic reviews with meta-analysis or network meta-analysis have investigated treatment options for adhesive capsulitis, often with conflicting conclusions. Recommended treatments range from physical therapy, intra-articular corticosteroid injections, intra-articular platelet-rich plasma injections, extracorporeal shockwave therapy, laser therapy, ultrasound therapy, SSNB, hydrodilatation, MUA and arthroscopic releases.[14 135 138–143] While some systematic reviews[12 14 139 143] have suggested that hydrodilatation may be superior to corticosteroid injection or physical therapy, our meta-analyses of RCTs indicated low to very low certainty evidence supporting the use of hydrodilatation over corticosteroid injection or the addition of hydrodilatation to physical therapy at 12 weeks. The marginal benefits seen with hydrodilatation are unlikely to be clinically meaningful based on the MCIDs reported in the previous literature. Furthermore, although approximately one third of the included studies offered additional injections, our subgroup analysis suggests that repeat injections may not necessarily confer additional benefits. Therefore, while hydrodilatation remains one of several treatment options for adhesive capsulitis, its superiority over other non-operative interventions remains uncertain. Given some or high concerns for risk of bias and methodological limitations in the included trials, clinicians should engage in shared decision-making with patients considering individual goals, accessibility, procedural risks, costs and the generally favourable natural history of adhesive capsulitis. Based on our review, the most common procedural risk was pain during the procedure, while septic arthritis, although extremely rare (0.02%), represents a potentially life-threatening complication if not promptly recognised and treated. Some of the trials included in our review performed SSNB prior to hydrodilatation, and the SSNB may not only help patients tolerate the procedure better but also provide additional benefits. One recent systematic review concluded that the SSNB can provide better pain relief, functional improvement and abduction up to 12 weeks.[142] Postprocedural exercise was a component of rehabilitation following the hydrodilatation procedure in the included studies, aligning with expert consensus recommendations.[144] However, a recent RCT challenged this view, reporting no significant differences in patient-reported outcome measures between watchful waiting and physical therapy following intra-articular steroid injection, while physical therapy was associated with significantly higher direct costs and greater economic burden on the healthcare system.[145]

Arthroscopic capsular release and MUA represent more invasive treatment options for adhesive capsulitis. While limited studies included in this review suggest that arthroscopic release may lead to improved ROM and patient-reported functional outcomes compared with hydrodilatation, the benefits of MUA are less well established. A systematic review with network meta-analysis, including both surgical and non-surgical interventions, concluded that no single treatment demonstrated clear superiority over others. However, arthroscopic release after failure of conservative management was associated with the greatest improvements in ROM.[140] Despite this potential benefit, hydrodilatation may serve as a non-surgical alternative prior to considering surgical approaches, given the risks and invasive nature of these approaches. In fact, in a large retrospective review of 2432 hydrodilatations, only 41 cases (1.7%) ultimately required arthroscopic capsular release, with repeat hydrodilatation reducing the need for further intervention.[72]

Several patient-related factors that can affect hydrodilatation outcomes include diabetes mellitus, concomitant rotator cuff tears, advanced stages, coracohumeral thickness and psychosocial variables, such as kinesiophobia, depression and anxiety. Given these findings, patient education should be individualised to address these specific risk factors and to set expectations regarding the recovery trajectory.

Limitations and future research direction

Our study has several limitations. First, there was substantial heterogeneity in the hydrodilatation procedures and postprocedural rehabilitation protocols across the studies included in our meta-analyses. Although we used random-effects models to account for this variability and conducted subgroup analyses based on injection volumes above and below 20 mL and number of injections, the optimal injection volume, corticosteroid dose, capsular rupture versus preservation and standardised rehabilitation protocols remain unclear and warrant further investigation. Second, the stages of adhesive capsulitis were not consistently reported across studies, making it difficult to determine which stage may be most appropriate for hydrodilatation. Third, the overall certainty of evidence derived from the GRADE assessment was rated ‘very low’ to ‘low’, mainly due to risk of bias, inconsistency and imprecision. Publication bias was not assessed because of the small number of included trials, which may further lower the overall certainty of evidence. Fourth, while some studies reported outcomes beyond 12 weeks, most studies, particularly those included in the meta-analyses, only assessed outcomes up to 12 weeks, making it difficult to determine the durability of treatment effects over the long term. It is also important to note that no study to date has compared hydrodilatation with a wait-and-see approach; therefore, it remains unknown whether hydrodilatation can facilitate recovery beyond the natural course of adhesive capsulitis.

Further high-quality RCTs are needed to optimise the hydrodilatation procedure and to establish standard protocols for injection volume, corticosteroid dose, capsular status and postprocedural rehabilitation strategies. Given the progressive nature of adhesive capsulitis, incorporating longer-term follow-ups will also be essential. Lastly, considering the higher prevalence of adhesive capsulitis among postmenopausal women, future research should consider exploring the sex-based differences and/or the role of hormonal factors in response to hydrodilatation.

CONCLUSION

Hydrodilatation using various techniques was associated with marginally greater external rotation at 12 weeks with low certainty of evidence and without significant differences in pain VAS, SPADI, abduction and forward flexion compared with corticosteroid injection. The benefit of adding hydrodilatation for pain and function in patients already undergoing physical therapy appears to be minimal, given the clinically insignificant improvements observed with low to very low certainty of evidence. Despite the limited evidence supporting hydrodilatation, when the procedure is considered, the anterior approach may offer a small advantage in pain reduction and abduction. Further high-quality trials are warranted to confirm

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clinically meaningful benefits of hydrodilatation and to determine the optimal injection volume, capsular status and number of injections.

Contributors HCR conceived and designed the study. HCR, JS, GO, RF, RCG, DBC, XP and JR had full access to all data in the study and take responsibility for the integrity of the data. HCR, JS, GO, RF, RCG, DBC, XP, JR and RD interpreted the data and wrote the first draft of the manuscript. DMR and KCM contributed to the review and editing of the manuscript. All authors reviewed and approved the final version of the manuscript. HCR is the guarantor. ChatGPT V.5.2 was used to check grammar and improve clarity throughout the manuscript.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement No data are available.

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