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Review article

The optimal treatment for stage 2–3 Goutallier rotator cuff tears: A systematic review of the literature

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ABSTRACT

Fatty infiltration is an important prognostic factor for cuff healing after rotator cuff repair. Treatment options for stage 2–3 Goutallier rotator cuff tears vary widely and there is lack of decent comparative studies.

Purposes: The objective of this study was 1) to give an overview of the treatment options of stage 2–3 Goutallier rotator cuff tears and their clinical outcome and 2) to give a recommendation of the optimal treatment within this specific subgroup.

Methods: We searched the databases of Medline, Embase, Cochrane library, NHS Centre for Reviews and Dissemination, PEDro from inception to December 12th, 2016. Two authors, F.H. and N.W., selected the studies after consensus. Data was extracted by one author (F.H.) and checked for completeness by a second author (N.W.). Our primary outcome was physical function, measured by shoulder-specific patient reported outcomes. Secondary outcomes were cuff integrity after rotator cuff repair, shoulder pain, general health, quality of life, activity level and adverse events.

Results: For the first research question 28 prospective as well as retrospective studies were included. For the clinical outcome of these treatments three randomized controlled trials were included.

Conclusions: Despite the high reported retear rate, rotator cuff repair has comparable results (clinical improvement) as partial repair and isolated bicepstenotomy or tenodesis. These findings suggest that the additional effect of rotator cuff repair compared to the less extensive treatment options like isolated bicepstenotomy or tenodesis should be studied, as these might form a good alternative treatment based on this systematic review.

Level of evidence: Level IV; systematic review.

1. Background

Rotator cuff tearing is a highly prevalent disorder of the shoulder joint of which its incidence increases with age. These lesions do not always result in a symptomatic shoulder joint. Under the age of 40 years, 4% of all cuff injuries remain asymptomatic, which increases up to 54% for patients aged 60 years or older.[1] Amongst elderly, tendon quality is often poor as tears are mostly degenerative by nature. Important qualitative factors to specify the amount of degeneration are the level of fatty infiltration and atrophy of the involved muscle, and retraction of the tendon. These factors are considered important for selecting appropriate candidates for rotator cuff repair.

In the literature several independent factors to define an irreparable rotator cuff tear are described such as ≥50% of fatty infiltration (Goutallier stage ≥ 3),[2] retraction of the tendon to the height of the glenoid[3] and acromio-humeral interval being less than 7 mm[4,5,6]

Amongst several identified negative prognostic factors for healing, fatty infiltration (FI) is frequently described as paramount predictor for healing, which implies anatomic integrity on the footprint after full recovery from surgery. The extend of FI in the rotator cuff was firstly classified by Goutallier et al[2] Several clinical studies on rotator cuff repair described the functional and radiologic outcome for the subgroups of this classification separately.[2,7–14] In general, for stages 0–1 (0–25% FI) the clinical outcome is described good to excellent, while stage 4 (> 50% FI) is associated with poor outcomes, high retear rates and minor functional improvement.[8] Consensus has been reached that cuff repair of these severe fatty infiltrated tendons should not be performed. The appropriate treatment for the remaining stage 2 and 3 fatty infiltrated cuff tears (25–50% FI) is still under discussion. Despite a high retear rate after rotator cuff repair in this patient category, patients clinically improve significantly with only minor functional differences between patients with healed repairs and patients with a retear.[10–12] It is still poorly understood which element is responsible for this improvement.

Alternative treatments for restoring shoulder function after a full-thickness rotator cuff tear beside cuff repair are conservative treatment,

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debridement, bicepstenotomy, bicepstenodesis, subacromial decompression, tendon transfers, arthroplasty, and other new developments in the tissue engineering industry.

1.1. Objectives

The aim of this study was to perform a systematic literature review to 1) outline the treatment options for stage 2–3 Goutallier fatty degenerated rotator cuff tears and their outcome and 2) to give a recommendation of the optimal treatment within this specific subgroup. Our hypothesis is that stage 2–3 Goutallier fatty degenerated rotator cuff tears can be treated with less extensive treatment options like conservative therapy and isolated bicepstenotomy achieving comparable functional results as compared with extensive treatment options like rotator cuff repair or tendon transfers.

2. Methods

This systematic review is reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[15]

2.1. Eligibility criteria

A literature search for studies describing the functional outcome for treated grade 2–3 Goutallier rotator cuff tears was conducted. Included treatments were: conservative treatment, open and arthroscopic rotator cuff repair, bicepstenotomy, bicepstenodesis, acromioplasty, debridement, partial repair, latissimus dorsi transfer, other tendon transfers, arthroplasty and tissue engineering or other new developments. Prospective as well as retrospective studies were included.

2.2. Search strategy

A systematic search of Embase, PubMed, Web of Knowledge, and the Cochrane Library was performed from 1995 to June 2014. The search terms included Medical Subject Headings terms, free-text word variations, and combinations of these. Cross-references and "cited-by" articles of the included articles were screened to ensure that no relevant studies were missed. An expert in this field was consulted to check for missing relevant studies. The Netherlands Journal of Orthopaedics, which is not available via the above-mentioned bibliographic databases, was searched for relevant Dutch articles. National and international trial registries were checked for ongoing or unpublished trials. This search was performed in June 2014 and updated in January 2015 and December 2016 (APPENDIX A).

2.3. Study selection

After removing duplicates, titles and abstracts were screened according to the following criteria: (1) the publication was a clinical study, (2) the study population consisted of adult patients with a MRI or CT-scan confirmed rotator cuff tear, and (3) the publication contained information on the functional outcome; radiological information on the quality of the rotator cuff tendons and postoperative integrity was not prerequisite. Based on the titles and abstracts, manuscripts identified as potentially eligible underwent a full-text review. Papers were included in the review based on the following criteria: (1) the study included stage 2–3 Goutallier fatty infiltration rotator cuff tears, described pre- or postoperatively; (2) in case of a cuff repair an arthroscopic, mini open or open surgical technique was used; (3) studies with mixed surgical techniques were included if data on the patients were separately available; (4) the article was written in English, Dutch, French or German; and (5) the full text of the paper could be obtained. For outlining the treatment options and their outcome, no selection was made in study designs. For the second objective, to give a recommendation of the optimal treatment within this specific subgroup, only randomized studies were selected.

2.4. Data items

From the included full-text papers, the following study characteristics were systematically extracted, applying the evidence table for intervention studies: bibliographic reference, study type, number of patients, multi- or single-centre study, patient characteristics (including age and gender), tear characteristics (including retear rate and level of fatty infiltration), type of intervention, diagnostic tool(s) (pre- and postoperative), the comparison, the length of follow-up, outcome measures and effect size (scores on function and cuff integrity) and source of funding.[16] A data-extraction sheet was developed a priori. One author (F.H.) extracted the data and a second author (N.W.) verified the extracted data and added data when necessary.

2.5. Assessment of risk of bias and methodological quality

Methodological quality assessment of selected papers was performed using the "methodology checklist for randomized controlled trials (RCT's), cohort studies and prognostic studies."[16] The RCT and cohort study checklist consisted of 4 main items: selection bias, performance bias, attrition bias and detection bias. Based on the score of their respective subitems, the main items were scored as low, unclear and high risk of bias. For each main item, a low risk indicated that the study was designed and conducted in a manner that minimized the risk of bias for that item. An unclear risk was given when the information required to score an item was not reported or was not reported clearly. A priori it was decided that studies would be excluded if more than 2 out of 4 main items scored a high risk of bias (low methodological quality).

The checklist for prognostic studies consisted of 6 main items: study sampling, loss to follow-up, prognostic factors, outcome, confounders, and statistical analysis. Based on the score of their respective subitems, the main items were scored as yes, unclear or no. For each main item, a yes response indicated that the study was designed and conducted in a manner that minimized the risk of bias for that item. An unclear response was given when the information required to score an item was not reported or was not reported clearly. A priori it was decided that studies with less than 3 yes responses on the 6 main items would be excluded from this review (low methodological quality). Screening of titles, abstracts, and full text, as well as the assessment of the methodological quality of the studies, was independently performed by 2 of the authors (F.H. and N.W.). Disagreements between reviewers were resolved by consensus. For the methodology assessment, consensus had to be reached on each subitem and main item of the methodology checklist.

2.6. Assessment of risk of bias across studies

In the retrieved studies, particular attention was paid to a clear description of the patient population, the in- and exclusion criteria and incomplete outcome data, concerning different risks of bias.

3. Results

3.1. Study selection

The literature search yielded a total of 3576 studies. After removing duplicates, 2321 articles remained. Titles and abstracts of the remaining 2321 studies were screened. 1547 records were discarded because they did not meet the criteria for inclusion. Full-text screening was then performed for the remaining 774 studies. 48 papers were assessed for their quality and risk of bias (Tables 1A–1C). Based on the risk of bias assessment another 20 papers were excluded. An overview

Table 1A
prognostic studies: Quality assessment of the included studies according to the 'Methodology checklist for prognostic studies.' All items were scored with a 'yes', 'no', or 'unclear'. A 'yes' response indicates that the study has been designed and conducted in such a way as to minimize the risk of bias for that item. An 'unclear' response was given when the answer to an item is not reported or is not reported clearly.

Study	Population	Drop-out	Prognostic factor	Outcome	Confounders	Statistical analysis	Inclusion?
Iannotti et al[22]	yes	yes	yes	yes	yes	no	Yes
Toussaint, 2011[62]	yes	no	unclear	yes	unclear	no	Yes
Kim et al[11,23]	yes	yes	yes	yes	yes	yes	Yes
Cho and Rhee[9]	yes	no	yes	yes	unclear	no	Yes
Edwards, 2002[46]	yes	unclear	unclear	unclear	yes	unclear	No
Koh, 2014[54]	yes	no	unclear	yes	unclear	unclear	No
Chung et al[10,19,38]	yes	no	yes	yes	unclear	unclear	Yes
Choi et al[18]	yes	no	yes	yes	unclear	unclear	Yes
Wiater et al[36]	yes	unclear	yes	yes	unclear	unclear	Yes
Lapner et al[24]	yes	unclear	yes	yes	yes	unclear	Yes
Vastamaki, 2013[63]	unclear	unclear	unclear	yes	unclear	no	No
Fuchs et al[20]	yes	yes	yes	yes	no	yes	Yes
Goutallier, 2003[49]	unclear	unclear	unclear	yes	unclear	no	No
Mellado et al[25]	yes	unclear	yes	yes	unclear	no	Yes
Goutallier, 2009[50]	yes	unclear	unclear	unclear	unclear	no	No
Zumstein et al[37]	unclear	yes	yes	yes	unclear	yes	Yes
Nich et al[30]	yes	unclear	yes	yes	unclear	no	Yes
Park et al[39]	yes	unclear	yes	yes	yes	yes	Yes
Chung et al[10,19,38]	yes	unclear	unclear	yes	yes	yes	Yes
Kim, 2016[55]	unclear	unclear	unclear	unclear	unclear	unclear	No

of the screening process is given in Fig. 1. No unpublished relevant studies were obtained from trial registries. For the first question on possible treatment options randomized and non-randomized studies were included (n = 28) (Table 2).[4,9,17–42] For the first research question on functional outcome only randomized studies, describing the functional results of each stage of fatty infiltration separately (n = 3), were included (Table 3).[21,26,27]

3.2. Risk of bias assessment

Tables 1A–1C show the results of the assessed risk of bias of the individual trials.

3.2.1. Results on treatment options for stage 2–3 Goutallier cuff tears

There are several options for treating Goutallier stage 2–3 rotator cuff tears. After a critical selection of literature, articles on arthroscopic cuff repair, partial cuff repair, debridement, bicepstenotomy, biceps-stenodesis, lattisimus dorsi transfer, arthroplasty and conservative treatment, were included. Literature on other therapeutical options like, ligament augmentation and other tendon transfers were not included because they did not meet the inclusion criteria or were not included due to poor study quality.

3.2.1.1. Rotator cuff repair. Twenty-three out of twenty-seven included articles described a rotator cuff repair of which 12 were prognostic studies, 5 cohort studies and 6 RCT's. Four prognostic studies were on open rotator cuff repair.[20,25,30,37] There were three prognostic studies that focused on cuff integrity related to the stage of fatty infiltration.[9,22,23] Iannotti et al[22] found more retears amongst patients with stage 2 Goutallier (50%) compared to stage 0 and 1 Goutallier (16%, 11%) with comparable functional outcomes.[22] The two other studies, Kim et al[23] and Cho and Rhee,[9] reported higher retear rates with Kim et al[23] reporting 100% failure of Goutallier stage 3 and Cho and Rhee[9] 62% failure of Goutallier stage 3 and 47% failure rate amongst stage 2, with excellent relief of pain and functional improvement to perform the activities of daily living, despite the structural failures. Within these two studies 44%–56% of the patients underwent additional treatment of the biceps tendon (tenotomy or

Table 1B
The cohort studies checklist consisted of 4 main items: selection bias, performance bias, attrition bias and detection bias. Based on the score of their respective subitems, the main items were scored as low, unclear and high risk of bias. For each main item, a low response indicated that the study was designed and conducted in a manner that minimized the risk of bias for that item. An unclear response was given when the information required to score an item was not reported or was not reported clearly. A priori, was decided that studies were excluded if more than 2 out of 4 main items would be scored as high risk of bias on the basis of low methodological quality.

Study	Selection bias	Performance bias	Attrition bias	Detection bias	Inclusion?
Park et al[32]	low	unclear	low	low	Yes
Franceschi, 2015[47]	unclear	unclear	unclear	unclear	No
Oh et al[31]	low	unclear	low	unclear	Yes
Cho et al[17]	unclear	unclear	low	low	Yes
Warner et al[35]	unclear	unclear	low	low	Yes
Ryu, 2015[60]	low	unclear	low	high	Yes
Taniguchi, 2015[61]	unclear	unclear	low	unclear	No
Hug, 2015[53]	unclear	unclear	unclear	low	No
Namdari, 2014[57]	high	unclear	unclear	low	No
Moraiti, 2014[29]	unclear	unclear	low	low	Yes
Warner and Parsons[35]	high	high	unclear	unclear	No
Boileau et al[4]	low	unclear	low	unclear	Yes
Lee, 2016[56]	high	high	high	unclear	No
Gasbarro, 2016[48]	unclear	unclear	unclear	unclear	No
Shin et al[40]	unclear	unclear	high	unclear	No
Paribelli, 2015[59]	high	high	low	unclear	No
Franceschi, 2015[47]	high	high	unclear	unclear	No

Table 1C
The randomized controlled trial checklist consisted of 4 main items: selection bias, performance bias, attrition bias and detection bias. Based on the score of their respective subitems, the main items were scored as low, unclear and high risk of bias. For each main item, a low response indicated that the study was designed and conducted in a manner that minimized the risk of bias for that item. An unclear response was given when the information required to score an item was not reported or was not reported clearly. A priori, was decided that studies were excluded if more than 2 out of 4 main items would be scored as high risk of bias on the basis of low methodological quality.

Study	Selection bias	Performance bias	Attrition bias	Detection bias	Inclusion?
Milano et al[27]	low	low	low	low	Yes
Van der Zwaal et al[34]	low	unclear	low	unclear	Yes
Gumina, 2012[51]	unclear	unclear	low	unclear	No
Gumina, 2012[52]	high	unclear	low	unclear	No
Milano, 2013[28]	low	low	low	low	Yes
Berth et al[44]	high	high	high	high	No
Grasso et al[21]	low	unclear	low	low	Yes
Milano et al[28]	low	unclear	low	low	Yes
Nicholas, 2016[58]	unclear	low	unclear	unclear	No
Bryant et al[42]	low	low	low	low	Yes
Kukkonen et al[41]	low	unclear	low	low	Yes

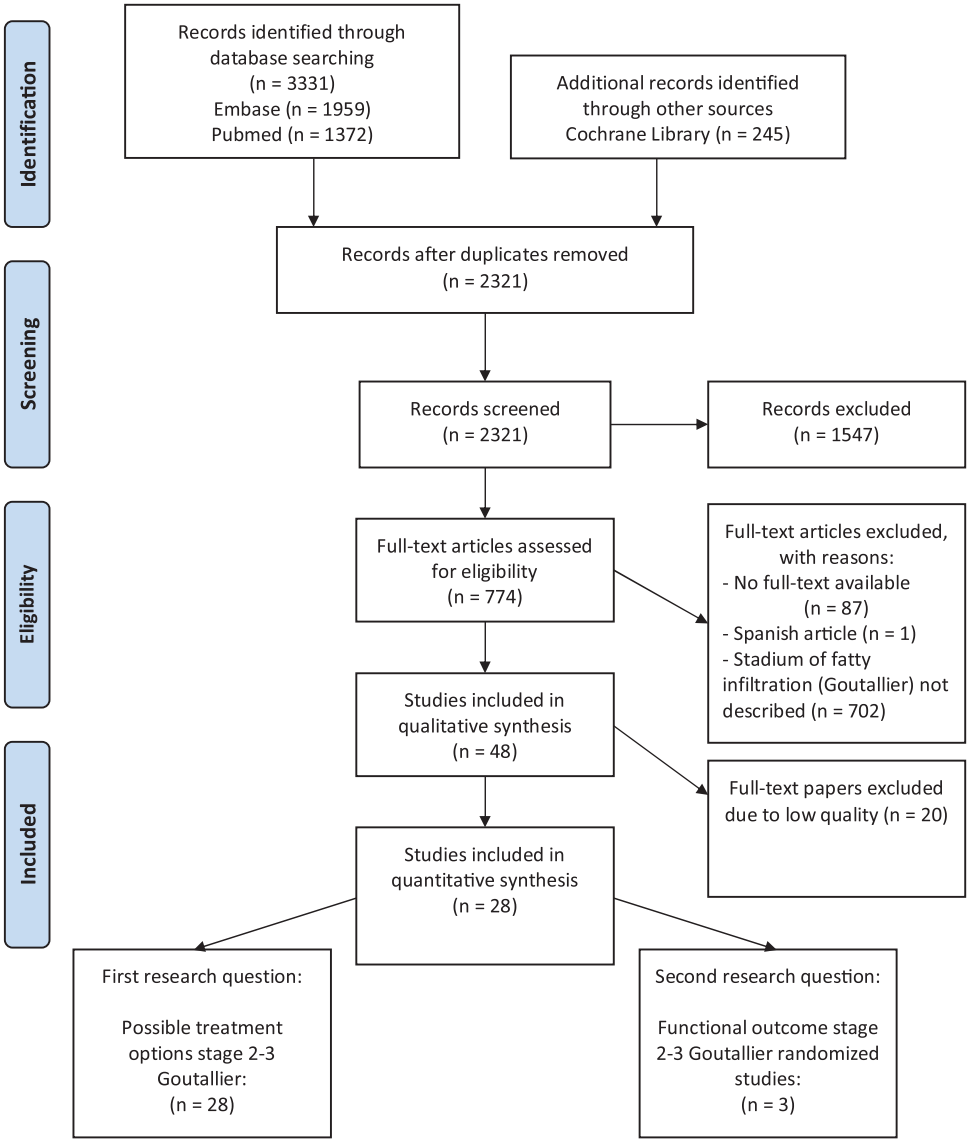

Fig. 1. Flow diagram of literature search.

tenodesis).[9,23] Performing a meta-analysis was not possible due to heterogeneous data. Average fatty infiltration ranged from 0.34 to 3.24 with a mean absolute Constant score ranging from 66.1 to 93.3 and a retear rate from 12% to 86% without any linearly relation observed (see Table 2).

3.2.1.2. Partial repair. One retrospectively designed study was included comparing partial with complete rotator cuff repair, open approach. Mellado et al[25] performed a partial repair in 6 out of 22 patients with massive rotator cuff tears. Results were comparable for the partial and complete repair group with a retear rate amongst the complete repair

Table 2
Results (possible treatment options, randomized and non-randomized studies).

Study	Study design	Treatment	Comparison	Sample size	Age at surgery	Length of follow-up (months)	Functional outcome (mean CMS and DASH score)	Retear rate	Average degree of FI	% stage 2–3 Goutallier	
										2	3
Boileau et al[4]	Cohort	Bicepstenotomy/ Bicepstenodesis	Tenotomy vs. Tenodesis	72	Tenotomy: 73.1 ± 6.2 Tenodesis: 69.8 ± 6.4	35 ± 7	*CMS:* Overall: 66.5 ± 16.3	/	ISP 2.33	29	22
Bryant et al[42]	RCT	Cuff repair	Repair alone vs. repair and augmentationpor-cine small intestine submucosa (SIS)	62	56.6 ± 10.8	24	*CMS:* *SIS: 79.3 ± 3.5* *No SIS: 87.5 ± 3.7*	60%	SSP: 1.5	61	3
Cho and Rhee[9]	Prognostic	Cuff repair	Intact vs. Retear	169	Intact 53.2 (38–67) Retear 58.4 (45–74)	39 (24–83)	/	22.5%	/	10	8
Cho et al[17]	Cohort	Cuff repair	Single vs. double row	64	Single: 58.1 ± 6.07 Double: 57.6 ± 10.39	7.5 (3–29)	*CMS:* *Single: 77.4* *Double: 76.2*	39%	/	7	63
Choi et al[18]	Prognostic	Cuff repair	/	147	62.8 (46–79)	23.4 (12–48)	*CMS: 84.3 (11–100)*	17.0%	SSP: *2.22*	46	27
Chung et al[10,19,38]	Prognostic	Cuff repair	/	288	59.53 ± 8.41	13.5 ± 2.7	/	22.9%	SSP: 2.35 ± 1.05	/	/
Chung et al[19]	Prognostic	Cuff repair	Intact vs. retear	108	63.7 ± 6.4	31.7 ± 15.8	*CMS:* *Intact: 77.1 ± 32.9* *Retear: 67.2 ± 27.2* *(NS)*	39.8%	SSP: 3.13 Intact: 2.84 Retear: 3.55	/	/
Fuchs et al[20]	Prognostic	Cuff repair (open)	/	32	59.0 (40–75)	38 (24–53)	*CMS: 78.1*	13%	SSP: Intact: 0.8 Retear: 1.0	/	/
Grasso et al[21]	RCT	Cuff repair	Single vs. double row	72	Single: 58.3 ± 10.3 Double: 55.2 ± 6.5	24.8 ± 1.4	*See* Table 3	/	/	39	24
Iannotti et al[22]	Prognostic	Cuff repair	Intact vs. Retear	113	Intact: 58.6 ± 9.4 Retear: 59.1 ± 9.09	12	/	17%	Intact: 2.13 ± 0.65 Retear: 2.39 ± 0.76	9	0
Kim et al[23]	Prognostic	Cuff repair	Intact vs. Retear	66	61.2 (50–75)	23.5 (15–38)	*CMS:* *Intact: 78.5* *Retear: 70.6*	42.4%	SSP: Intact: 1.74 ± 0.92 Retear 2.54 ± 0.84	/	/
Kukkonen et al[41]	RCT	Cuff repair/ conservative/ acromioplasty	1. Conservative 2. Acromioplasty 3. Cuff repair	180	Conservative: 64 ± 5.6 Acromioplasty: 65 ± 5.1 Cuff repair 65 ± 5.8	24	CMS improvement: 1. 18.4 (14.2–22.6) 2. 20.5 (16.4–24.6) 3. 22.6 (18.4–26.8) (p = 0.38)	31% cuff repair group	/	1. 32 (53%) 2. 29 (48%) 3. 30 (53%)	1. 1 (2%) 2. 5 (8%) 3. 2 (4%)
Lapner et al[24]	Prognostic	Anatomic total shoulder	/	62	67 (34–90)	12	/	/	SSP 1.41	34	3
Mellado et al[25]	Prognostic	Partial and complete cuff repair (open)	/	6 vs. 22	59.8 ± 6.8	44.4 (13–96)	/	68%	SSP: 1.52 ± 0.8	/	/
Milano et al[26]	RCT	Cuff repair	Bio vs. metal anchors	110	Bio: 62.8 ± 7.9 Metal: 60.4 ± 8.6	24.4 ± 2.6	*See* Table 3	/	/	34	29

(*continued on next page*)

Table 2 (*continued*)

Study	Study design	Treatment	Comparison	Sample size	Age at surgery	Length of follow-up (months)	Functional outcome (mean CMS and DASH score)	Retear rate	Average degree of FI	% stage 2–3 Goutallier	
										2	3
Milano et al[27]	RCT	Cuff repair	+/− subacromial decompression	80	61 ± 7.0 59.7 ± 9.7	24	*See* Table 3	/	/	38	25
Milano et al[28]	RCT	Cuff repair	+/− Microfracture	80	Microfracture 63.1 ± 9.2 Standard repair 60.6 ± 10.1	28.1 ± 3	*CMS:* *Microfracture:* *92.7 ± 16.7* *Standard repair:* *94.5 ± 14* *DASH: Microfracture:* *28.6 ± 21.3* *Standard repair:* *23.3 ± 20.1*	/	SSP: 1.97	34	25
Moraiti et al[29]	Cohort	Cuff repair	Over 70 vs. under 50 years old	80	/	> 70 yrs 13.8 < 50 yrs 12.9	*CMS:* *> 70 yrs 74.6_12.02* *< 50 yrs* *77.18_11.02*	/	SSP: > 70 yrs 1.90 < 50 yrs 0.81	30	11
Nich et al[30]	Prognostic	Cuff repair (open)	/	47	59	87 (60–133)	*CMS:* 73.7	12%	SSP: 0.81	/	/
Oh et al[31]	Cohort	Cuff repair	non-pseudoparalytic vs. pseudoparalytic	58	Pseudo 64.6 ± 9.5 Non-pseudo 65.3 ± 7.0	30.5 ± 18.1 (12–72)	*CMS:* *Pseudo: 53.2 ± 18.5* *Non-pseudo:* *79.0 ± 56.0*	Healing rate: 33.3% in the pseudoparalytic 47.4% in the non-pseudoparalytic group	/	7	31
Park et al[32]	Cohort	Cuff repair	Single vs. double row	78	55.8	25.1 (22–30)	*CMS:* *Single row:* *76.68 ± 8.56* *Double row:* *79.66 ± 4.52*	/	SSP: Single row 1.70 ± 1.07 Double row 1.95 ± 1.33	/	/
Park et al[39]	Prognostic	Cuff repair	Intact vs. retear	339	59.8 ± 7.9	20.8 (22–66)	*CMS:* Overall: 67.1 ± 12.2 (NS between groups)	13.3%	SSP: 1.91 ± 0.82	/	/
Ryu et al[33]	Cohort	Cuff repair	Conventional vs. modified suture-bridge	71	Conventional 57.0 ± 4.4 Modified 57.6 ± 4.6	Conventional 58 (44–77) Modified 26 (15–35)	*CMS:* *Conventional* *73.4 ± 10.3* *Modified 77.0 ± 9.8*	15%	SSP: 0.34	/	/
Shin et al[40]	Cohort	Cuff repair	Small vs. medium vs. large size tears	164	55.2 ± 9	24	*CMS:* No significant difference between groups	Exclusion criteria		3	0
Van der Zwaal et al[34]	RCT	Cuff repair	Arthroscopic (AA) vs. mini-open (MO)	100	AA 57.2 ± 8.0 MO 57.8 ± 7.9	12	*CMS:* *AA 66 (1.6)* *MO 62 (1.6)* *DASH:* *AA 65.6 (60.8–70.5)* *MO 69.1 (64.3–73.9)*	13–17%	/	16	0
Warner and Parsons[35]	Cohort	Latissimus dorsi transfer	Primary vs. revision	6 vs. 16	Primary 62 (38–78) Revision 56 (26–75)	25 (18–31)	*CMS (age/gender adjusted):* *Primary 69% (58–81)* *Revision 52% (37–75)*	36%	SSP 3.09	27	36

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Table 2 (*continued*)

Study	Study design	Treatment	Comparison	Sample size	Age at surgery	Length of follow-up (months)	Functional outcome (mean CMS and DASH score)	Retear rate	Average degree of FI	% stage 2–3 Goutallier	
										2	3
Wiater et al[36]	Prognostic	Reverse total shoulder	/	30	71 ± 10	30 ± 7	*CMS:* 67.27 ± 13.07	/	SSP 3.1	7	20
Zumstein et al[37]	Prognostic	Cuff repair (open)	/	27	53.7	9.9 years	*CMS:* *Overall: 71* *Intact 81* *Retear: 64*	57%	SSP: Intact: 1.5 Retear: 1.5	/	/

Abbreviations: SSP: supraspinatus tendon; SSC: Subscapularis; ISP: infraspinatus; SIS: small intestine submucosa; yrs: years; +/− microfracturing: with or without microfracturing; +/− subacromial decompression: with or without subacromial decompression

*Tenosan: arginine L-alpha-ketoglutarate, methylsulfonylmethane, hydrolyzed type I collagen and bromelain.

group of 68% after a mean follow-up of 44.4 months (range: 13–96).[25] The University of California at Los Angeles (UCLA) score improved from an average of 12.5 ± 2.8 point for the total study population to 29.7 ± 5.3 and 31.8 ± 3.6 ($p < 0.0001$) point at final follow-up for respectively complete and partial rotator cuff repair.[25]

3.2.1.3. Isolated bicepstenotomy or tenodesis. Boileau et al[4] studied the outcome of isolated bicepstenotomy (n = 39) versus tenodesis (n = 33) for the treatment of irreparable massive rotator cuff tears without the presence of true pseudoparalysis. The reparability was determined by preoperative computed tomographic arthrography and direct arthroscopic evaluation. Functional results showed no significant differences between groups. For both groups the mean Constant score improved from 46.3 ± 11.9 points preoperatively to 66.5 ± 16.3 points postoperatively ($P < 0.001$). From the 72 patients treated with either tenotomy or tenodesis of the biceps tendon, stage 2–3 Goutallier FI of the infraspinatus tendon was described in 51% (n = 37) (stage 2: 29% (n = 21); stage 3: 22% (n = 16)) and FI of the subscapularis tendon in 40% (n = 29) (stage 2: 32% (n = 23); stage 3: 8% (n = 6)). The extend of FI for the supraspinatus tendon was not specified. Functional results for these subgroups were not available.[4]

3.2.1.4. Lattisimus dorsi transfer. Scrutinizing the stages of FI of interest in the study by Warner et al,[35] functional outcome decreases with the severity of FI. For the 6 patients with stage 2 FI, the mean Constant score was 69% (range 48%–75%). In contrast, the 8 patients with stage 3 FI achieved a mean Constant score of 52% (range 38%–68%). Differences in functional outcome between stage 2 and stage 3 FI were statistically significant ($P < 0.05$).[35]

3.2.1.5. Arthroplasty (reverse and anatomic total shoulder replacement). One article, by Wiater et al,[36] regarded reversed total shoulder arthroplasty. They studied the association between deltoid and rotator cuff muscle FI and clinical outcome. Quantitative fatty infiltration of the infraspinatus (30.47% ± 15.01% (range: 0–100%)) was correlated with decreased postoperative external rotation ($P = 0.037$). Correlation with increased level of supraspinatus fatty infiltration, which was found to have the highest degree of fatty infiltration, and functional impairment was not found.[36]

For anatomic total shoulder arthroplasty the condition of the supraspinatus tendon is paramount. Lapner et al[24] described a negative association between a preoperatively greater supraspinatus percent of FI with preoperative shoulder strength ($P = 0.001$) and Constant score ($P = 0.001$). The postoperative infraspinatus percent of FI was negatively associated with postoperative strength ($P = 0.021$) and Constant score ($P = 0.04$). Multivariable regression analysis of possible predictive factors demonstrated that preoperative supraspinatus percent muscle area ($P = 0.016$) was associated with better follow-up Constant score, and preoperative supraspinatus strength was associated with postoperative strength ($P = 0.002$). Higher degrees of preoperative percent of FI were not associated with worse patient-reported outcomes postoperatively.[24] From the total study population stage 2–3 Goutallier FI of supraspinatus tendon was represented in 35% (stage 2: 32% (n = 21); stage 3: 3% (n = 2)). Results were not specified for each stage of FI separately.

3.2.1.6. Conservative treatment. Kukkonen et al performed a methodological high quality randomized controlled trial in which they compared three type of treatments (physiotherapy-only, acromioplasty and physiotherapy, rotator cuff repair combined with acromioplasty and physiotherapy). Population characteristics were, mean age 65 years (55–81) with a full-thickness supraspinatus tear on MRI with the absence of pseudoparalysis and 51% stage 2 and 5% stage 3 Goutallier FI. There were no significant differences in baseline and in outcome (VAS pain, Constant score, range of motion) up to 2 years after surgery. They did not specify outcome for stage of FI

separately.

Table 2 presents the characteristics and reported outcomes of the included studies.

3.2.2. Results on functional outcome related to fatty infiltration

3.2.2.1. Characteristics of included studies. Table 3 presents the outcomes of the included studies. Only randomized studies are presented to answer the second research question of which only three described the functional outcome for each stage of fatty infiltration separately (Milano et al, Grasso et al, Milano et al).[21,26,27]

3.2.2.2. Results of included studies. The included randomized studies all reported shoulder-specific physical function.[21,26,27] They all used the age and gender adjusted Constant score and DASH score. Table 3 presents the functional outcome for stage 2 and 3 of fatty infiltration separately. Milano et al[26] compared the clinical outcome of arthroscopic cuff repair with metal and biodegradable suture anchors. Functional outcome (DASH and Constant score) was significantly influenced by the level of FI after a mean follow-up of 24.4 ± 2.6 months. Functional outcome was significantly better for stage 2 FI of the supraspinatus tendon compared to stage 3 FI.[26] Grasso et al[21] compared the clinical outcome of arthroscopic rotator cuff repair with single-row and double-row techniques in which no significant difference was found between the stage of FI and clinical results.[21] Milano et al[27] compared the clinical outcome of arthroscopic cuff repair with and without subacromial decompression. Functional outcome and quality of life after 2 years was significantly influenced by the level of FI. The subitem Work-DASH score was significantly better for stage 2 FI of the supraspinatus tendon compared to stage 3 FI. The general DASH and Constant score were not significantly influenced by the level of FI.

4. Discussion

The aim of this study was to perform a systematic literature review to outline the treatment options for stage 2–3 Goutallier fatty degenerated rotator cuff tears and their outcome and to give a recommendation of the optimal treatment within this specific subgroup. Currently, the appropriate treatment for stage 2 and 3 fatty infiltrated cuff tears (25–50% FI) is still under discussion. To answer our first question on treatment options for Goutallier 2–3 rotator cuff tears we included 28 studies on arthroscopic cuff repair, partial cuff repair, bicepstenotomy or −tenodesis, lattisimus dorsi transfer, arthroplasty and conservative treatment.[4,9,17–42] For the first research question on functional outcome, describing the functional results of each stage of fatty infiltration separately, only randomized studies were included which implicated three studies on rotator cuff repair.[21,26,27]

Considering the first research question most studies consisted of mixed and heterogeneous data, which made it difficult to compare their clinical outcome. Additionally, most studies presented an average degree of fatty infiltration for their study population with a clinical outcome in terms of means, while we were also in search of the clinical outcome for each subgroup of fatty infiltration separately. There were three well designed RCT's by Milano and Grasso et al[21,26,27] describing these results. Milano et al[26,27] showed that functional outcome was significantly influenced by the level of fatty infiltration using a multivariate regression analysis. Grasso et al[21] showed that functional outcome was not influenced by the level of fatty infiltration. Besides FI, age was the only other significant prognostic factor determining functional outcome.[21,26,27] Unfortunately they did not report integrity of the repaired tendons at follow-up. Recurrent tearing is not uncommon amongst the degenerative rotator cuff tendons, which surprisingly not always results in deterioration of functional outcome. Interestingly, 46% underwent additional tenotomy or tenodesis of the long head of the biceps tendon, which did not result in a significant difference in functional outcome as compared with an untreated biceps tendon. Although this did not result in increased functional improvement, an isolated tenotomy or tenodesis is suggested to give comparable results from at least stage 2 FI as shown by Boileau et al[4] The other included non-randomized studies did not show a linear correlation between the level of fatty infiltration and functional outcome neither with the retear rate. Additionally, the length of follow-up amongst all included studies was not associated with increased retear rate. Again, included studies were very heterogeneous which makes it difficult to draw conclusions based on these data. Recently, Jacquot et al[43] compared acromioplasty and bicepstenotomy with or without arthroscopic rotator cuff repair amongst patients older than 60 years of age. They found arthroscopic rotator cuff repair functionally superior to only performing a subacromial decompression and additional bicepstenotomy with a mean follow-up of 4 years. However, they excluded stage 3 and 4 Goutallier FI and did not mention the average degree of FI for their study groups which is, based on previous literature, the most important prognostic factor. This suggested they included patients with relatively good quality of their rotator cuff tendons for which cuff repair is known to be superior as compared to subacromial decompression in combination with a bicepstenotomy.

Only one article was included describing the results of partial cuff repair. Mellado et al[25] included 6 patients with massive rotator cuff tears and reported good results. The small sample size and retrospectively design makes it difficult to draw conclusions. In contrary, Berth et al,[44] which was excluded due to methodological poor quality, prospectively included 42 patients and compared debridement with partial cuff repair. The study population had Goutallier stage 3 (n = 35) and 4 (n = 7) fatty infiltration. After a mean follow-up of 24 ± 2 months both groups had similar pain relief and level of satisfaction (DASH). Regardless of high rates of structural failure of the partial rotator cuff repair, the results of arthroscopic partial rotator cuff repair demonstrated only slightly better functional outcome than debridement.[44] One should realize that performing a partial repair entails

Table 3
Functional results stage 2–3 fatty infiltration.

	Sample size	Treatment	Age	Length of follow-up	Outcome parameter	Stage Goutallier fatty infiltration (n)	
						2	3
Milano et al[26]	101	Bio vs. metal anchors	61.6 ± 8.3	24.4 ± 2.6		(n = 34)	(n = 29)
					Constant[a]	104.4 ± 12.5	91.3 ± 25.3
					DASH	14.6 ± 14.1	28.9 ± 19.4
Grasso et al[21]	72	Single vs. double row	56.8 ± 8.7	24.8 ± 1.4		(n = 28)	(n = 17)
					Constant[a]	102.7 ± 24	106.4 ± 14.9
					DASH	14.5 ± 13.8	14.1 ± 13
					Strength (lb)	12.6 ± 6.6	12.8 ± 5.5
Milano et al[27]	71	+/− subacromial decompression	Group 1 61 ± 7.0 Group 2 59.7 ± 9.7	24		(n = 27)	(n = 18)
					Constant[a]	103.6 ± 12.2	94.2 ± 21.2
					DASH	18.1 ± 15.5	23.6 ± 20.1

[a] age and gender adjusted Constant score.

higher costs and longer period of patient recovery compared to only a debridement.

In case of subscapularis insufficiency latissimus dorsi transfer could be indicated. As shown in the included study by Wiater et al[36] functional outcome is worse when the level of fatty infiltration increases. However, acceptable results are described even in case of increased fatty infiltration of the affected cuff.[35] In case of posterosuperior cuff deficiency and low degree of fatty infiltration of the infraspinatus tendon, latissimus dorsi transfer could also be combined with reverse total shoulder arthroplasty.[45]

The role of conservative treatment in degenerative non-traumatic tears has not been studied widely. The included study by Kukkonen et al[41] suggest that in the absence of functional disability preoperatively, physiotherapy alone could be a good alternative treatment as compared to rotator cuff repair and acromioplasty. Unfortunately they did not specify their outcome for the stages of FI separately, although more than 50% had Goutallier stage 2 FI[41]

Based on the results from this systematic performed review, in which we scrutinized treatment options and clinical outcome for stage 2–3 Goutallier fatty infiltrated rotator cuff tears, we could recommend for this specific subgroup conservative treatment, partial repair and isolated bicepstenotomy or −tenodesis as appropriate alternative for rotator cuff repair with comparable results. The conservative treatment and isolated bicepstonotomy or −tenodesis are less extensive and with comparable results might be cost-effective (shorter duration of surgery, faster recovery and less absenteeism). RCT's are needed to observe the additional effect of rotator cuff repair compared to the less extensive treatment options like an isolated bicepstenotomy or tenodesis.

5. Conclusion

Our aim was to review the published literature optional treatments on stage 2–3 Goutallier fatty infiltrated rotator cuff tears describing the clinical results and to give a recommendation for optimal treatment within this subgroup. Despite the high reported retear rate, clinical improvement after rotator cuff repair is reported. Comparable results are reported after conservative treatment, partial repair and isolated bicepstenotomy or tenodesis. Amongst patients undergoing reverse total shoulder arthroplasty the level of supraspinatus fatty infiltration seems not to influence the outcome where in anatomic total shoulder arthroplasty it does. In conclusion, conservative treatment, partial repair, isolated bicepstenotomy and tenodesis seem good treatment options in patients with stage 2–3 Goutallier fatty infiltrated rotator cuff tears.

Disclaimer

None.

International review board approval

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Conflict of interest statement

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

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Appendix A. Supplementary data

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