Systematic Review

The Effectiveness of High-Energy Extracorporeal Shockwave Therapy Versus Ultrasound-Guided Needling Versus Arthroscopic Surgery in the Management of Chronic Calcific Rotator Cuff Tendinopathy: A Systematic Review

Jan K. G. Louwerens, M.D., Ewout S. Veltman, M.D., Arthur van Noort, M.D., Ph.D., and Michel P. J. van den Bekerom, M.D.

Purpose: The objectives of this comprehensive quantitative review of the treatment of calcific tendinopathy of the rotator cuff were to investigate if there is a sustainable positive effect on outcomes after treatment with high-energy extracorporeal shockwave therapy (ESWT) or ultrasound (US)—guided needling and to compare these results with those of treatment with arthroscopic surgery. **Methods:** The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines were followed to conduct this review. A systematic literature search was conducted in December 2014 to identify relevant clinical articles in peer-reviewed journals with at least 6 months' follow-up. Each article was scored using the Coleman Methodology Score. The primary endpoints were functional outcome and radiologic change in the size of the calcific deposit. **Results:** Twenty-two studies were included (1,258 shoulders). The mean Coleman Methodology Score for the included studies was 77.1 ± 9.1. Overall, good to excellent clinical outcomes were achieved after treatment with either high-energy ESWT, US-guided needling, or arthroscopic surgery, with an improvement in the Constant-Murley score ranging between 26.3 and 41.5 points after 1 year. No severe side effects or long-term complications were encountered. **Conclusions:** Patients can achieve good to excellent clinical outcomes after high-energy ESWT, US-guided needling, and arthroscopy for calcific tendinopathy of the shoulder. Side effects and post-treatment complications should be taken into account when a decision is being made for each individual patient. Physicians should consider high-energy ESWT and US-guided needling as minimally invasive treatment options when primary conservative treatment fails. Arthroscopy can safely be used as a very effective but more invasive secondary option, although the extent of deposit removal and the additional benefit of subacromial decompression remain unclear. **Level of Evidence:** Level IV, systematic review of Level I, II, and IV studies.

See commentary on page 176

Calcific rotator cuff tendinopathy is a common cause of subacromial pain syndrome.[1] It is thought to be an active, cell-mediated process, although the exact pathophysiology remains unclear.[2] The disease mainly affects individuals in the third to fifth decade of life, with women being affected more often than men.[3-5] The condition is generally self limiting and can be managed with appropriate nonoperative treatment such as nonsteroidal anti-inflammatory drugs, physical therapy, and subacromial corticosteroid injections.[2,6] Some cases, however, progress to a chronic symptomatic phase despite conservative treatment.[7] Minimally invasive treatment modalities such as high-energy extracorporeal shockwave therapy (ESWT) and ultrasound (US)—guided needling have been developed for patients in whom nonoperative treatment fails.[8] Several recent studies have shown the short-term

From the Research Center Linnaeus Institute (J.K.G.L.) and Department of Orthopaedic Surgery (J.K.G.L., E.S.V., A.v.N.), Spaarne Hospital, Hoofddorp; and Department of Orthopaedic Surgery, Onze Lieve Vrouwen Gasthuis (M.P.J.v.d.B.), Amsterdam, Netherlands.

The authors report that they have no conflicts of interest in the authorship and publication of this article.

Received April 8, 2015; accepted June 30, 2015.

Address correspondence to Jan K. G. Louwerens, M.D., Research Center Linnaeus Institute and Department of Orthopaedic Surgery, Spaarne Hospital, Spaarnepoort 1, 2134TM, Hoofddorp, Netherlands. E-mail: jlouwerens@spaarneziekenhuis.nl

0749-8063/15332/$36.00

http://dx.doi.org/10.1016/j.arthro.2015.06.049

effectiveness of these treatment options.[8-10] Treatment-resistant cases may, however, necessitate surgical removal of the calcific deposit, and surgery has long been the treatment of choice for patients with calcific rotator cuff tendinopathy.[4] Surgical management options include arthroscopic procedures to remove the calcified deposit and to perform subacromial decompression.[11-15] These procedures have been shown to have a high chance of success in restoring shoulder function and reducing pain. Controversies exist, however, regarding the extent of calcification removal, the long-term impact on the rotator cuff tendons, and the use of subacromial decompression.[9,14]

The recent focus on minimally invasive treatment modalities suggests that surgery is gradually being superseded by these new options in the management of chronic rotator cuff tendinopathy. The objectives of this study were to investigate if there is a sustainable positive effect in terms of functional outcome and resorption of calcific deposits after treatment with high-energy ESWT and US-guided needling and to compare these results with those of treatment with arthroscopic surgery. A systematic review of the currently available literature was conducted to search for evidence pertaining to the effectiveness and safety of these treatment modalities with a minimum follow-up of 6 months.

Methods

This review was performed and reported following the principles of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.[16] The literature search conducted for this systematic review was limited to clinical studies concerning the minimally invasive and arthroscopic treatment of chronic calcific tendinopathy of the rotator cuff with at least 6 months' follow-up. Three interventions were included: high-energy ESWT, US-guided needling, and arthroscopic surgery. ESWT can be classified as low energy or high energy according to the amount of energy released by the sonic pulses expressed as energy flux density (EFD) in millijoules per square millimeter. There is no universal agreement concerning the threshold of these subdivisions. For this study, we defined high-energy ESWT as having an EFD of greater than 0.20 mJ/mm^2. Several recent systematic reviews have shown the superiority of high-energy ESWT to low-energy ESWT in the treatment of calcific rotator cuff tendinopathy.[8,9,17] We therefore focused solely on high-energy ESWT.

Study inclusion was limited to trials involving patients aged 18 years or older with symptoms of subacromial pain syndrome in combination with radiographically or sonographically proven calcific tendinopathy who did not respond to conservative treatment with nonsteroidal anti-inflammatory drugs, physiotherapy, or subacromial corticosteroid injections. Studies involving patients with evidence of a full-thickness rotator cuff tear (physical examination, sonography, or magnetic resonance imaging), systemic inflammatory disorders, previous surgery on the shoulder, instability of the shoulder, dysfunction of the upper limb, ESWT/needling within the past year, acute bursitis, or osteoarthritis of the glenohumeral or acromioclavicular joint were excluded. Our study focused on validated outcome measures for shoulder function and change in radiologic size of the calcific deposit. Baseline outcome parameters in combination with post-treatment results had to be reported. Studies that did not report both of these parameters were excluded.

Table 1. PubMed/Medline Search Strategy

Search strategy 1: (calcif* [All Fields])
Search strategy 2: ("tendinopathy"[MeSH Terms] OR "tendinopathy"[All Fields] OR "tendinosis"[All Fields] OR "tendinitis"[All Fields])
Search strategy 3: ("shoulder"[MeSH Terms] OR "shoulder"[All Fields]) OR ("rotator cuff"[MeSH Terms] OR ("rotator"[All Fields] AND "cuff"[All Fields]) OR "rotator cuff"[All Fields]) OR supraspinatus[All Fields])
Search strategy 4: ("shock*"[All Fields] OR "needling"[All Fields] OR "percutaneous"[All Fields] OR "ultrasound"[All Fields] OR "arthroscopy"[MeSH Terms] OR "arthroscopy*"[All Fields])

*Truncation symbol.

A search term with Boolean operators was constructed (Table 1), and the following databases were searched from 1978 to 2014: Medline, Embase, PEDro, CINAHL (Cumulative Index to Nursing and Allied Health Literature), SPORTDiscus, and the Cochrane Database of Systematic Reviews. A range of keywords (calcific tendinopathy, shoulder, rotator cuff, shockwave, ultrasound guided, needling, arthroscopy) relevant to the review were grouped into 4 categories to maximize search results, and the search was independently performed by 2 reviewers (J.K.G.L., E.S.V.). The lists of references of retrieved publications and the "find-similar" function in Medline and Embase were manually checked for additional studies potentially meeting the inclusion criteria. The search was restricted to articles written in the English, German, or Dutch language.

Studies were selected by reviewing the title and abstract to identify potentially relevant articles. The full article was retrieved when the title or abstract included insufficient information to determine appropriateness for inclusion. All identified studies were independently assessed by 2 reviewers (J.K.G.L., E.S.V.) for inclusion using the aforementioned criteria. Disagreement was resolved by discussion, with arbitration by a third reviewer (M.P.J.v.d.B.) when differences remained.

Two reviewers (J.K.G.L., E.S.V.) independently extracted the following information from each included study: study design; patient characteristics (e.g., number of participants, age, sex, and mean duration of symptoms); study characteristics (e.g., follow-up

Table 2. Study Characteristics

Author (Year)	LOE/CS	No. of Patients (No. of Shoulders)	Age, yr*	Sex (F/M Ratio)	Duration of Symptoms*	Follow-up, mo	Technique†	Outcome Measures
High-energy ESWT								
Kim et al.[32] (2014)	I/87	29	57.4 (47-78)	8.7	NR	1.5, 3, 6, 12, 24	1,000 × 0.36 × 3/maximum sore spot	ASES, SST, VAS, resolution of deposit
Ioppolo et al.[31] (2012)	I/83	23	57.1 ± 16.4	1.9	6.9 ± 1 mo	3, 6	2,400 × 0.20 × 4/calcific deposit	CMS, VAS, resolution of deposit
Hsu et al.[30] (2008)	I/77	33	54.4 (30-70)	1.2	12.3 mo (6-72)	1.5, 3, 6, 12	1,000 × 0.55 × 2/affected area	CMS, VAS, resolution of deposit
Perlick et al.[33] (2003)	I/80	40	48.4 (38-64)	1.2	32 mo	3, 12	2,000 × 0.42 × 2/calcific deposit	CMS, resolution of deposit
Pleiner et al.[34] (2003)	I/85	23 (31)	54 ± 11	1.9	>6 mo	3, 7	2,000 × 0.28 × 2/maximum point of tenderness	CMS, VAS, resolution of deposit
Gerdesmeyer et al.[29] (2003)	1/94	48	51.6 ± 8.5	2.7	51.6 ± 8.5 mo	3, 6, 12	1,500 × 0.32 × 2/calcific deposit	CMS, VAS, resolution of deposit
Cosentino et al.[23] (2003)	I/62	35	51.8 (35-68)	1.3	15 mo (10-20)	6	1,200 × 0.28 × 4/calcific deposit	CMS, resolution of deposit
Daecke et al.[24] (2002)	IV/83	115	49 (28-77)	0.7	5 yr (1-36 yr)	3, 6, 48	Group I: 2,000 × 0.3 × 1/calcific deposit Group II: 2,000 × 0.3 × 2/calcific deposit	CMS, resolution of deposit
Rompe et al.[36] (1998)	I/81	50	47 (29-60)	1.6	33 mo (12-120)	1.5, 6	1,500 × 0.28 × 1/calcific deposit	CMS, resolution of deposit
US-guided needling								
Kim et al.[32] (2014)	I/87	25	53.9 (45-76)	11.5	NR	1.5, 3, 6, 12, 24	Single needle	ASES, SST, VAS, resolution of deposit
De Witte et al.[25] (2013)	I/91	23	53.7 ± 7.3	1.1	NR	1.5, 3, 6, 12	Single needle	CMS, DASH, WORC, resolution of deposit
Yoo et al.[41] (2010)	IV/70	30 (35)	51.3 (34-77)	2	44.8 mo (6-240)	0.3, 3, 6	Singe needle	CMS, ASES, resolution of deposit
De Conti et al.[26] (2010)	IV/76	123	48.0 (31-65)	1.7	11 mo (6-15)	6	Double needle with lavage and aspiration	CMS
Serafini et al.[39] (2009)	II/84	219 (235)	40.3 (29-72)	1.5	NR	0.3, 3, 12, 60, 120	Double needle with lavage and aspiration	CMS, VAS
Del Cura et al.[27] (2007)	IV/63	65 (67)	47.0 (31-72)	1.6	30 mo (1-168)	2.5, 12	Double needle with lavage and aspiration	SPADI
Arthroscopy								
Sabeti et al.[37] (2014)	I/70	20	47.6	NR	31.5 mo	1.5, 9	Bursectomy, fluoroscopy, needling, blunt removal, no tendon repair	CMS, VAS, resolution of deposit
Balke et al.[11] (2012)	IV/71	62 (70)	54.0 (39-74)	1.6	2.6 yr (1.5-15 yr)	72	Bursal debridement, ASD on indication, removal with resector/curette	CMS, ASES, resolution of deposit
El Shewy[28] (2011)	IV/76	56	48.6 (37-54)	0.5	5.2 mo (3.5-7.1)	90-120 (range)	Bursectomy, ASD on indication, removal with arthroscopy knife/shaver	CMS, ASES, UCLA, resolution of deposit

(continued)

Table 2. Continued

Author (Year)	LOE/CS	No. of Patients (No. of Shoulders)	Age, yr*	Sex (F/M Ratio)	Duration of Symptoms*	Follow-up, mo	Technique†	Outcome Measures
Yoo et al.[14] (2010)	IV/68	35	49.8	1.4	39.1 mo	31	Bursectomy, acromioplasty on indication, full removal of deposit	CMS, ASES, VAS
Seyahi and Demirhan[40] (2009)	IV/61	28 (30)	48.3	1.8	15 mo	38	Bursectomy, sectioning of CA ligament, use of curette/resector, full removal of deposit	CMS, VAS, resolution of deposit
Seil et al.[38] (2006)	IV/85	54 (58)	45.4	0.8	52 mo	3, 6, 12, 24	Longitudinal incision, blunt exploration and removal	CMS, resolution of deposit
Porcellini et al.[35] (2004)	IV/74	63	37.0	2	20 mo (14-60)	36	Bursal debridement, use of resector/curette, full removal of deposit	CMS, resolution of deposit
Rubenthaler et al.[13] (2003)	II/76	14	50.4	6	NR	17.1	Removal of deposit, no tendon repair, ASD in all cases	CMS, Patte score, resolution of deposit

ASD, arthroscopic subacromial decompression; ASES, American Shoulder and Elbow Surgeons score; CA, coracoacromial ligament; CS, Coleman Methodology Score; CMS, Constant-Murley Scale; DASH, Disabilities of the Arm, Shoulder and Hand score; ESWT, extracorporeal shockwave therapy; F, female; LOE, Level of Evidence; M, male; NR, not reported; SPADI, Shoulder Pain and Disability Index; SST, Simple Shoulder Test; UCLA, University of California, Los Angeles score; VAS, visual analog scale; WORC, Western Ontario Rotator Cuff index.

*Data presented as mean (range) or mean ± standard deviation (range).

†ESWT data are presented as pulses × energy flux density (in millijoules per square millimeter) × sessions/focus shockwaves.

period, types of outcome measures, and baseline measurements); and treatment characteristics (e.g., treatment technique, effects of treatment at various periods of follow-up, post-treatment regimen, and complications). Studies that included more than 2 treatment arms were treated as separate interventions for the purpose of this review. The reviewers were not blinded to author, affiliation, or source.[18] Disagreement between reviewers was resolved by discussion, with arbitration by a third author (M.P.J.v.d.B.) when differences remained.

The criteria developed by Coleman et al.[19] were used to assess the methodologic quality of each article. The Coleman scoring system is a method of analyzing the quality of the studies reviewed. It has been validated[20] and proved accurate and reproducible in systematic reviews.[19,21,22] Each study was independently assessed by 2 reviewers (J.K.G.L., E.S.V.), and any discrepancies were resolved by discussion; a total Coleman Methodology Score of between 0 and 100 was given (Table 2). A perfect score of 100 represents a study design that largely avoids the influence of chance, various biases, and confounding factors. The synthesis approach was data driven. Treatment effect was examined through meta-analyses, but these were conducted only if studies were determined to be clinically homogeneous. Clinical homogeneity was defined a priori by setting, treatment technique, duration of follow-up, and outcome measure used. If the study arms were heterogeneous, a qualitative/narrative data synthesis approach was performed.

Results

Search Results

The search of the Medline, Embase, CINAHL, Cochrane, PEDro, and SPORTDiscus databases provided a total of 942 citations (Fig 1). The search was performed on December 9, 2014. After adjustment for duplicates, 393 studies remained. Of these studies, 336 were discarded for not meeting the inclusion criteria after review of the abstracts. The full text of the remaining 57 studies was examined in more detail. Twenty-two studies, including 1,258 treated shoulders, met the inclusion criteria and were included in the

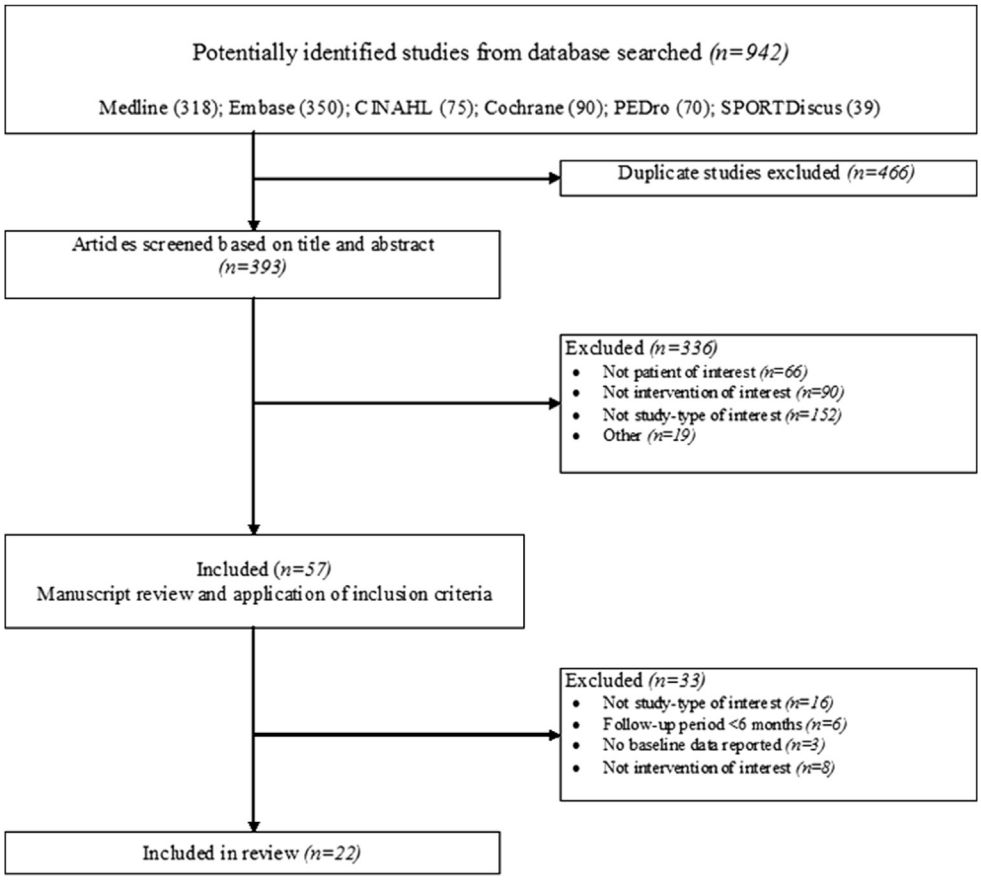

Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement flow diagram of the search process. (CINAHL, Cumulative Index to Nursing and Allied Health Literature.)

systematic review.[11,13,14,23-41] Of the studies, 8 involved treatment with high-energy ESWT,[23,24,29-31,33,34,36] 5 concerned treatment with US-guided needling,[25-27,39,41] 1 involved a group treated with high-energy ESWT and a group treated with US-guided needling,[32] and 8 concerned the use of arthroscopic surgery.[11,13,14,28,35,37,38,40] No additional studies were identified by the find- similar function in the Medline and Embase databases or by checking the references of retrieved publications.

Characteristics

General patient characteristics and interventions are summarized in Table 2. The longest mean follow-up time was 4 years for the ESWT studies, 10 years for the US-guided needling studies, and 6 years for the arthroscopy studies.

Methodologic Quality

The Coleman Methodology Score for the included studies varied from 61 to 94, with a mean score of 77.1 and an SD of 9.1. Eleven studies were constructed as prospective randomized controlled trials (RCTs), 1 as a prospective non-RCT, 6 as prospective cohort studies, and 4 as retrospective cohort studies. A mean Coleman score of 81.8 was given to the ESWT studies, with mean scores of 76.0 and 72.6 given to the US-guided needling studies and arthroscopy studies, respectively. The numbers of patients in the various studies and differences in follow-up times in combination with the different types of studies accounted for the differences in Coleman scores given to the studies.

Outcome Measures: Type and Timing

Assessments of pain, shoulder function, and the radiologic appearance of calcific resorption after treatment were the most frequently reported outcome measures. All studies reported on shoulder function. The Constant-Murley Scale (CMS)[42] was the most commonly reported shoulder function outcome measure. In addition to the CMS, 5 studies used the American Shoulder and Elbow Surgeons (ASES)[43] assessment form. A single study used each of the following measures: Disabilities of the Arm, Shoulder and Hand questionnaire[44]; Patte score[45]; Shoulder Pain and Disability Index[46]; Simple Shoulder Test[47]; University of California, Los Angeles scale[48]; and Western Ontario Rotator Cuff index.[49]

Of the 22 studies, 18 reported changes in radiologic size or appearance of the calcific deposit.[13,23-25,27-37,40,41]

Table 3. Results

Author (Year)	No. of Patients (No. of Shoulders)	Baseline	6 mo	1 yr	2 yr	>2 yr	>5 yr	Resorption/Change in Size
High-energy ESWT								
Kim et al.[32] (2014)	29	ASES: 49.9 SST: 34%	ASES: 76.4 SST: 70.8%	ASES: 74.6 SST: 70.8%	ASES: 78.3 SST: 78.6%			Partial, 16.7%; full, 42.6%; none, 41.7% Pre: 11 ± 1 mm Post: 5.6 ± 0.8 mm
Ioppolo et al.[31] (2012)	23	CMS: 49.26 ± 8.6	CMS: 79.4 ± 0.33					Full, 42.6% Size reduction: 135.91 ± 71.69 mm^2
Hsu et al.[30] (2008)	33	CMS: 57.3	CMS: 85	CMS: 88				Partial, 36.3%; full, 21.2%; none, 45.5% Pre: 11.9 ± 5.4 mm Post: 5.5 ± 6.3 mm
Perlick et al.[33] (2003)	40	CMS: 48.4		CMS: 73.2				Partial, 20.0%; full, 25%; none, 45%
Pleiner et al.[34] (2003)	23 (31)	CMS: 46 ± 21	CMS: 70					Partial, 19.4%; full, 19.4%; none, 61.2%
Gerdesmeyer et al.[29] (2003)	48	CMS: 60 ± 11	CMS: 91.0 (95% CI, 86.7-95.3)	CMS: 91.6 (95% CI, 87.3-96.0)				Full, 60.4% Size reduction: 128.9 mm^2 (170-87.7 mm^2)
Cosentino et al.[23] (2003)	35	CMS: 45 ± 18	CMS: 76 ± 16					Partial, 40%; full, 31.5%; none, 28.5%
Daecke et al.[24] (2002)								
Group I	56	CMS: 49 ± 13		CMS: 67 ± 17		CMS: 88 ± 8		Radiologic changes: 47% at 6 mo and 93% at 4 yr
Group II	59	CMS: 44 ± 12		CMS: 69 ± 19		CMS: 85 ± 8		Radiologic changes: 77% at 6 mo and 93% at 4 yr
Rompe et al.[36] (1998)	50	CMS: 53 ± 13.1	CMS: 88 ± 11.5					Partial, 42%; full, 22%
Total or mean	Total: 346	Mean CMS: 50.2	Mean CMS: 82.9	Mean CMS: 76.5		Mean CMS: 86.5		
US-guided needling								
Kim et al.[32] (2014)	25	ASES: 41.5 SST: 38.2	ASES: 85.2 SST: 74.1	ASES: 90.1 SST: 83.3	ASES: 91.1 SST: 91.7			Partial, 11.1%; full, 72.2%; none, 16.7% Pre: 14.8 ± 1.7 mm Post: 0.45 ± 0.3 mm
De Witte et al.[25] (2013)	23	CMS: 71.6 ± 12.3 DASH: 32.6 ± 18.5 WORC: 49.6 ± 20.3	CMS: 78.6 ± 16.7 DASH: 24.6 ± 20.7 WORC: 63.5 ± 26.2	CMS: 86.0 (80.3-91.6) DASH: 19.6 (9.5-29.8) WORC: 69.7 (57.6-81.8)				Partial, 39%; full, 56%; none, 5% Pre: 11.6 ± 6.4 mm Post: 5.1 ± 5.7 mm
Yoo et al.[41] (2010)								
Group I	24 (30)	CMS: 53.7 ± 16.3 ASES: 48.0 ± 14.5	CMS: 87.9 ± 8.7 ASES: 84.6 ± 12.8					Pre: 13.6 ± 5 mm Post: 5.6 ± 6.5 mm
Group II	6	CMS: 55.4 ± 7.4 ASES: 48.6 ± 9.4	CMS: 92 ± 16.9 ASES: 47.5 ± 17.5					Pre: 13.1 ± 4.8 mm Post: 12.7 ± 7.1 mm
De Conti et al.[26] (2010)	123							
Group I		CMS: 28.6	CMS: 81.4					
Group II		CMS: 34.1	CMS: 71.1					
Serafini et al.[39] (2009)	219 (235)	CMS: 57.3 ± 3.4		CMS: 91.7 ± 3.1		CMS: 90.9 ± 3.6	CMS: 91.8 ± 5.0	
Del Cura et al.[27] (2007)	65 (67)	SPADI: 50.2 (10-90.1)		SPADI: 14.7 (0-62.8)				Partial, 18.8%; full, 78.1%; none, 3.1%
Total or mean	Total: 485	Mean CMS: 49.9	Mean CMS: 79.4	Mean CMS: 91.2		Mean CMS: 90.9	Mean CMS: 91.8	
Arthroscopy								
Sabeti et al.[37] (2014)	20	CMS: 44.9 ± 14.4		CMS: 90.33 ± 14.7				Partial, 6%; full, 94%
Balke et al.[11] (2012)	62 (70)	ASES: 38.3					ASES: 81.5 CMS: 74.4	
El Shewy[28] (2011)	56	CMS: 63.3 ASES: 57.2 UCLA: 52.8					CMS: 97.8 ASES: 95 UCLA: 95	Partial, 26%; full, 74%

(continued)

Table 3. Continued

Author (Year)	No. of Patients (No. of Shoulders)	Baseline	6 mo	1 yr	2 yr	>2 yr	>5 yr	Resorption/Change in Size
Yoo et al.[14] (2010)	35	CMS: 63.2 ± 20 ASES: 39 ± 17				CMS: 87 ± 15 ASES: 89 ± 13		
Seyahi and Demirhan[40] (2009)	28 (30)	CMS: 42				CMS: 100		Partial, 3%; full, 97%
Seil et al.[38] (2006)	54 (58)	CMS: 32.8			CMS: 90.9			
Porcellini et al.[35] (2004)	63	CMS: 55.1				CMS: 86.4 ± 7.2		Full resorption in 21%, microcalcifications in 71%, deposits <10 mm in size in 8%
Rubenthaler et al.[13] (2003)	14	CMS: 64.1			CMS: 97.6			Partial, 42%; full, 58%
Total or mean	Total: 332	Mean CMS: 48.8		Mean CMS: 90.3	Mean CMS: 92.2	Mean CMS: 89.8	Mean CMS 84.4	

NOTE. Data are presented as mean, mean ± standard deviation, mean (range), or percent unless otherwise indicated.

ASES, American Shoulder and Elbow Surgeons score; CI, confidence interval; CMS, Constant-Murley Scale score; DASH, Disabilities of the Arm, Shoulder and Hand score; ESWT, extracorporeal shockwave therapy; Post, postoperative; Pre, preoperative; SPADI, Shoulder Pain and Disability Index; SST, Simple Shoulder Test; UCLA, University of California, Los Angeles score; WORC, Western Ontario Rotator Cuff index.

Sixteen studies reported whether there was no change, partial resorption, or total resorption.[13,23,25,27-37,40] Four studies described the change in length in millimeters,[25,30,32,41] whereas Gerdesmeyer et al.[29] and Ioppolo et al.[31] described the change in size in square millimeters.

High-Energy ESWT

Techniques. Nine studies (8 RCTs), including a total of 346 patients, used high-energy ESWT as the treatment modality.[23,24,29-34,36] Although these trials all used high-energy ESWT, the reported EFD (0.2 to 0.55 mJ/mm^2), number of pulses applied (1,000 to 2,400), and number of sessions (1 to 4) varied. The shockwave energy was focused on the calcific deposit in 6 trials and on the maximum point of tenderness in 2 trials. Hsu et al.[30] did not report details on the focus area.

Clinical Outcome. Functional outcome scores after treatment with high-energy ESWT are summarized in Table 3. Compared with baseline parameters, high-energy ESWT significantly improved shoulder function in 7 trials at 6 months' follow-up. On the basis of 5 trials, the improvement in shoulder function remained at 1 year. Kim et al.[32] reported a significant increase in the ASES score (78.3 points *v* 49.9 points) and Simple Shoulder Test score (78.6% *v* 34%) in 29 patients after 2 years. Daecke et al.[24] reported promising results on the CMS in 2 high-energy ESWT series (88 ± 8 points *v* 49 ± 13 points and 85 ± 8 points *v* 44 ± 12 points) in 115 patients after 4 years in their prospective non-RCT.

Safety. All studies reported on adverse effects; a summary is provided in Table 4. All complications affected only a small number of participants, and the effects resolved within a few days after treatment. No clinically relevant post-treatment complications were reported.

US-Guided Needling

Techniques. Six US-guided needling studies (2 RCTs), comprising a total of 485 patients, were included in this

Table 4. Treatment Side Effects and Post-Treatment Complications

Treatment Modality	Peri-Treatment Side Effects	Post-Treatment Complications
High-energy ESWT (404 shoulders)	Frequent: pain, erythema, local intracutaneous petechial bleeding, subcutaneous hematomas	None reported
US-guided needling (508 shoulders)	Frequent: pain, discomfort Rare: vagal reactions, fainting	Rare: frozen shoulder (2.4%), subacromial bursitis (5%)
Arthroscopy (346 shoulders)	Frequent: pain, RC defects due to extensive debridement requiring intraoperative RC repair	Frequent: postoperative pain Rare: frozen shoulder (3.7%), partial RC tears (3.5%), subacromial bursitis (<1%), secondary surgical RC repair (<1%)

ESWT, extracorporeal shockwave therapy; RC, rotator cuff; US, ultrasound.

study.[25-27,32,39,41] Three studies used a double-needle technique, and 3 used a single-needle technique. Lavage and aspiration were performed in all trials using 2 needles. The needle gauge ranged between 16 and 25, with 16-gauge needles most commonly used. In all studies a subacromial corticosteroid injection was administered after the needling procedure. All US-guided needling procedures were performed with patients under local anesthesia.

Clinical Outcome. Outcome scores after treatment with US-guided needling are summarized in Table 3. At 6 months' follow-up, 3 of 4 trials reported significant improvements on functional outcome scales, whereas de Witte et al.[25] did not find a significant improvement on the CMS; Disabilities of the Arm, Shoulder and Hand questionnaire; or Western Ontario Rotator Cuff index after 6 months. On the basis of the 4 trials, the functional outcome after 1 year was significantly improved in all trials, including that of de Witte et al. Kim et al.[32] and Serafini et al.[39] reported excellent long-term results after 2 years and 5 to 10 years, respectively.

Safety. Two trials reported re-needling rates of 45% and 25%. Yoo et al.[41] reported a 28% clinical failure rate at 6 months' follow-up and conversion to arthroscopy in 17% of cases. All studies reported on side effects and complications after US-guided needling; these results are summarized in Table 4. All of the side effects were minor, with no reported long-term disability.

Arthroscopy

Techniques. Eight arthroscopic surgery studies, comprising a total of 332 patients, were included in this review.[11,13,14,28,35,37,38,40] In 4 studies the anesthesia protocol was reported.[11,28,35,40] In 3 studies the operation was performed with patients under general anesthesia, and 1 trial used a combined scalene block with general anesthesia.[35] All surgeons started the surgical procedure with a diagnostic intra-articular arthroscopy. Seven studies proceeded with a subacromial bursectomy; one article did not provide additional data on this particular phase.[38] Rubenthaler et al.[13] subsequently proceeded with an acromioplasty and coracoacromial ligament incision. Seyahi and Demirhan[40] only performed sectioning of the coracoacromial ligament without acromioplasty. Four studies only performed decompression on indication, such as signs of mechanical impingement, fraying of the coracoacromial ligament, or erosions on the undersurface of the acromion.[11,14,35,38] The calcific deposit was localized by fluoroscopy in 2 studies,[37,40] US in 1 study,[37] and needling in the remaining studies. The means of calcific deposit removal differed and included use of an arthroscopic knife and shaver, use of a curette and synovial resector, and use of blunt instruments. Seyahi and Demirhan used side-to-side stitches in all cases after removal of the deposit. Yoo et al.[14] and Porcellini et al.[35] used side-to-side sutures or suture anchors depending on the size of the rotator cuff lesion. Three studies reported no additional use of sutures.

Clinical Outcome. Outcome scores after treatment with arthroscopic surgery are summarized in Table 3. None of the studies reported data at 6 months' follow-up. Sabeti et al.[37] found an improvement of 45.5 points in the CMS score in 20 patients after 1 year. Five trials reported data after 1.5 to 3 years' follow-up, with improvements in CMS scores ranging from 23.8 to 58.1 points. Balke et al.[11] reported a significant improvement in the ASES score of 43.2 points at 6 years' follow-up. At 7 years' follow-up, El Shewy[28] reported significant improvements of 37.8 points in the ASES score and 42.2 points in the University of California, Los Angeles score.

Side Effects, Complications, and Rehabilitation Protocol

Adverse events were reported by all studies but one.[35] The most commonly reported complications after surgery were prolonged postoperative pain and stiffness (Table 4). All cases of shoulder stiffness could be treated with subacromial or intra-articular infiltrations of corticosteroids and/or nonsteroidal anti-inflammatory drugs, with no reported long-lasting disability. Yoo et al.[14] reported intraoperative rotator cuff tears in most cases because of extensive debridement of the calcific deposit, all of which were immediately repaired with suture anchors or side-to-side stitches with good clinical outcomes. Balke et al.[11] reported 11 partial supraspinatus ruptures during US examinations at last follow-up. No serious adverse events such as infection or hyperesthesia and no secondary operations were reported.

Four studies used an immediate passive and active exercise rehabilitation protocol.[11,13,38,40] Porcellini et al.[35] started with 3 weeks of passive training before adding active exercises, El Shewy[28] chose to immobilize the shoulder with a sling for 2 weeks in combination with passive motion exercise, and Yoo et al.[14] chose to immobilize the shoulder with an abduction brace for 3 weeks.

Discussion

The results of treatment with high-energy ESWT, US-guided needling, and arthroscopy in patients with calcific tendinitis of the shoulder were evaluated. Good results concerning improvement of shoulder function and resorption of the calcific deposit at final follow-up were achieved by all 3 treatment modalities, with an

improvement in the Constant-Murley score ranging between 26.3 and 41.5 points after 1 year.

ESWT has been studied extensively, with a large heterogeneity in reported treatment protocols and large differences in shockwave intensity. ESWT uses monophasic pressure pulses that have a high peak pressure and a short duration that is focused on a small target through reflectors. The exact mechanism by which ESWT relieves tendon-associated pain is still unclear. The theoretical benefits are the stimulation of tissue healing[50] and the breakdown of calcifications.[51] The intensity of ESWT is measured by the EFD, which is reported in millijoules per square millimeter, and the overall effect is dependent on the EFD, the number of pulses, and the focus of the focal point. Several attempts have been made to stratify the energy into 2 or 3 groups, but no consensus currently exists on what the exact cutoff point is between low- and high-energy shockwaves. In general, an EFD of less than 0.08 mJ/mm^2 corresponds to low energy whereas high-energy extracorporeal shockwaves have an EFD of greater than 0.28 mJ/mm^2. Although a clear dose-response relation between low- and high-energy ESWT has not been defined, studies have shown that high-energy ESWT (>0.28 mJ/mm^2) has a better chance of improving shoulder function and pain reduction in patients with chronic calcific tendinopathy than low-energy ESWT (<0.08 mJ/mm^2). The advantage of high-energy ESWT is that it is widely applicable in out-of-hospital settings and is relatively inexpensive. Good clinical results can be achieved, and treatment is administered without any severe side effects or long-term complications. However, in general, patients have to undergo multiple ESWT sessions to achieve these results, which makes this treatment more time consuming than US-guided needling.

US-guided needling uses sonographic guidance to visualize the calcific deposit, which is then punctured and irrigated with a needle to break it down. The procedure removes part of the calcific deposit and promotes further reabsorption of the remaining calcific material. Some authors prefer a single needle to prevent damage to the surrounding tendon tissue, whereas others describe a 2-needle technique including aspiration and lavage to promote resorption and create a continuous flow of fluid in which the calcific deposits are dissolved. A recent review by Gatt and Charalambous[10] showed no difference in outcome when comparing a 1-needle technique versus a 2-needle technique. Two studies reported re-needling rates of 28% and 45%. The most reported side effects were discomfort during treatment and shoulder pain after treatment, which resolved with nonoperative treatment. US-guided needling can be performed in an outpatient clinical setting with patients under local anesthesia and is therefore widely applicable. The costs are similar to those of high-energy ESWT, and the included studies did not report serious side effects or long-term complications. This review showed that, on the basis of the available level of evidence, US-guided needling is a safe and effective treatment modality in the midterm to long-term.

Surgical removal of the calcific deposit has been the preferred treatment for chronic calcific rotator cuff tendinopathy for several years. Open and endoscopic techniques are available for this purpose, but arthroscopy is currently favored because it is minimally invasive and provides clinical results equivalent to open techniques.[13] The arthroscopic techniques used by the authors in this review differed primarily in the choice of additional subacromial decompression and the extent of calcific deposit removal. Up to this point, numerous studies have failed to prove a benefit of additional acromioplasty. The extent to which the calcific deposit has to be removed is another issue. Maier et al.[12] stated that calcific removal with preservation of the rotator cuff yielded good to excellent results and that arthroscopic techniques with complete removal of the calcific deposit often require repair of the rotator cuff defect. Prolonged immobilization because of a rotator cuff repair can also add to a higher chance of postoperative shoulder stiffness.[52] Arthrofibrosis and postoperative pain were the most commonly reported complications and must be taken into account when one is appreciating the high clinical success rate of arthroscopic removal.

Pooling of data was not possible because of the heterogeneity of the included studies. However, we were able to provide a clear overview of the literature reporting outcomes after treatment for calcific tendinopathy of the shoulder. Arthroscopy and US-guided needling resulted in different complications compared with ESWT, the most important complications being postoperative pain and shoulder stiffness. All frozen shoulders responded well to nonoperative treatment.

Limitations

A limitation of this study is the heterogeneity of the methodologic quality of the included studies. Shockwave therapy was the only modality for which extensive Level I evidence was available. The results for the arthroscopic surgery group were primarily based on Level IV studies with an emphasis on the long-term results. The flaws of these individual studies are reflected in our results and in the differences in the Coleman scores. It remains under considerable debate whether the good clinical results and resorption of the calcific deposit after treatment with any of the 3 treatment modalities are due to the effect of the treatment or due to the natural course of the condition.[53] A pearl of this study is that it gives a comprehensive overview of the available literature for the top 3 treatment

modalities for calcific rotator cuff tendinopathy. Arthroscopy, high-energy ESWT, and US-guided needling have all proved to provide good clinical outcomes at midterm to long-term follow-up. Future research should focus on comparative studies reporting the long-term clinical (patient-reported) outcomes and assessments of patients' quality of life after ESWT, US-guided needling, and arthroscopy for calcific tendinopathy of the rotator cuff.

Conclusions

Patients can achieve good to excellent clinical outcomes after high-energy ESWT, US-guided needling, and arthroscopy for calcific tendinopathy of the shoulder. Side effects and post-treatment complications should be taken into account when a decision is being made for each individual patient. Physicians should consider high-energy ESWT and US-guided needling as minimally invasive treatment options when primary conservative treatment fails. Arthroscopy can safely be used as a very effective but more invasive secondary option, although the extent of deposit removal and the additional benefit of subacromial decompression remain unclear.

References

1. Harmon PH. Methods and results in the treatment of 2,580 painful shoulders, with special reference to calcific tendinitis and the frozen shoulder. *Am J Surg* 1958;95:527-544.
2. Hurt G, Baker CL. Calcific tendinitis of the shoulder. *Orthop Clin North Am* 2003;34:567-575.
3. Louwerens JK, Sierevelt IN, van Hove RP, van den Bekerom MP, van Noort A. Prevalence of calcific deposits within the rotator cuff tendons in adults with and without subacromial pain syndrome. Clinical and radiologic analysis of 1219 subjects. *J Shoulder Elbow Surg* 2015;24:1588-1593.
4. Bosworth B. Calcium deposits in the shoulder and subacromial bursitis: A survey of 12,122 shoulders. *JAMA* 1941;116:2477-2482.
5. Welfling J, Kahn MF, Desroy M, Paolaggi JB. Calcifications of the shoulder. The disease of multiple tendinous calcifications. *Rev Rhum Mal Osteoartic* 1965;32:325-334 [in French].
6. Gosens T, Hofstee DJ. Calcifying tendinitis of the shoulder: Advances in imaging and management. *Curr Rheumatol Rep* 2009;11:129-134.
7. Uhthoff HK, Sarkar K, Maynard JA. Calcifying tendinitis: A new concept of its pathogenesis. *Clin Orthop Relat Res* 1976:164-168.
8. Louwerens JK, Sierevelt IN, van Noort A, van den Bekerom MP. Evidence for minimally invasive therapies in the management of chronic calcific tendinopathy of the rotator cuff: A systematic review and meta-analysis. *J Shoulder Elbow Surg* 2014;23:1240-1249.
9. Bannuru RR, Flavin NE, Vaysbrot E, Harvey W, McAlindon T. High-energy extracorporeal shock-wave therapy for treating chronic calcific tendinitis of the shoulder: A systematic review. *Ann Intern Med* 2014;160:542-549.
10. Gatt DL, Charalambous CP. Ultrasound-guided barbotage for calcific tendonitis of the shoulder: A systematic review including 908 patients. *Arthroscopy* 2014;30:1166-1172.
11. Balke M, Bielefeld R, Schmidt C, Dedy N, Liem D. Calcifying tendinitis of the shoulder: Midterm results after arthroscopic treatment. *Am J Sports Med* 2012;40:657-661.
12. Maier D, Jaeger M, Izadpanah K, Bornebusch L, Suedkamp NP, Ogon P. Rotator cuff preservation in arthroscopic treatment of calcific tendinitis. *Arthroscopy* 2013;29:824-831.
13. Rubenthaler F, Ludwig J, Wiese M, Wittenberg RH. Prospective randomized surgical treatments for calcifying tendinopathy. *Clin Orthop Relat Res* 2003:278-284.
14. Yoo JC, Park WH, Koh KH, Kim SM. Arthroscopic treatment of chronic calcific tendinitis with complete removal and rotator cuff tendon repair. *Knee Surg Sports Traumatol Arthrosc* 2010;18:1694-1699.
15. Jerosch J, Strauss JM, Schmiel S. Arthroscopic treatment of calcific tendinitis of the shoulder. *J Shoulder Elbow Surg* 1998;7:30-37.
16. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *BMJ* 2009;339:b2535.
17. Huisstede BM, Gebremariam L, van der Sande R, Hay EM, Koes BW. Evidence for effectiveness of extracorporal shock-wave therapy (ESWT) to treat calcific and non-calcific rotator cuff tendinosis—A systematic review. *Man Ther* 2011;16:419-433.
18. Jadad AR, Moore RA, Carroll D, et al. Assessing the quality of reports of randomized clinical trials: Is blinding necessary? *Control Clin Trials* 1996;17:1-12.
19. Coleman BD, Khan KM, Maffulli N, Cook JL, Wark JD. Studies of surgical outcome after patellar tendinopathy: Clinical significance of methodological deficiencies and guidelines for future studies. Victorian Institute of Sport Tendon Study Group. *Scand J Med Sci Sports* 2000;10:2-11.
20. Jakobsen RB, Engebretsen L, Slauterbeck JR. An analysis of the quality of cartilage repair studies. *J Bone Joint Surg Am* 2005;87:2232-2239.
21. Frost A, Zafar MS, Maffulli N. Tenotomy versus tenodesis in the management of pathologic lesions of the tendon of the long head of the biceps brachii. *Am J Sports Med* 2009;37:828-833.
22. Tallon C, Coleman BD, Khan KM, Maffulli N. Outcome of surgery for chronic Achilles tendinopathy. A critical review. *Am J Sports Med* 2001;29:315-320.
23. Cosentino R, De Stefano R, Selvi E, et al. Extracorporeal shock wave therapy for chronic calcific tendinitis of the shoulder: Single blind study. *Ann Rheum Dis* 2003;62:248-250.
24. Daecke W, Kusnierczak D, Loew M. Long-term effects of extracorporeal shockwave therapy in chronic calcific tendinitis of the shoulder. *J Shoulder Elbow Surg* 2002;11:476-480.
25. de Witte PB, Selten JW, Navas A, et al. Calcific tendinitis of the rotator cuff: A randomized controlled trial of

ultrasound-guided needling and lavage versus subacromial corticosteroids. *Am J Sports Med* 2013;41:1665-1673.
26. De Conti G, Marchioro U, Dorigo A, et al. Percutaneous ultrasound-guided treatment of shoulder tendon calcifications: Clinical and radiological follow-up at 6 months. *J Ultrasound* 2010;13:188-198.
27. del Cura JL, Torre I, Zabala R, Legorburu A. Sonographically guided percutaneous needle lavage in calcific tendinitis of the shoulder: Short- and long-term results. *AJR Am J Roentgenol* 2007;189:W128-W134.
28. El Shewy MT. Arthroscopic removal of calcium deposits of the rotator cuff: A 7-year follow-up. *Am J Sports Med* 2011;39:1302-1305.
29. Gerdesmeyer L, Wagenpfeil S, Haake M, et al. Extracorporeal shock wave therapy for the treatment of chronic calcifying tendonitis of the rotator cuff: A randomized controlled trial. *JAMA* 2003;290:2573-2580.
30. Hsu CJ, Wang DY, Tseng KF, Fong YC, Hsu HC, Jim YF. Extracorporeal shock wave therapy for calcifying tendinitis of the shoulder. *J Shoulder Elbow Surg* 2008;17:55-59.
31. Ioppolo F, Tattoli M, Di Sante L, et al. Extracorporeal shock-wave therapy for supraspinatus calcifying tendinitis: A randomized clinical trial comparing two different energy levels. *Phys Ther* 2012;92:1376-1385.
32. Kim YS, Lee HJ, Kim YV, Kong CG. Which method is more effective in treatment of calcific tendinitis in the shoulder? Prospective randomized comparison between ultrasound-guided needling and extracorporeal shock wave therapy. *J Shoulder Elbow Surg* 2014;23:1640-1646.
33. Perlick L, Luring C, Bathis H, Perlick C, Kraft C, Diedrich O. Efficacy of extracorporal shock-wave treatment for calcific tendinitis of the shoulder: Experimental and clinical results. *J Orthop Sci* 2003;8:777-783.
34. Pleiner J, Crevenna R, Langenberger H, et al. Extracorporeal shockwave treatment is effective in calcific tendonitis of the shoulder. A randomized controlled trial. *Wien Klin Wochenschr* 2004;116:536-541.
35. Porcellini G, Paladini P, Campi F, Paganelli M. Arthroscopic treatment of calcifying tendinitis of the shoulder: Clinical and ultrasonographic follow-up findings at two to five years. *J Shoulder Elbow Surg* 2004;13:503-508.
36. Rompe JD, Burger R, Hopf C, Eysel P. Shoulder function after extracorporal shock wave therapy for calcific tendinitis. *J Shoulder Elbow Surg* 1998;7:505-509.
37. Sabeti M, Schmidt M, Ziai P, Graf A, Nemecek E, Schueller-Weidekamm C. The intraoperative use of ultrasound facilitates significantly the arthroscopic debridement of calcific rotator cuff tendinitis. *Arch Orthop Trauma Surg* 2014;134:651-656.
38. Seil R, Litzenburger H, Kohn D, Rupp S. Arthroscopic treatment of chronically painful calcifying tendinitis of the supraspinatus tendon. *Arthroscopy* 2006;22:521-527.
39. Serafini G, Sconfienza LM, Lacelli F, Silvestri E, Aliprandi A, Sardanelli F. Rotator cuff calcific tendonitis: Short-term and 10-year outcomes after two-needle us-guided percutaneous treatment—Nonrandomized controlled trial. *Radiology* 2009;252:157-164.
40. Seyahi A, Demirhan M. Arthroscopic removal of intraosseous and intratendinous deposits in calcifying tendinitis of the rotator cuff. *Arthroscopy* 2009;25:590-596.
41. Yoo JC, Koh KH, Park WH, Park JC, Kim SM, Yoon YC. The outcome of ultrasound-guided needle decompression and steroid injection in calcific tendinitis. *J Shoulder Elbow Surg* 2010;19:596-600.
42. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. *Clin Orthop Relat Res* 1987:160-164.
43. Richards RR, An KN, Bigliani LU, et al. A standardized method for the assessment of shoulder function. *J Shoulder Elbow Surg* 1994;3:347-352.
44. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: The DASH (disabilities of the arm, shoulder and hand). The Upper Extremity Collaborative Group (UECG). *Am J Ind Med* 1996;29:602-608.
45. Patte D. Classification of rotator cuff lesions. *Clin Orthop Relat Res* 1990:81-86.
46. Roach KE, Budiman-Mak E, Songsiridej N, Lertratanakul Y. Development of a shoulder pain and disability index. *Arthritis Care Res* 1991;4:143-149.
47. Jobe FW, Bradley JP. The diagnosis and nonoperative treatment of shoulder injuries in athletes. *Clin Sports Med* 1989;8:419-438.
48. Ellman H, Hanker G, Bayer M. Repair of the rotator cuff. End-result study of factors influencing reconstruction. *J Bone Joint Surg Am* 1986;68:1136-1144.
49. Kirkley A, Griffin S, McLintock H, Ng L. The development and evaluation of a disease-specific quality of life measurement tool for shoulder instability. The Western Ontario Shoulder Instability Index (WOSI). *Am J Sports Med* 1998;26:764-772.
50. Schmitz C, DePace R. Pain relief by extracorporeal shockwave therapy: An update on the current understanding. *Urol Res* 2009;37:231-234.
51. Loew M, Jurgowski W, Mau HC, Thomsen M. Treatment of calcifying tendinitis of rotator cuff by extracorporeal shock waves: A preliminary report. *J Shoulder Elbow Surg* 1995;4:101-106.
52. Chang KV, Hung CY, Han DS, Chen WS, Wang TG, Chien KL. Early versus delayed passive range of motion exercise for arthroscopic rotator cuff repair: A meta-analysis of randomized controlled trials. *Am J Sports Med* 2015;43:1265-1273.
53. Wittenberg RH, Rubenthaler F, Wolk T, Ludwig J, Willburger RE, Steffen R. Surgical or conservative treatment for chronic rotator cuff calcifying tendinitis—A matched-pair analysis of 100 patients. *Arch Orthop Trauma Surg* 2001;121:56-59.