



Chronic calcific tendonitis of the rotator cuff: a systematic review and meta-analysis of randomized controlled trials comparing operative and nonoperative interventions

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Background: Calcific tendinitis is a relatively common shoulder disorder, with 7%-17% of individuals with shoulder pain having rotator cuff calcium deposits. Several nonoperative interventions, extracorporeal shockwave therapy (ESWT) and ultrasonography-guided needling (UGN), and surgical techniques have been described to treat calcific tendonitis with satisfactory outcomes. Clinical guidelines are lacking for surgical excision in cases refractory to nonoperative treatment. Several arthroscopic and open operative techniques have been described to treat calcific tendonitis with satisfactory clinical outcomes. The purpose of this systematic review of randomized controlled trials is to compare outcomes and complications of nonoperative vs. operative management of chronic calcific tendinitis of the rotator cuff, to provide evidence-based treatment guidelines for practitioners.

Methods: EMBASE, PubMed, and OVID [MEDLINE] were searched from database inception until February 20, 2022, for randomized controlled trials reporting outcomes related to operative or nonoperative management for calcific tendonitis of the shoulder. Clinical outcomes including pain on visual analog scale (VAS), Constant-Murley Shoulder Outcome Score (CMS), and resolution of calcific deposits were evaluated. Continuous data at last follow-up was pooled into mean differences using a random effects model for meta-analysis.

Results: A total of 27 studies (2212 nonoperative patients and 140 operative patients) met the final inclusion criteria. Pooled mean difference in VAS for ESWT was -3.83 (95% confidence interval [CI] $-5.38, -2.27$); $P < .001$, compared to -4.83 (95% CI $-5.44, -4.22$; $P < .001$) for UGN, and -4.65 (95% CI $-5.47, -3.82$; $P < .001$) for the operative interventions. Pooled mean difference in CMS score after ESWT was 18.30 (95% CI $10.95, 25.66$; $P < .001$) compared to 22.01 (95% CI $8.17, 35.84$; $P = .002$) for UGN, and 38.35 (95% CI $31.68, 45.02$; $P < .001$) for the operative interventions. Eighty-five percent of patients receiving operative and 67% of patients receiving UGN management had complete radiographic resolution of calcific deposit.

Conclusions: Surgical treatment of chronic calcific tendonitis of the rotator cuff results in larger improvement in functional outcome scores and comparable pain reduction to nonoperative interventions, particularly UGN. Both operative and nonoperative treatment modalities are likely to have clinically significant improvements in function and pain, and thus it is reasonable to trial UGN and ESWT as

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first-line treatment. Cost-effectiveness analyses will be needed to support one treatment over the other. High-quality randomized controlled trials directly comparing nonoperative interventions to operative interventions in patients prior to failing conservative treatment are needed to establish high-quality evidence-based guidelines.

Level of evidence: Level II; Systematic Review and Meta-Analysis

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Keywords: Calcific tendonitis; shoulder; rotator cuff; surgery; nonoperative management; randomized controlled trial; systematic review; meta analysis

Calcific tendinitis is a relatively common shoulder disorder, with 7%-17% of individuals with shoulder pain having rotator cuff calcium deposits.¹⁷ It is associated with middle-aged individuals and is caused by reactive or degenerative intracellular calcium hydroxyapatite deposition. The most commonly affected area is the midsubstance and hypovascular region of the supraspinatus tendon.⁴⁵ Calcific deposits eventually undergo resorption by cell-mediated phagocytosis. Acute pain is generated by active resorption, chemical irritation and bursitis caused by presence of calcium, as well as localized swelling and reduced subacromial space.²⁴ Once resorbed or surgically excised, the remaining space may become filled with granulation tissue, and it is doubtful that new tendon is formed.

Calcific tendonitis is often self-limited, and thus initial treatment is often conservative with symptom relief using oral anti-inflammatory or analgesic medication, subacromial steroid injection, and physical therapy. If the symptoms persist beyond 8 weeks, the calcific tendonitis is considered chronic and alternative nonoperative therapies are considered in the form of extracorporeal shock-wave therapy (ESWT) or ultrasonography-guided needle barbotage (UGN). These nonoperative therapies have shown to provide reliable successful outcomes in 70%-80% of patients with chronic calcific tendinitis.^{7,10,14} However, patients with chronic symptomatic calcium deposits may still have spontaneous healing within a few weeks. In the other 20%-30% that have persistent symptoms following the nonoperative interventions, surgery for symptom relief may be performed.^{7,44}

There remain no high-quality evidence-based guidelines to support the current clinical treatment of chronic calcific tendonitis. Most recently, Surace et al⁵² in a Cochrane review comparing the use of ESWT to placebo, described few clinical benefits of ESWT, and there was uncertainty regarding its safety. In another systematic review, LaFrance et al²⁸ described superior effectiveness of UGN over ESWT; however, the evidence was of low-quality. Despite this uncertainty, nonoperative therapies have remained first-line treatment for chronic calcific tendonitis.² There are several arthroscopic and open surgical techniques that have been described to treat calcific tendonitis, and all have shown satisfactory clinical outcomes with low complication rates.^{20,33,34,54} The purpose of this systematic review of level II studies is to compare outcomes and complications of nonoperative vs. operative management of chronic

calcific tendinitis of the rotator cuff, to provide evidence-based treatment guidelines for practitioners.

Materials and methods

Literature search

Using methodology outlined by the Cochrane Collaboration¹⁸ and PRISMA guidelines,²⁹ the literature was searched using 3 main online databases: EMBASE, PubMed, and MEDLINE. Literature was searched from database inception until February 20, 2022, for articles related to operative or nonoperative management of calcific tendonitis of the shoulder. Free text was supplemented with MeSH and Emtree terms to increase sensitivity. Full search strategy ([Supplementary Appendix S1](#)).

Study screening

All titles, abstracts, and full texts were screened in duplicate by two independent reviewers (H.A., M.O.). Any disagreements at the title and abstract stages were moved forward to the next round of screening to ensure relevant articles were not missed. Disagreements at the full-text stage were reviewed with a third senior author to determine the final eligibility of the article (M.C.G.).

Study eligibility

The inclusion and exclusion criteria of this study were established a priori. The following were the inclusion criteria: (1) randomized controlled trials only, (2) clinical symptoms related to calcific tendonitis of the shoulder confirmed by radiologic or ultrasonographic examination, (3) outcomes of operative or nonoperative management were included, and (4) articles published in English. The following were the exclusion criteria: (1) nonrandomized studies, (2) diagnostic studies, (3) articles without adequately reported functional outcomes (eg, technique papers), and (4) cadaver/nonhuman studies.

Quality assessment

The quality of individual studies was assessed by the reviewers (H.A., M.C.G.). The Cochrane Risk of Bias Tool was used for all randomized controlled trials (RCTs). The tool assesses potential selection bias, reporting bias, performance bias, detection bias, attrition bias, and other sources of bias. A score of either high, low, or unclear bias is given for each domain.

Data abstraction

Relevant data from included studies were abstracted into a Microsoft Excel spreadsheet (Microsoft Excel for Microsoft 365 MSO). Demographic data included author, study location, study design, and year of publication. Descriptive statistics included age, sex, BMI, sample size, percentage male, follow-up time points, affected tendon, baseline percentage calcification, and size of lesion. Elements of study design were also abstracted, such as randomization, blinding, treatment protocol, postintervention treatment protocol, inclusion and exclusion criteria, preexisting pathology, and history of prior treatment. Outcome measures that were abstracted include functional improvement—Constant-Murley score (CMS), pain reduction (visual analog scale [VAS]), resolution of calcific deposit (radiologic classifications), treatment complications, and loss to follow-up.

Statistical analysis

Descriptive statistics including proportions, means, ranges, and measures of variance (eg, standard deviations [SDs], 95% confidence intervals [CIs]) are presented where applicable as a range of all values reported at final follow-up within the individual studies. Continuous data at last follow-up were pooled into mean differences using a random effects model for meta-analysis. Final follow-up ranged from 3 weeks to 12 years, had a median last follow-up of 12 months, and 12 months was the most reported last follow-up. A kappa (κ) statistic was used to evaluate inter-reviewer agreement at all screening stages. Agreement was categorized a priori as follows: ICC/ κ of 0.81-0.99 was considered as almost perfect agreement, 0.61-0.80 as substantial agreement, 0.41-0.60 as moderate agreement, 0.21-0.40 as fair agreement, and values ≤ 0.20 were considered slight agreement.⁵⁵ Calculations were performed using Microsoft Excel (version 2016; Microsoft, Redmond, WA, USA).

Review Manager 5.4 (The Cochrane Collaboration, 2020) was used to perform the meta-analysis. Continuous data were presented as mean differences with a 95% CI. The χ^2 and I^2 statistics were used to measure the heterogeneity of results within the included studies. $P < .05$ was considered significant for the χ^2 test. The I^2 test was categorized as follows: 0.0%-24.9% to indicate no heterogeneity; 25.0%-49.9%, low heterogeneity; 50.0%-74.9%, moderate heterogeneity; and 75.0%-100.0%, high heterogeneity.¹⁹ Heterogeneity was addressed using a random effects model and performing subgroup analyses where applicable.

Results

Study identification

The initial search yielded 503 studies, of which 27 full-text articles met the inclusion criteria (Fig. 1). Agreement on study inclusion for title was substantial ($\kappa = 0.609$, 95% CI 0.529, 0.690), for abstract was perfect ($\kappa = 0.889$, 95% CI 0.801, 0.976), and for full-text was substantial

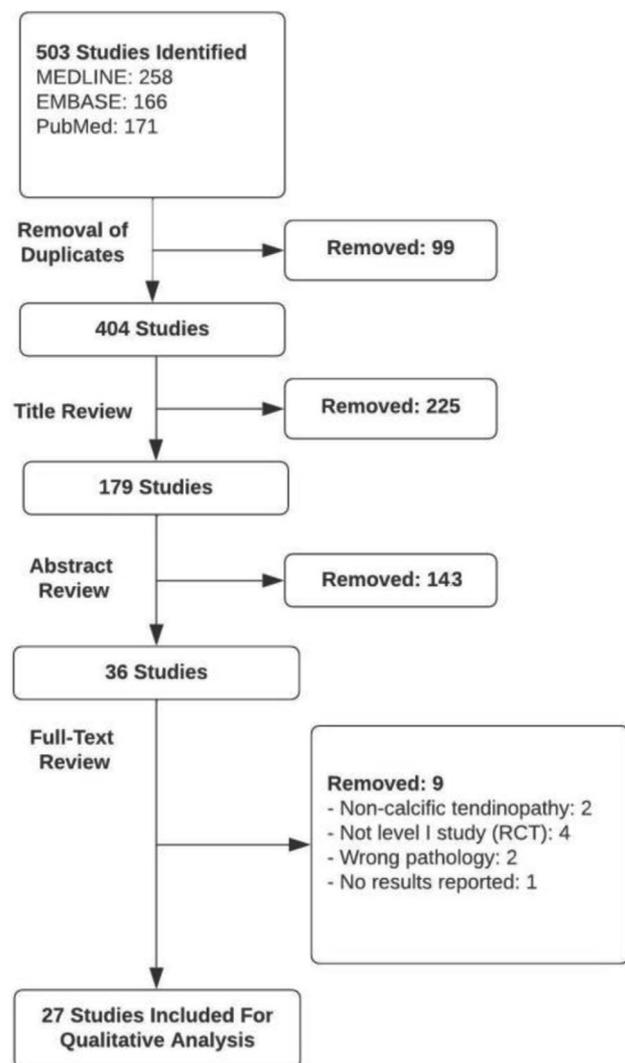


Figure 1 A summary of literature search and screening results according to PRISMA guidelines.

($\kappa = 0.680$, 95% CI 0.392, 0.968). The characteristics of all included studies can be found in Table I.

Study characteristics

All included studies were conducted between 1997 and 2020.^{1,3,5,6,8,13,15,21,25,26,31,35-41,47,49,50,55-58,60} There were 3 studies (140 patients) that included operative interventions. Surgical techniques varied between the included studies. Clement et al⁵ performed arthroscopic bursectomy with shaver, removal of calcific deposits, and comparison of procedures with or without subacromial decompression. Rotator cuff ruptures were excluded from the study, and rotator cuff repair was not performed. Rubenthaler et al⁵² compared endoscopic vs. open partial removal of subacromial bursa, decompression with acromioplasty, and ligament incision with calcium deposit removal. Tendon incisions were closed in the open treatment group and left

Table I Summary of level II evidence for operative and nonoperative management of rotator cuff calcific tendonitis

Study	Interventions	Sample size	% male	Age, mean (y)	Mean duration of symptoms preintervention (mo)	Postprocedure protocol	Follow-up (mo)	Outcome measures
Louwerens (2020) ³¹	ESWT; UGN	82	31.7	ESWT: 51.6 UGN: 52.7	>4	PT, analgesics	1.5, 3, 6, 12	CMS, DASH, VAS, resolution of deposit, radiologic (radiographs)
Papadopoulos (2019) ³⁷	Acupuncture; Sham	38	44.7	Acupuncture: 46 Sham: 45	NA	Exercise protocol	0.75, 18-24	VAS, ROM using goniometer, Instrumental Activities of Daily Living Scale, Beck Depression Inventory, radiologic (radiographs)
Pieber (2018) ⁴⁰	UGN; Sham	45	51.1	49.1	>4	NA	9, 120	CMS, resolution of deposit, radiologic (radiographs)
Frassanito (2018) ¹³	ESWT + Kinesio tape; ESWT	41	51.2	ESWT + Kinesio tape: 54.1 ESWT: 48.7	>0.5	NA	0.25, 1, 3	VAS, DASH, SSRQ, Oxford Shoulder Score, radiologic (US, radiographs, MRI)
de Witte (2017) ⁵⁷	UGN + subacromial corticosteroid injection; UGN	48	47.9	52	NA	NSAIDs/ analgesics, ice, second barbotage if persisting symptoms at 6 mo	1.5, 3, 6, 12, 60	CMS, WORC, DASH, VAS, disability of the arm, resolution of deposit, radiologic (US, radiographs)
Orlandi (2017) ³⁵	UGN–single needle; UGN–double needle	211	36.5	41.6	NA	Ice	1, 3, 12	CMS, radiologic (US)
Battaglia (2017) ³	UGN + triamcinolone injection; UGN + methylprednisolone	40	55.0	48.7	NA	Ice, NSAIDs, standardized exercise program	0.03, 0.23, 0.5, 1, 1.5, 6	CMS, VAS, use of NSAIDs, resolution of deposit, radiologic (US)
Del Castillo-González (2016) ⁸	ESWT; UGN	243	26.3	49	NA	NSAIDs	3, 6, 12	VAS, resolution of deposit, radiologic (US)
Clement (2015) ⁵	Surgery–abd with decompression; Surgery–abd without decompression	80	73.8	49	6.75 (median)	Encouraged immediate movement	1.5, 12	DASH, SF-12, CMS, radiologic (radiographs)
Kim (2014) ²⁵	UGN; ESWT	48	52.1	UGN + SA injection: 57.4 ESWT: 53.9	>3	NSAIDs, no activity limitations	1.5, 3, 6, 12	American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form, Simple Shoulder Test, VAS, resolution of deposit, radiologic (US, radiographs)
Sabeti (2014) ⁴⁸	Surgery–abd conventional; Surgery–abd US	20	NA	47.6 ± 7.91	31.5	NA	1.5, 9	CMS, VAS, resolution of deposit
de Witte (2013) ⁵⁸	UGN; Subacromial corticosteroid injection	46	50.0	52	>3	NSAIDs, ice, PT	1.5, 3, 6, 12	CMS, WORC, DASH, VAS, disability of the arm, resolution of deposit, radiologic (US, radiographs)
Ioppolo (2012) ²¹	ESWT–high energy; ESWT–low energy	462	5.0	ESWT-H: 57.09 ESWT-L: 51.65	>4-6	NSAIDs before treatment	3, 6, 12	Resolution of deposit, radiologic (radiographs)
Sconfienza (2012) ⁵⁰	UGN–warm saline; UGN–room temperature saline	81	235.8	39.7	NA	Ice, no other specified procedure	1, 2, 3, 12	VAS, ease of calcium dissolution, procedure duration, resolution of deposit, radiologic (US)

(continued on next page)

Table I Summary of level II evidence for operative and nonoperative management of rotator cuff calcific tendonitis (continued)

Study	Interventions	Sample size	% male	Age, mean (y)	Mean duration of symptoms preintervention (mo)	Postprocedure protocol	Follow-up (mo)	Outcome measures
Tornese (2011) ⁵⁵	ESWT-neutral; ESWT-hyperextended and internal rotation	80	17.5	ESWT-neutral: 53 ESWT-hyperextended and internal rotation: 52.2	NA	PT, no analgesics	3	CMS, resolution of deposit, radiologic (radiographs)
Zhu (2008) ⁶⁰	UGN-with aspiration; UGN-without aspiration	80	62.5	UGN-aspirate: 52.3 UGN-no aspirate: 53.1	UGN-aspirate: 11 UGN-no aspirate: 10	NSAIDs, PT	0.25, 0.5, 0.75, 1.5, 3, 6, 9	VAS, shoulder function and satisfaction, radiologic (US, plain radiographs)
Albert (2007) ¹	ESWT-high energy; ESWT-low energy	90	50.0	ESWT-H: 46.6 ESWT-L: 47.5	>6	NSAIDs, no activity limitations	3	CMS, VAS, resolution of deposit, radiologic (radiographs)
Cacchio (2006) ⁴	RSWT; Sham	50	100.0	RSWT: 56.12 Sham: 56.42	RSWT: 14 Sham: 13	NA	6	UCLA, VAS, resolution of deposit, radiologic (US, MRI)
Sabeti-Aschraf (2005) ⁴⁹	ESWT-feedback; ESWT-navigation	80	27.5	ESWT-feedback: 52.96 ESWT-navigation: 52.4	>6	NA	3	CMS, VAS, resolution of deposit, radiologic (CT, radiographs)
Krasny (2005) ²⁶	UGN + ESWT; ESWT	57	68.4	48.4	>12	NSAIDs, ice	4.1	CMS, resolution of deposit, radiologic (US, plain radiographs, MRI)
Pleiner (2004) ⁴¹	ESWT-high energy; ESWT-low energy	70	17.1	ESWT-H: 54 ESWT-L: 50	>6	Not standardized	0.25, 3, 7	CMS, VAS, resolution of deposit, radiologic (radiographs)
Cosentino (2003) ⁶	ESWT; Sham	80	33.8	51.8	ESWT: 15 Sham: 14.5	NA	1, 6	CMS, resolution of deposit, radiologic (radiographs)
Perlick (2003) ³⁸	ESWT-high energy; ESWT-low energy	144	25.0	48.4	>12	NA	3, 12	CMS, VAS, resolution of deposit, radiologic (US, plain radiographs, MRI)
Gerdesmeyer (2003) ¹⁵	ESWT-high energy; ESWT-low energy; ESWT-sham	60	95.0	ESWT-H: 51.6 ESWT-L: 47.3 Sham: 52.3	>6	PT, NSAIDs/ analgesics	3, 6, 12	CMS, VAS, resolution of deposit, radiologic (radiographs)
Pan (2003) ³⁶	ESWT; TENS	21	100.0	ESWT: 55.21 TENS: 58	>6	NA	0.5, 1, 3	CMS, VAS, manual muscle test, radiologic (US)
Rubenthaler (2003) ⁴⁷	Surgery-open; Surgery-endoscopic	40	17.5	Open:51.6 Endoscopic: 50.4	NA	PT	Open:15.7 Endoscopic: 17.1	CMS, Patte, radiologic (radiographs)
Perron (1997) ³⁹	Acetic acid iontophoresis (AAI)+ UGN; Sham	35	17.1	AAI + UGN: 43 Sham: 40	AAI + UGN: 45 Sham: 31	Analgesics, no icing, warming, or massages, limited activity	0.25, 0.5, 0.75	ROM, pain intensity, resolution of deposit, radiologic (US)

ESWT, extracorporeal shockwave therapy; UGN, ultrasonography-guided needle barbotage; RSWT, radial shockwave therapy; TENS, transcutaneous electric nerve stimulation; SA, subacromial; NA, not available; PT, physical therapy; NSAIDs, nonsteroidal anti-inflammatory drugs; CMS, Constant-Murley score; DASH, Disabilities of the Arm, Shoulder, and Hand questionnaire; VAS, visual analog scale; ROM, range of motion; SSRQ, Short Form Self-Regulation Questionnaire; US, ultrasonography; MRI, magnetic resonance imaging; WORC, Western Ontario Rotator Cuff Index; SF-12, 12-Item Short Form Health Survey; UCLA, University of California, Los Angeles Shoulder Rating Scale; CT, computed tomography.

Surgery-abd with decompression: surgery—arthroscopic bursectomy debridement of rotator cuff with subacromial decompression; *Surgery-abd without decompression*: surgery—arthroscopic bursectomy debridement of rotator cuff without subacromial decompression; *Surgery-open*: open surgery—removal of the subacromial bursa followed by decompression with acromioplasty and ligament incision in addition to calcium deposit removal; *Surgery-endoscopic*: endoscopic surgery—removal of the subacromial bursa followed by decompression with acromioplasty and ligament incision in addition to calcium deposit removal; *Surgery-abd conventional*: surgery—arthroscopic bursectomy and debridement of rotator cuff with conventional localization; *Surgery-abd US*: surgery—arthroscopic bursectomy and debridement of rotator cuff with ultrasonographic localization.

Table II Cochrane risk of bias of included randomized controlled trials

Study	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Anonymizing of participants and personnel (performance bias)	Anonymizing of outcome of assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)
Louwerens (2020) ³¹	+	?	-	+	+	+
Papadopoulos (2019) ³⁷	+	+	?	+	+	-
Pieber (2018) ⁴⁰	?	?	?	+	-	+
Frassanito (2018) ¹³	+	+	-	?	+	+
de Witte (2017) ⁵⁷	+	+	+	+	+	+
Orlandi (2017) ³⁵	+	?	-	-	+	+
Battaglia (2017) ³	+	?	+	+	+	-
Del Castillo-González (2016) ⁸	+	?	-	?	-	-
Clement (2015) ⁵	+	?	+	+	+	+
Kim (2014) ²⁵	+	?	-	+	+	+
Sabeti (2014) ⁴⁸	?	?	?	+	-	+
de Witte (2013) ⁵⁸	+	+	+	+	+	+
Ioppolo (2012) ²¹	+	?	?	+	-	+
Sconfienza (2012) ⁵⁰	?	?	-	-	-	+
Tornese (2011) ⁵⁵	+	?	?	+	+	+
Zhu (2008) ⁶⁰	?	?	?	?	-	+
Albert (2007) ¹	+	+	?	+	+	+
Cacchio (2006) ⁴	+	+	?	+	+	+
Sabeti-Aschraf (2005) ⁴⁹	+	+	?	+	+	+
Krasny (2005) ²⁶	+	+	?	+	+	+
Pleiner (2004) ⁴¹	?	?	+	+	-	-
Cosentino (2003) ⁶	-	-	+	?	?	?
Perlick (2003) ³⁸	?	?	?	?	?	?
Gerdesmeyer (2003) ¹⁵	+	+	+	-	?	+
Pan (2003) ³⁶	+	?	-	-	+	+
Rubenthaler (2003) ⁴⁷	+	+	-	?	+	+
Perron (1997) ³⁹	?	?	?	+	?	?

open in the endoscopic group. Sabeti et al⁵⁵ performed arthroscopic bursectomy with a high-frequency device (a shaver was not used) and compared conventional vs. ultrasonographic localization for calcium deposit removal. No rotator cuff tendons were repaired. There were 1130 patients who received UGN as part of their intervention, and UGN was included as an intervention in 13 studies. There were 786 patients that received ESWT as part of their intervention and ESWT was included as an intervention in 13 studies. Injection of either corticosteroids, triamcinolone, methylprednisolone, or acetic acid were interventions in 4 studies. There were also other interventions that only appeared in single studies, including radial shockwave therapy, kinesio tape, transcutaneous electric nerve stimulation, and acupuncture. The studies including injections, radial shockwave therapy, kinesio tape, transcutaneous electric nerve stimulation, and acupuncture as interventions were pooled together as “nonoperative” studies along with studies that included UGN and ESWT. There were 24 nonoperative studies, and this pooled group included 2212 patients. The nonoperative group included combined interventions (eg, UGN + ESWT). Overall, a total of 2352 participants received an intervention for calcific tendonitis

of the shoulder. The mean sample size of the included studies was 90.5 patients (range, 20-243). Of these patients, 53.6% were male, with a mean age of 48.3 ± 8.3 years, with a median duration of symptoms before participating in the study of >6 months, with a median overall follow-up postintervention of 4.5 months, and a median last follow-up postintervention of 12 months. Rotator cuff repairs were not included in the protocols for the surgical studies. Nineteen of the studies described a postprocedure rehabilitation program. These rehabilitation protocols included a combination of anti-inflammatory medications, ice, activity limitations, and formalized physical therapy.

Study quality and risk of bias

A total of 27 randomized studies were included in this review and all the studies were of level II evidence (n = 27) (Table II).^{1,3,5,6,8,13,15,21,25,26,31,35-38,40,41,47,49,50,55,57,58,60} The included studies were generally at low risk of reporting and selection bias, moderately low risk of attrition and detection bias, and unclear risk of performance and selection bias (Fig. 2, Table II). Of the 27 included studies, only 4 included a sham/control group.^{4,15,39} The other 23 studies

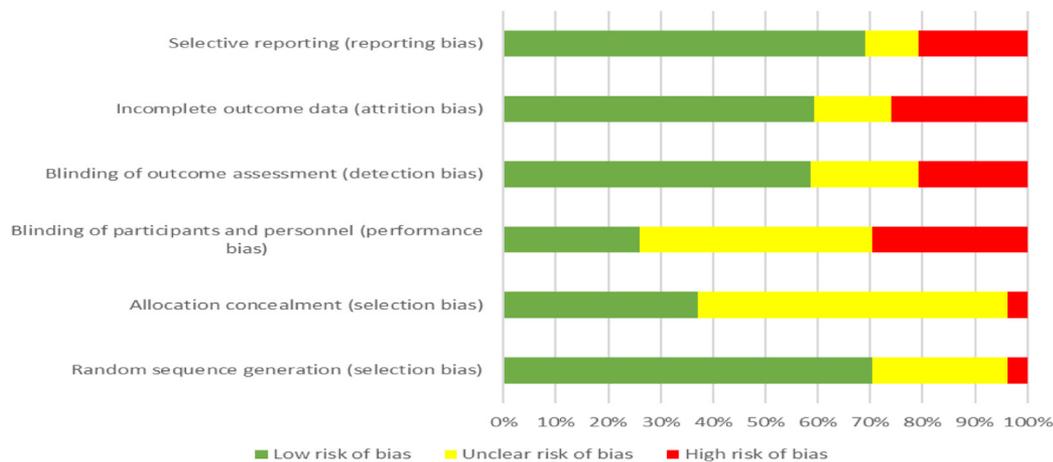


Figure 2 Cochrane risk of bias of included randomized controlled trials.

do not include a control group, but compared different interventions (eg, ESWT vs. UGN), different techniques (eg, high-energy vs. low-energy ESWT), or different combinations of treatments (eg, UGN + subacromial corticosteroid injection vs. UGN).

Postintervention VAS pain

Seventeen of the 27 studies reported postintervention pain as an outcome (Table III). The last follow-up for these studies had a median of 9 months and ranged from 3 months to 5 years. At the last follow-up, mean differences in VAS scores from pretreatment to post-treatment after ESWT was -3.83 (95% CI $-5.38, -2.27$; $P < .001$), compared to -4.83 (95% CI $-5.44, -4.22$; $P < .001$) for UGN, and -4.65 (95% CI $-5.47, -3.82$; $P < .001$) for the operative interventions (Fig. 3). For nonoperative studies (ie, ESWT and UGN), the mean difference in VAS scores from pre- to post-treatment was -4.92 (95% CI $-5.44, -4.40$; $P < .001$) (Fig. 3). The mean decrease in VAS for all the treatments exceeded the minimal clinically important difference (MCID) of 2.4 for VAS.⁵³ Significant heterogeneity was found between studies that reported VAS scores for nonoperative interventions ($I^2 = 93%$, $P < .001$).

Postintervention functional scores

Sixteen of the 27 studies reported postintervention functional outcomes as CMS (Table IV). The last follow-up for these studies had a median of 12 months and ranged from 3 months to 10 years. At the last follow-up, mean differences in CMS scores from pretreatment to post-treatment after ESWT was 18.30 (95% CI 10.95, 25.66; $P < .001$) compared to 22.01 (95% CI 8.17, 35.84; $P = .002$) for UGN, and 38.35 (95% CI 31.68, 45.02; $P < .001$) for the operative interventions. For nonoperative studies (ie, ESWT and UGN), the mean difference in CMS scores from

pre- to post-treatment was 18.17 (95% CI 10.11, 26.22; $P < .001$) (Fig. 4). All treatment modalities were found to have significant mean improvement in shoulder function as defined by the MCID of 10.4 for CMS.²⁷ Significant heterogeneity was found between studies that reported CMS scores for nonoperative interventions ($I^2 = 96%$, $P < .001$).

Postintervention resolution of calcific deposits

Seventeen of the 27 studies reported radiographic outcomes for the resolution of calcific deposits at last follow-up. The last follow-up for these studies had a median of 12 months and ranged from 3 months to 10 years. At the last follow-up, the mean percentage of total patients that had complete resolution of calcific deposit was 27.3% (0%-70.6%) after ESWT, compared to 66.7% (57%-100%) for UGN, and 85% for the single surgical study that reported radiographic outcomes. For nonoperative studies, the mean percentage of complete resolution was 36.8% (0%-100%) (Tables V and VI).

Discussion

This systematic review and meta-analysis of level II RCTs aimed to compare the effectiveness of nonoperative vs. operative management of chronic calcific tendinitis of the rotator cuff, to provide evidence-based treatment guidelines for practitioners. The main finding of the review is that at last follow-up (median: 12 months), nonoperative treatment in the form of ESWT and UGN, as well as operative treatment, had clinically meaningful improvements in pain and function. Operative treatment had a larger improvement in shoulder functional outcome scores and comparable pain outcomes to nonoperative interventions; however, statistical significance of these differences could not be evaluated because of a lack of directly comparable studies.

Table III Summary of pain clinical outcome, VAS (visual analog scale–pain)

Study	Last follow-up (mo)	Intervention A	Sample size, n	Pretreatment mean ± SD	Post-treatment mean ± SD	Intervention B	Sample size, n	Pretreatment mean ± SD	Post-treatment mean ± SD	P value
Louwerens (2020) ³¹	12	ESWT	43	5.8 ± 1.8	NA	UGN	43	6 ± 1.5	NA	.05
Battaglia (2017) ³	6	UGN + methylprednisolone	20	NA	0.9 ± 1	UGN + triamcinolone injection	20	NA	0.4 ± 0.9	.10
Kim (2014) ²⁵	12	UGN	25	6.8	1.4	ESWT	29	6.3	3.3	<.05
Sabeti (2014) ⁴⁸	9	Surgery–abd conventional	10	7.8 ± 1.8	1.8 ± 1.9	Surgery–abd US	10	7.6 ± 1.9	2.4 ± 2.4	NA
Toppolo (2012) ²¹	6	ESWT-H	23	8.45 ± 0.7	2.1 ± 1.5	ESWT-L	23	8.4 ± .8	5.4 ± 0.8	<.001
Sconfienza (2012) ⁵⁰	12	UGN–warm saline	233	8.9 ± .6	3 ± 0.7	UGN–room temperature saline	229	9.2 ± 0.4	3.2 ± 0.8	.49
Zhu (2008) ⁶⁰	9	UGN–with aspiration	41	6.8 ± 1.4	3.5 ± 2.1	UGN–without aspiration	40	6.4 ± 1.8	3.6 ± 2.4	NA
Albert (2007) ¹	0.5	ESWT-H	40	5.6 ± 14.5	5.8 ± 12.8	ESWT-L	40	5.6 ± 12.8	4.3 ± 12.6	.06
Cacchio (2006) ⁴	1.5	RSWT	45	7.96 ± 0.88	1 ± 1	Sham	45	7.72 ± 1.03	6.8 ± 2.4	.001
Sabeti-Aschraf (2005) ⁴⁹	0.75	ESWT–feedback	25	68.4 ± 15.3	33.4 ± 20.1	ESWT–navigation	25	66.0 ± 21.7	18.2 ± 21.3	.024
Pleiner (2004) ⁴¹	7	ESWT-H	31	4.8 ± 2.6	2.4 ± 2.2	ESWT-L	26	4.3 ± 2.9	2.9 ± 2.5	<.05
Pertick (2003) ³⁸	12	ESWT-L	40	3.2 ± 2.7	9 ± 3.7	ESWT-H	40	4.2 ± 2.5	10.5 ± 3.2	NA
Gerdesmeyer (2003) ¹⁵	12	ESWT-H	48	6.5 ± 1.3	NA	Sham	48	5.6 ± 1.6	NA	<.001
Pan (2003) ³⁶	3	ESWT	33	6.5 ± 1.81	NA	TENS	30	6.7 ± 1.42	NA	<.001
Papadopoulos (2019) ³⁷	0.75	Acupuncture	20	7.8	1.5	Sham	20	8.1	4.6	<.05
Rubenthaler (2003) ⁴⁷	16	Surgery–open	19	8.4	1.9	Surgery–endoscopic	14	8.9	1.8	NA
Clement (2015) ⁵	12	Surgery–abd with compression	40	5.9 ± 2	1.6 ± 2.5	Surgery–abd without decompression	40	6.5	2.5 ± 2.8	.12

ESWT, extracorporeal shockwave therapy; UGN, ultrasonography-guided needle barbotage; ESWT-H, ESWT–high energy; RSWT, radial shockwave therapy; ESWT-L, ESWT–low energy; SD, standard deviation; NA, not available; TENS, transcutaneous electric nerve stimulation.

Surgery–open: open surgery—removal of the subacromial bursa followed by decompression with acromioplasty and ligament incision in addition to calcium deposit removal; Surgery–abd with decompression: surgery—arthroscopic bursectomy debridement of rotator cuff with subacromial decompression; Surgery–abd US: surgery—arthroscopic bursectomy and debridement of rotator cuff with ultrasonographic localization.

Operative interventions had comparable radiographic outcomes to UGN, with the majority of patients in both groups having complete resolution of calcific deposits. UGN had larger reductions in pain, gain in shoulder function, and percentage of patients reaching complete calcific deposit resolution compared with ESWT.

In current clinical practice, operative treatment for chronic calcific tendonitis is reserved for patients who do not respond to nonoperative methods.^{24,45} However, evidence for this practice is of low quality. Although operative management is not a common recommendation for calcific tendonitis of the shoulder, the results of the current study support operative management as a reliable option in refractory chronic cases. Despite variation in exact procedure details between the 3 surgical studies included in the systematic review, they shared the common techniques of bursectomy and direct calcium deposit removal without rotator cuff repair. Homogenous and well-localized deposits are more easily identified and can be effectively removed by surgery without significant secondary damage to the rotator cuff.⁴⁶ Therefore, detailed imaging review to evaluate the caliber of the calcific lesion is recommended prior to suggestion of surgery, especially since the integrity of the rotator cuff has been reported as a critical factor for adequate outcomes after surgical treatment of calcific tendonitis. In the included studies, the extent to which the

calcific deposits have to be removed was left at the choice of the treating surgeon in most studies. Several authors reported good to excellent results with complete removal of calcific deposit with preservation of the rotator cuff.^{30,32,51} Preserving the integrity of the rotator cuff was associated with a considerably low rate of postoperative shoulder stiffness or temporary pain (0%-12%),^{2,11,32,51} whereas concomitant rotator cuff repair may lead to shoulder stiffness in up to 18% of patients.^{22,59} In a retrospective review of 340 patients who underwent arthroscopic subacromial débridement of calcific deposits, additional glenohumeral exploration may increase risk of adhesive capsulitis by 5-fold.¹¹ Nonetheless, results following arthroscopic débridement of calcific tendonitis followed by rotator cuff repair are comparable to arthroscopic repair of similar-sized rotator cuff tears.¹²

In the current study, most patients receiving operative management had complete radiographic resolution of the calcific deposit, whereas about two-thirds of patients receiving UGN treatment had complete radiographic resolution. However, only 27% of ESWT patients had complete radiographic resolution of their deposits. In a post hoc analysis of RCT for UGN treatment for calcific tendonitis of the shoulder, Dumoulin et al⁹ reported that for all time points evaluated, calcification resorption was associated with good clinical outcomes. The current study suggests

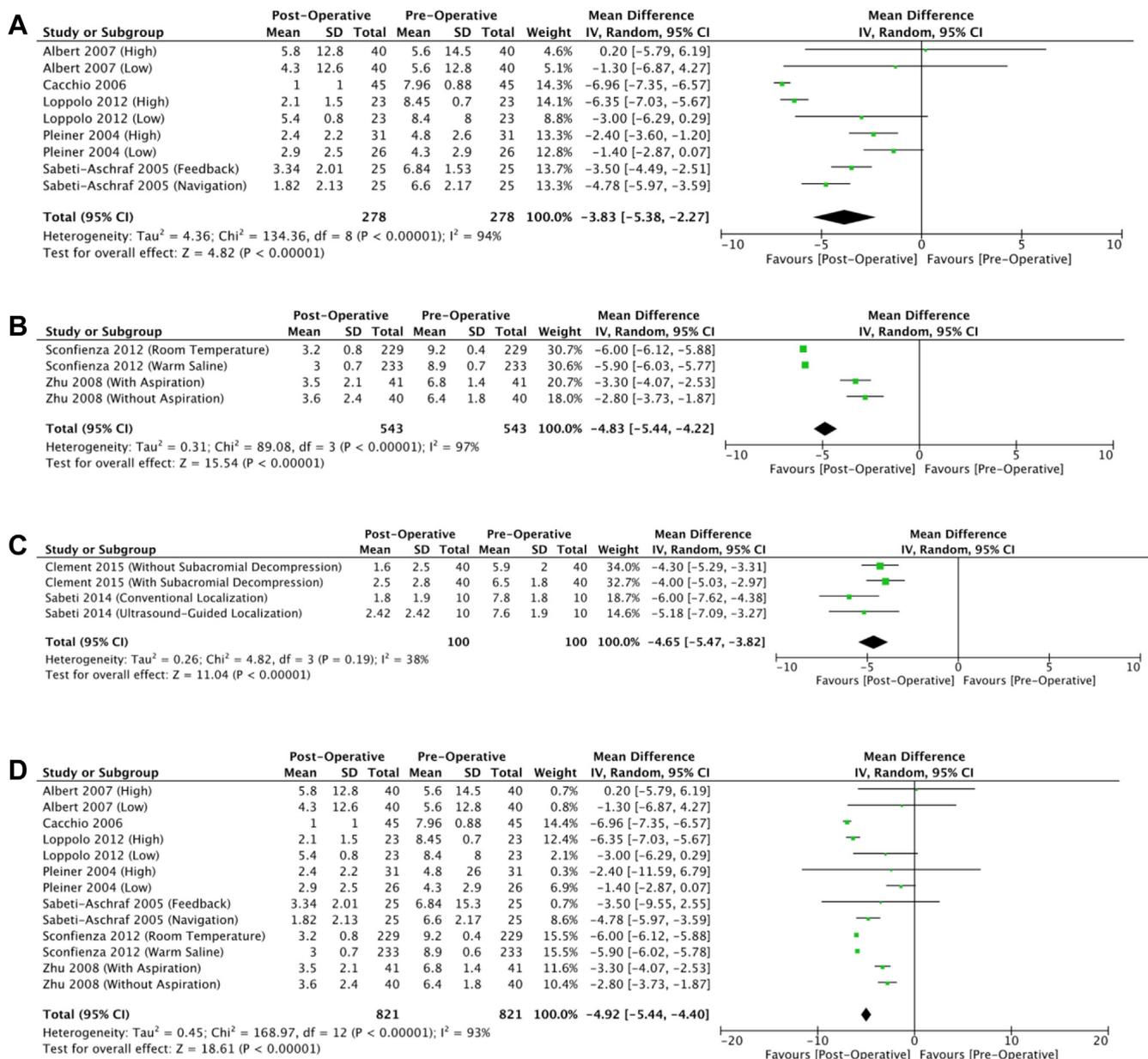


Figure 3 Postoperative pain on visual analog scale (VAS): (A) ESWT, (B) UGN, (C) surgical, and (D) nonoperative. *ESWT*, extracorporeal shockwave therapy; *UGN*, ultrasonography-guided needle barbotage.

that the correlation between radiographic resolution of calcific deposits and functional improvement should be evaluated further in future studies, as clinical improvement was seen even in patients with low levels of radiographic resolution.

With respect to conservative management, significant variability exists in the administration of ESWT and UGN technologies; variations often in the forms of energy output, application type, treatment frequency, session duration, or the use of single- or double-needling. The authors of this review decided against subgroup analysis to compensate for this discrepancy considering the small sample sizes of each. Also, the nonoperative interventions do have associated risk. Studies including ESWT reported

the complications of acute pain, superficial skin lesions, and local hematomas, particularly in treatment groups that received higher-energy shockwaves, whereas for studies including UGN, frozen shoulder, bursitis, and mild vagal reactions were reported complications. Access to the nonoperative methods is also of concern. ESWT is not readily available, it must be performed by an experienced therapist, costs are not entirely covered by most health insurance, and it can be a painful procedure in an already inflamed shoulder. Similarly, radiology referral for UGN treatment may be associated with delays in treatment and additional health care costs. Issues with accessibility and availability for patients must be considered for nonoperative techniques.

Table IV Summary of functional clinical outcome, CMS (Constant-Murley score—shoulder function)

Study	Last follow-up (mo)	Intervention A	Sample size, n	Pretreatment mean \pm SD	Post-treatment mean \pm SD	Intervention B	Sample size, N	Pretreatment mean \pm SD	Post-treatment mean \pm SD	P value
Louwerens (2020) ³¹	3	ESWT	43	67.7 \pm 12.2	NA	UGN	43	66.4 \pm 12.7	NA	.13
Pieber (2018) ⁴⁰	120	UGN	36	76.3 \pm 17.3	94 \pm 9.66	Sham	35	69.9 \pm 22.3	90.1 \pm 14.6	.72
de Witte (2017) ⁵⁷	60	UGN	23	71.6 \pm 12.2	89.5 \pm 14.9	SA corticosteroid injection	25	66 \pm 11.2	87 \pm 15.7	.58
Orlandi (2017) ³⁵	12	UGN—single needle	100	55 \pm 7.7	92 \pm 4	UGN—double needle	11	57 \pm 6	57 \pm 6	NA
Battaglia (2017) ³	6	UGN + methylprednisolone	20	NA	93.8 \pm 7.9	UGN + triamcinolone injection	20	NA	93.8 \pm 7.9	.01
Sabeti (2014) ⁴⁸	9	Surgery—abd conventional	10	40.8 \pm 14	91.0 \pm 12.1	Surgery—abd US	10	48.9 \pm 14.3	89.5 \pm 18.5	NA
de Witte (2013) ⁵⁸	12	UGN	23	71.6 \pm 12.3	86 \pm 13.1	SA corticosteroid injection	25	66 \pm 11.2	73.9 \pm 15	.005
Ioppolo (2012) ²¹	1.5	ESWT-H	23	49.2 \pm 8.6	79.4 \pm 10.3	ESWT-L	23	47.7 \pm 12.2	57.91 \pm 6.53	NA
Albert (2007) ¹	3	ESWT-H	40	50.7 \pm 57.8	63.2 \pm 103.5	ESWT-L	40	50.3 \pm 87.0	54.8 \pm 104.6	<.001
Sabeti-Aschraf (2005) ⁴⁹	0.75	ESWT—feedback	25	55.64 \pm 12.5	73 \pm 16.3	ESWT—navigation	25	49.4 \pm 12.3	49.4 \pm 12.33	.021
Cosentino (2003) ⁶	6	ESWT	35	45	76	Sham	35	48	44	<.001
Perlick (2003) ³⁸	12	ESWT-L	40	46.3	68.3	ESWT-H	40	48.4	73.2	.13
Gerdesmeyer (2003) ¹⁵	12	ESWT-H	48	60 \pm 11	NA	Sham	48	64.2 \pm 12.8	NA	<.001
Pan (2003) ³⁶	3	ESWT	33	64.2 \pm 12.8	NA	TENS	30	63.8 \pm 14.2	NA	<.001
Tornese (2011) ⁵⁵	3	ESWT—neutral	17	55.6 \pm 12.6	67.9 \pm 13.2	ESWT—hyperextended and internal rotation	18	64 \pm 7.1	76.9 \pm 11.7	>.05
Clement (2015) ⁵	12	Surgery—abd with decompression	40	45.9 \pm 12.2	82.4 \pm 10.8	Surgery—abd without decompression	40	45.5 \pm 15.5	77.5 \pm 15.3	.17

ESWT, extracorporeal shockwave therapy; UGN, ultrasonography-guided needle barbotage; ESWT-H, ESWT—high energy; ESWT-L, ESWT—low energy; SD, standard deviation; NA, not available; SA, subacromial; TENS, transcutaneous electric nerve stimulation.

Surgery—abd conventional: surgery—arthroscopic bursectomy and debridement of rotator cuff with conventional localization; Surgery—abd with decompression: surgery—arthroscopic bursectomy debridement of rotator cuff with subacromial decompression; Surgery—abd US: surgery—arthroscopic bursectomy and debridement of rotator cuff with ultrasonographic localization; Surgery—abd without decompression: surgery—arthroscopic bursectomy debridement of rotator cuff without subacromial decompression.

Operative management had clinically significant and overall greater increase in functional outcome scores when compared to nonoperative interventions, comparable pain alleviation, and adequate resolution of calcific deposits. However, patients included in operative studies had a history of failed conservative treatment and a longer duration of symptoms prior to the intervention compared to nonoperative patients (15–36 months of symptoms for operative patients compared to >6 months for nonoperative patients). Although there are a few prospective and retrospective cohort studies in the literature directly comparing the use of operative treatment and nonoperative techniques for calcific tendonitis of the shoulder,^{2,23,42,43,46,51} our literature search did not identify any RCTs directly comparing the two. Our meta-analysis has allowed for some evidence-based comparisons, but direct comparison of operative and nonoperative techniques through high-quality studies is warranted. There is also currently no consensus on the preferred surgical procedure for calcific tendonitis of the shoulder. In a 2017 systematic review, Verstraelen et al⁵⁶ reported similar functional and clinical outcomes in the 3 available surgical techniques (acromioplasty with débridement, acromioplasty without

débridement, and solely débridement). In the included operative studies, both arthroscopic and open approaches were used, and the studies differed in the choice of additional subacromial decompression and the extent of calcific deposit removal. Like the nonoperative interventions, more consistent regimens for the surgical management of calcific tendonitis need to be developed. Importantly, a concern for surgical interventions is the risk of operative complications; however, Clement et al⁵ reported that only 1 patient had postoperative adhesive capsulitis that resolved at 1-year follow-up, Rubenthaler et al⁴⁷ did not report postoperative complications, and Sabeti et al⁴⁸ reported that 1 patient had significant shoulder stiffness 6 weeks postoperation that required a subacromial injection. These results suggest that there is a low risk of serious complications with the surgical management of calcific tendonitis of the shoulder, and when complications do occur, they can be managed with additional conservative treatment.⁵⁶ One must also be aware that surgical interventions may incur higher health care costs. This concern is substantiated by Haake et al¹⁶ who reported that surgical treatment for calcific tendonitis of the shoulder had 5–7 times higher cost compared to ESWT.

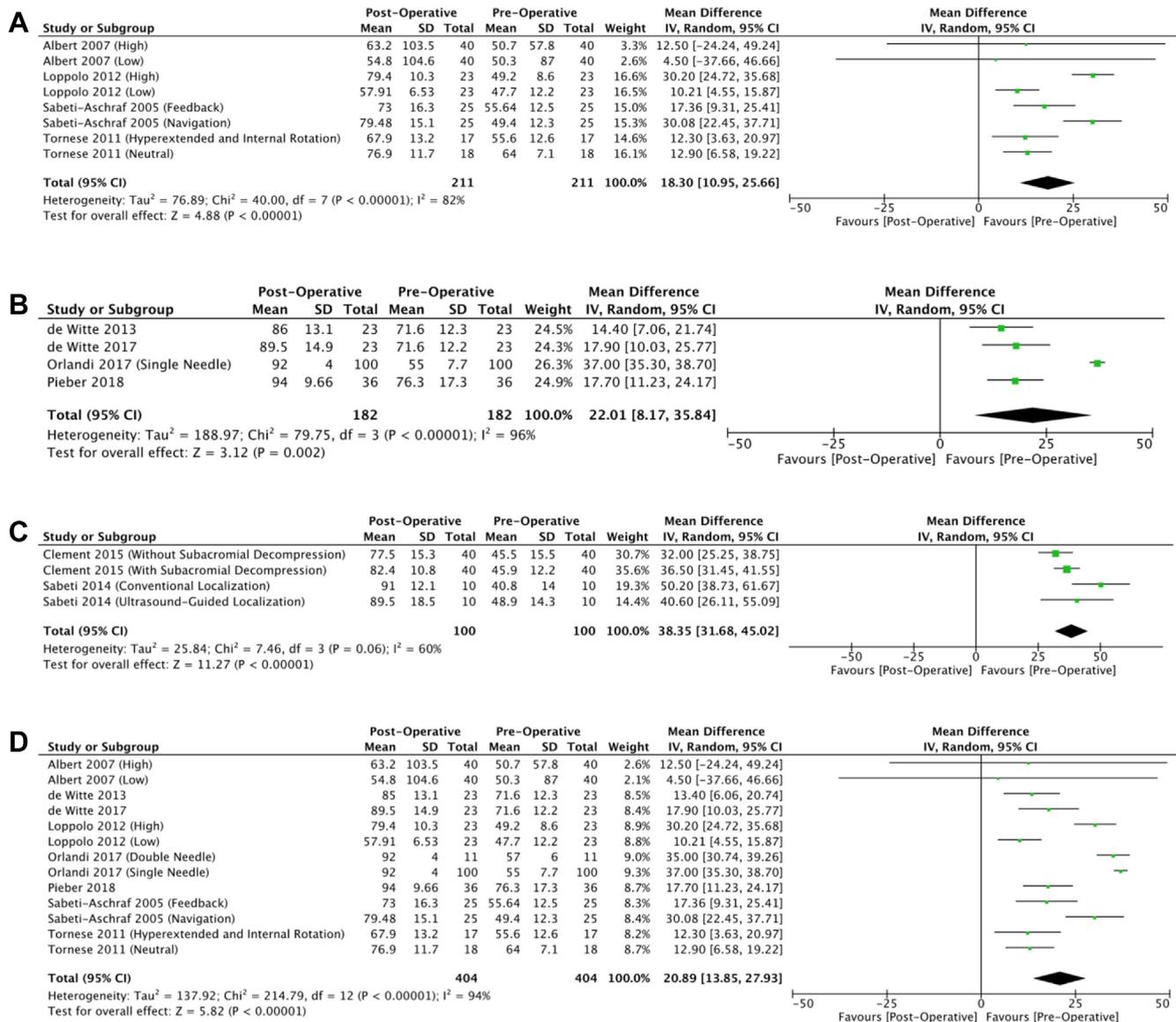


Figure 4 Constant-Murley scores: (A) ESWT, (B) UGN, (C) operative, and (D) nonoperative. ESWT, extracorporeal shockwave therapy; UGN, ultrasonography-guided needle barbotage

Table V Radiographic resolution of calcific deposits in calcifying tendonitis of the rotator cuff at last follow-up.

Intervention	Sample size, n	Complete resolution, % (range)	Partial resolution, % (range)	Unchanged, % (range)
ESWT	593	27.3 (0-70.6)	19.6 (0-48)	21.8 (0-80)
UGN	171	66.7 (57-100)	20.5 (0-39.1)	5.8 (0-16)
Operative	20	85	5	10
Nonoperative	744	36.8 (0-100)	19.1 (0-48)	17.9 (0-80)

ESWT, extracorporeal shockwave therapy; UGN, ultrasonography-guided needle barbotage.

Strengths and limitations

The main advantage of this review is that only studies of level II evidence were included. The exclusion of studies

of lower level of evidence provided the most powerful and highest-quality data set possible to compare interventions for calcific tendonitis of the shoulder. The use of only RCTs also reduced the risk of selection bias being present

Table VI Summary of radiographic clinical outcome, resolution of calcific deposit

Study	Last follow-up (mo)	Intervention A	Sample size, n	Deposit resolution	Mean size decrease, mm	Intervention B	Sample size, n	Deposit resolution	Mean size decrease, mm
Louwerens (2020) ³¹	6	ESWT	43	Complete: 14 Partial: 10 Unchanged: 17		UGN	43	Complete: 27 Partial: 13 Unchanged: 0	
Battaglia (2017) ³	6	UGN + triamcinolone injection	20	Complete: 20		UGN + methylprednisolone	20	Complete: 12	
Kim (2014) ²⁵	12	UGN	25	Complete: 18 Partial: 3 Unchanged: 4	-14.35	ESWT	29	Complete: 12 Partial: 5 Unchanged: 12	-5.4
Sabeti (2014) ⁴⁸	9	Surgery—abd conventional	10	Complete: 9 Partial: 1		Surgery—abd US	10	Complete: 8 Partial: 0	
de Witte (2013) ⁵⁸	12	UGN	23	Complete: 13 Partial: 22	11.6 ± 6.4	SA corticosteroid injection	25	Complete: 6 Partial: 17	-5.1 ± 5.7
Ioppolo (2012) ²¹	6	ESWT-H	23	Complete: 11		ESWT-L	23	Complete: 12	
Albert (2007) ¹	3	ESWT-H	40	Complete: 6 Partial: 3		ESWT-L	40	Complete: 2 Partial: 5	
Cacchio (2006) ⁴	0.25	RSWT			-20.45	Sham			-0.85
Sabeti-Aschraf (2005) ⁴⁹	3	ESWT—feedback	25	Complete: 1 Partial: 12 Unchanged: 12		ESWT—navigation	25	Complete: 6 Partial: 9 Unchanged: 20	
Krasny (2005) ²⁶	3	UGN + ESWT	40	Complete: 24 Partial: 10 Unchanged: 6		ESWT	40	Complete: 13 Partial: 14 Unchanged: 13	
Pleiner (2004) ⁴¹	3	ESWT-H	40	Complete: 4 Partial: 8		ESWT-L	40	Complete: 2 Partial: 3	
Cosentino (2003) ⁵	12	ESWT	35	Complete: 11 Partial: 14		Sham	35	Complete: 0 Partial: 0	
Perlick (2003) ³⁸	12	ESWT-H	40	Complete: 14 Partial: 8 Unchanged: 18		ESWT-L	40	Complete: 6 Partial: 9 Unchanged: 25	
Gerdesmeyer (2003) ¹⁵	12	ESWT-H	48		-162 mm ²	ESWT-L	48		-91.5 mm ²
Pan (2003) ³⁶	3	ESWT	33		-4.39 ± 3.8	TENS	30		-1.65 ± 2.8
Papadopoulos (2019) ³⁷	0.75	Acupuncture	20	Complete: 15	-13	Calcium deposit removal	20	Complete: 8	-9.2
Tornese (2011) ⁵⁵	3	ESWT—neutral	17	Complete: 16 Unchanged: 11		ESWT—hyperextended and internal rotation	18	Complete: 12 Unchanged: 6	

ESWT, extracorporeal shockwave therapy; UGN, ultrasonography-guided needle barbotage; ESWT-H, ESWT—high energy; SA, subacromial; ESWT-L, ESWT—low energy; TENS, transcutaneous electric nerve stimulation.

Surgery—abd conventional: surgery—arthroscopic bursectomy and debridement of rotator cuff with conventional localization; Surgery—abd US: surgery—arthroscopic bursectomy and debridement of rotator cuff with ultrasonographic localization.

in the included studies. The meta-analysis also allowed for stronger data-analysis by pooling numerous relatively small studies that may have been underpowered on their own to detect significant differences. A notable weakness of this systematic review was the significant heterogeneity between studies, particularly the nonoperative studies. This can be attributed to the variation in intervention protocols such as energy levels, dosages, combination of treatments, follow-up, and postoperative rehabilitation. Furthermore, this study analyzed interventions in patients with chronic symptomatic calcium deposits; however, symptomatic cases may still spontaneously heal within a few weeks in the absence of treatment. Another limitation of this review is that few studies directly compared different treatment modalities (eg UGN vs. ESWT), no studies directly compared operative to nonoperative intervention, only 4 studies included a control group that received a sham or placebo treatment, and limited level II

data on surgical intervention as only 3 studies (140 patients) were included. This prevented statistical comparison between pooled treatment groups and the current study narrowed the analysis to within-group post-intervention outcomes. There is a need for future randomized control trials to directly compare nonoperative and operative interventions.

Conclusion

Surgical treatment of chronic calcific tendonitis of the rotator cuff results in larger improvement in functional outcome scores and comparable pain reduction to nonoperative interventions, particularly UGN. Both operative and nonoperative treatment modalities are likely to have clinically significant improvements in function and pain, and thus it is reasonable to trial UGN

and ESWT as first-line treatment. Cost-effectiveness analyses will be needed to support one treatment over the other. High-quality RCTs directly comparing nonoperative interventions to operative interventions in patients prior to failing conservative treatment are needed to establish high-quality evidence-based guidelines.

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Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jse.2023.03.017>.

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