Medical Research Archives

European Society of Medicine

OPEN ACCESS

Published: December 31, 2023

Citation: Arismendi, A., et al., 2023. Arthroscopic double Mac surgical technique for repairing massive rotator cuff tears. Medical Research Archives, [online] 11(12). https://doi.org/10.18103/mra.v11i12.4967

DOI: https://doi.org/10.18103/mra.v11i12.4967

ISSN: 2375-1924

RESEARCH ARTICLE

Arthroscopic double Mac surgical technique for repairing massive rotator cuff tears

Andres Arismendi[1], Ana María Arcila[2], Ana Milena Herrera[3*]

[1]Orthopedic surgeon. Arm and Shoulder Orthopedics. Clínica del Campestre. Medellín. Colombia.

[2]Clínica del Campestre. Medellín, Colombia

[3]Epidemiology Unit, Clínica del Campestre. Medellin, Colombia

[*]amht73@gmail.com

ABSTRACT

Background: Massive rotator cuff tears pose a challenge to shoulder surgeons. Numerous surgical management strategies have been utilized, and studies have shown varied results regarding shoulder pain, range of motion, strength, and overall function. The novel double Mac technique combines the biomechanical properties of the double-row suture and Mac stitch for the massive rotator cuff tears repair.

Aims: To describe the short and mid-term clinical and functional results of the complete repair of massive rotator cuff tears using the double Mac technique in a cohort of carefully selected patients.

Methods: Clinical records of patients operated using the double Mac technique for massive rotator cuff tears (≥ 2 tendons) from January 2018 to October 2022 were retrieved. The surgical technique is described. A prospective follow-up of patients with a minimum of six months postoperative was carried out. The Constant-Murley Shoulder Score was used to assess the function of the operated and contralateral side. Pain level was investigated using a visual analog scale, and the retearing and complications incidences. Follow-up were categorized as short (up to 34 months) and mid-term (34 to 60 months). Descriptive and bivariate statistics were used.

Results: There were 71 patients, with an average age of 61.7 years and 59.2% women. Most (66.2%) massive rotator cuff tears were degenerative, and in 80.3% compromised 4 tendons. The median follow-up was 14 months, 93% short-term. The median visual analog scale was 0. The average Constant-Murley shoulder score was 82.2, corresponding to 100.9% of the contralateral (score 82.5). There were only 3 reported complications consisting of adhesive capsulitis. No events of retearing had occurred. Most patients (91.5%) were very satisfied with the results.

Conclusion: The complete repair of massive rotator cuff tears using the double Mac arthroscopic technique yielded excellent functional results with very low or no pain at short and mid-term follow-ups. The retear rate was zero.

Introduction

Massive rotator cuff tears (MRCT), whose prevalence among all rotator cuff (RC) tears ranges from 10 to 48%[1–3], represent a challenge for even the most experienced orthopedic surgeon given the substantial disability they cause and their associated poor outcomes and late development of glenohumeral osteoarthritis[4].

A massive rotator cuff tear has been classically defined as the complete tear of two or more tendons[5], or a tear of 5 cm or more (the sum of medial-lateral and anterior-posterior lengths)[6], or the combination of both. More recently, a consensus of experts suggested exposure of at least 67% of the greater tuberosity in the sagittal plane or the retraction of the torn tendon in the coronal or axial plane as an alternative definition for MRCT[7].

Multiple joint-preserving arthroscopic surgical alternatives for treating MRCT have been reported in the literature. Amongst those are the debridement[8] with biceps tenotomy or tenodesis[9], tendon transfer[10], partial repair[11], patch grafts[12], and arthroscopic superior capsular reconstruction with autograft[13,14], allograft[15,16], or mesh augmentation[17]. For older patients, reverse total shoulder arthroplasty (RTSA) is perhaps the most recommended surgical option in the literature[18,19].

No matter the technique, all efforts are directed to reduce re-ruptures, which can occur in up to 79% of the cases, as shown in a pooled analysis by Henry et al.[20]. The ideal RC arthroscopic repair restores biomechanics, decreases pain, improves function, and achieves a stronger fixation that allows an aggressive rehabilitation and optimal tendon-bone healing[21,22].

The tendon quality and bone conditions, as much as the suture configuration used for the repair, are essential for a proper repair, adequate tendon-bone integration, and posterior healing[23,24]. A successful suture achieves an equal distribution of tendon-bone pressure in the repaired area. The most used and studied arthroscopic sutures are the anchor-based single-row (SR) and double-row (DR) repairs, with predominant importance of techniques such as the suture bridge or transosseous equivalent in the later[23,24]. Biomechanically, there are conflicting results; a pooled analysis favors DR over SR repair[25], but some other studies show equivalence between SR and DR[26,27].

The bridge-type suture exhibits excellent biomechanical properties as it broadens the contact area on the RC footprint, showing better healing rates and clinical outcomes than the DR technique alone[24,28]. The Mac stitch (the massive cuff stitch) has been described as a simple modification of suture positioning, combining a horizontal and vertical loop at the repair location, improving the strength of the tissue fixation[29,30].

The double Mac technique was proposed by the senior author of this manuscript (AA), who has performed it as an alternative for repairing MRCT using a row with two double-loaded suture anchors and a configuration that allows a much more anatomical fixation of the tendon to the insertional footprint. In this configuration, the tendon adheres completely without folds between the sutures towards the left subacromial space. The author reported short-term outcomes of the first small series of patients surgically treated with this technique in 2018[31]. The degree of clinical functional recovery was evaluated after selectively

applying the double Mac technique in patients with MRCT.

This study aimed to evaluate the clinical and functional outcomes of the double Mac technique for treating MRCT. The hypothesis was that the double Mac technique would lead to a low rate of recurrent tearing after surgical repair and satisfactory functional outcomes in the short and mid-term, having the non-operated shoulder as a reference.

Methods

This was a retrospective-prospective observational study of patients treated for a MRCT with the double Mac technique from January 2018 to October 2022. The institutional ethics committee approved the study, and all subjects signed informed consent after being comprehensively informed about the study's objective. The study was carried out following the World Medical Association Declaration of Helsinki.

To be included in the study, compliance with all the following criteria was necessary:

- Age ≥ 18 years
- Clinical signs and magnetic resonance imaging (MRI) confirmation of a MRCT according to the Gerber et al.[5] criteria (complete tear of ≥ 2 tendons)
- Tear size between 20 – 50 mm
- Goutallier stage I or II in sagittal MR images
- Patients who had an arthroscopic repair of the MRCT using the double Mac technique
- Patients with at least six months post-surgery

Patients were excluded if any of the following was present: pseudoparalysis[32], Hamada ≥3 in x-rays[33], a tendon retraction stage 3 in the MRI[34], previous shoulder surgery, cervical spine lesion, degenerative arthritis, inflammatory arthritis, any cognitive deficiency that could make difficult the functional assessment, and not signing of informed consent.

The clinical records of all patients arthroscopically treated with the double Mac technique for MRCT from 2018 to October 2022 were retrieved; patients who complied with inclusion criteria were telephonically invited to participate in the study and were scheduled for a follow-up visit after a positive answer. The last follow-ups were performed in May of 2023.

Patients were followed in a private practice setting by a single shoulder surgeon (principal author) and a general practitioner; every patient received a complete clinical examination and functional assessment with the Constant-Murley (CM) Shoulder Score[35] of the operated and non-operated shoulder.

The occurrence of retearing since the surgery was recorded, and if so, the MR images of the event were examined to evaluate the presence of glenohumeral arthropathy and the extent of the RC retraction.

SURGICAL TECHNIQUE

The same surgeon and main author, a specialist in shoulder surgery, performed all surgeries.

1. The patient is set in a lateral decubitus position with the extremity to be operated on a shoulder arthroscopy traction device.
2. A posterior subacromial arthroscopic portal is done with articular and bursal arthroscopy to evaluate the actual size, retraction, and tissue quality of the torn rotator cuff.
3. Next, an anterolateral portal is developed, and an 8.5 mm arthroscopic cannula is introduced.

4. Articular and bursal side rotator cuff freeing and mobilization ensures that residual high tension is avoided. The rotator cuff humeral insertion site is debrided.

5. Two or three anterior and posterior medial mini portals are created for anchor passage. The first two 4.5 mm HEALIX Ti™ Dual Threaded Suture Anchors (DePuy Mitek, Inc., Johnson & Johnson) are placed through these mini portals. The anterior anchor is placed in just lateral to the humeral head cartilage and posterior to the entrance of the bicipital groove. The posterior anchor is placed in the posterior most area of anatomic rotator cuff insertion in the same fashion as the anterior anchor, which is immediately lateral to the humeral head cartilage (figure 1). Suture passage through the rotator cuff tendon begins. Sutures from the posterior anchor come first.

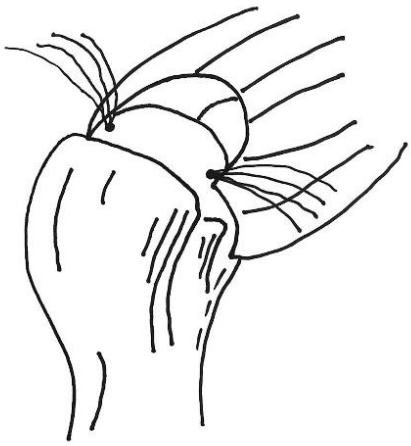

Figure 1

6. A posterior Mac configuration is developed with one horizontal suture and a vertical mattress branch. The same Mac configuration is developed for the anterior anchor (figure 2).

Figure 2.

7. Once the anterior and posterior Mac stitches are ready, an empty space in the middle of the rotator cuff, from anterior to posterior, is created (figure 3).

Figure 3.

8. A third 4.5 mm HEALIX Ti™ Anchor is placed right in the middle of the humeral head, approximately 2 cm from the lateral border of the greater tuberosity. Using the ExpreSew suture passer (DePuy Mitek, Inc., Johnson & Johnson), two vertical sutures are placed in the empty space between the anterior and posterior Mac configurations (figure 4).

Figure 4.

9. Now, all the sutures are set, and the tying sequence starts. First, the two strands that are tied belong to the third and last lateral anchor that was placed. These two vertical strands are denominated lateral tractors and are the first to be tied with a sliding SMC knot[36] (figure 5).

Figure 5.

10.Once the two lateral tractors are tied, we start tying the bridge technique from the anterior and posterior medial Mac stitches. The first step initiates with the tying up of the most posterior strand of the horizontal mattress of the anterior anchor with the most anterior strand of the horizontal mattress of the posterior anchor. These are retrieved through the 8.5 mm cannula, tied outside with a simple knot, and the remaining strands are cut (figure 6).

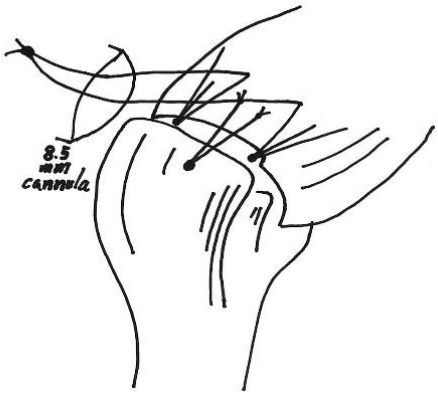

Figure 6.

11.Then, the most anterior strand from the horizontal mattress of the anterior anchor and the most posterior strand from the horizontal mattress of the posterior anchor from the two Macs are pulled, and the tied-up mattress is retrieved back tightly against the rotator cuff into a water-tight construct against the humeral bone (figure 7).

Figure 7.

12. Next, the long strands used to pull this first knot, which belongs to the most anterior horizontal mattress of the anteromedial

anchor and the most posterior horizontal mattress of the posterior anchor, is tied up with a non-gliding technique underneath the two vertical strands of both medial anchors (figure 8).

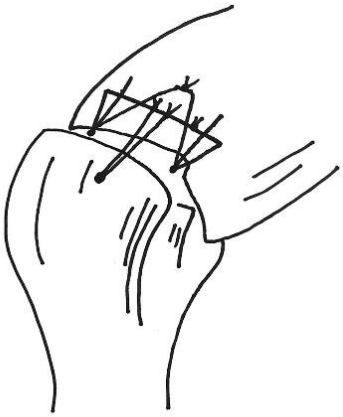

Figure 8.

13.Finally, these two vertical strands are tied up using SMC sliding technique. If done correctly, the rotator cuff must look flat from the bursal side and water-tight sealed from the articular side (figure 9).

Figure 9.

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS ver. 25.0 (SPSS Inc., Chicago, IL, USA). After distribution evaluation (Kolmogorov-Smirnov test), the clinical and functional quantitative measurement data were presented as means with standard deviations (SD; ±) or medians and ranges of minimum and maximum, and the qualitative variables as absolute and relative frequencies. Stratified analysis was performed considering two categorized variables: age group (≥ 65 years and < 65 years) and follow-up (short-term and mid-term). The short and mid-term were defined according to the systematic review by Ahmad et al.[37]; short-term up to 34 months after surgery, and mid-term between 34 and 60 months after surgery. The proportion of the CM shoulder score of the operated shoulder over the CM shoulder score of the contralateral shoulder expressed as a percentage was considered an indicator of functional recovery. A $p < 0.05$ was considered statistically significant.

Results

Seventy-one patients satisfied the inclusion criteria and were enrolled in the study. The mean age was 61.7 ± 7.7 years (range 36 -76); 44 patients (62%) were 65 years or older, and 27 (38%) were younger than 65. The sex distribution was 29 (40.8%) males and 42 (59.2%) females. Of the 71 patients, 43 (60.5%) worked in office-related activities, 14 (19.7%) in household activities, and 14 (19.7%) in manual labor. Comorbidities were registered as follows: eight patients (11.3%) were affected by diabetes, twenty (28.2%) by hypertension, and twelve (16.9%) by hypothyroidism. In 44 patients (62%), the affected and operated shoulder corresponded to the dominant side. In 24 cases (33.8%), the cause of RC tear was traumatic, and 66.2%

was degenerative. In the diagnostic MRI, all patients had acromion type II according to the Bigliani classification[38] and 46 (64.8%) had signs of acromioclavicular arthrosis. The number of compromised tendons was four in 57 patients (80.3%), three in 3 patients (4.2%), and two tendons in 11 (15.5%).

The mean operative time was 57.7 ± 4.5 minutes (range 50 - 65). Tenotomy of the biceps tendon was required in nine cases (12.7%), and in 45 (63.4%), clavicular resection was performed. There were no intrasurgical complications.

The median follow-up for all patients was 14 months (range 6 - 54). For the short-term (n=66; 93%), the median follow-up was 13.5 months (range 6 - 29), and for the mid-term (n=5; 7%), it was 43 months (range 35 – 54). The median VAS for the whole sample was 0 (range 0 - 10); the VAS values are graphed by age and follow-up in Figure 10.

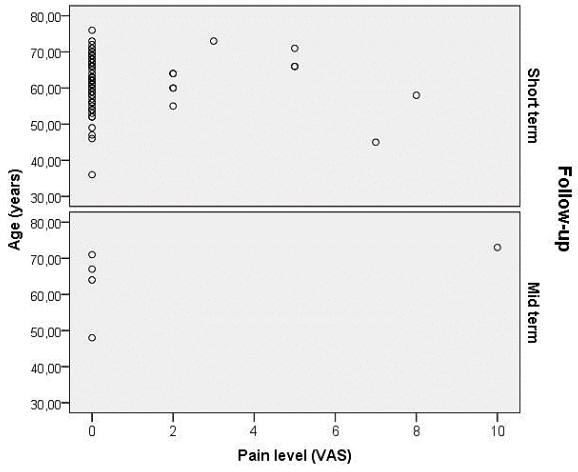

Figure 10. VAS levels at short and mid-term according to age. VAS was 0 in 83.1%, VAS of 2 or 3 in 8.4%, VAS 5 or 7 in 5.6%, and VAS 8 or 10 in 2.8% of the whole sample.

The mean CM shoulder score was 82.2 ± 8.4 (range 61 - 98) for the operated shoulder was not significantly different from the contralateral no operated shoulder with a score of 82.5 ± 10.2 (range 44 - 100) (p = 0.787). The CM shoulder score of the operated side was 100.9 ± 15.5% (68.5 - 188.6%) of the contralateral shoulder. Although the mean CM shoulder score of the operated side was higher in patients of 65 years or older (83.6 ± 8.9) than in those younger than 65 years (79.9 ± 6.9), there was no statistically significant difference among the age categories (figure 11).

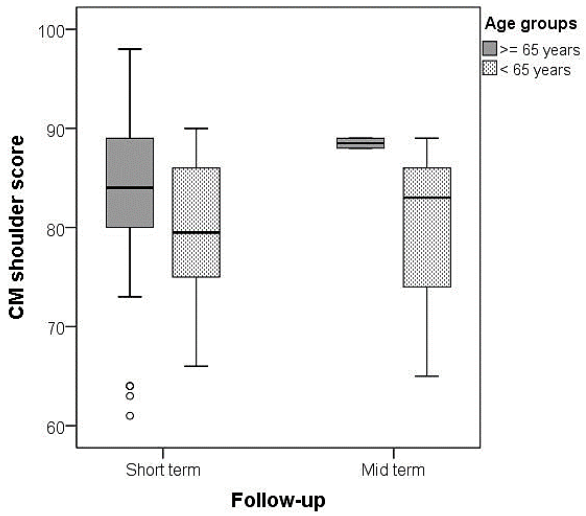

Figure 11. CM shoulder score at short and mid-term according to age groups. The median CM shoulder score in the short-term follow-up patients was 84 (≥ 65 years) and 79.5 (< 65 years), and for those of mid-term follow-up it was 88.5 (≥ 65 years) and 83 (< 65 years).

The different baseline patients' characteristics and outcomes according to the follow-up (short and mid-term) are presented in table 1.

Table 1. Basal characteristics and outcomes by follow-up

	Short-term follow-up (n=66)	Mid-term follow-up (n=5)
Age	61.5 ± 7.6	67 (48 - 73)*
Age group (n)		
≥ 65 years	42	2
< 65 years	24	3
Sex (n)		
Females	41	1
Males	25	4
Rotator cuff tear mechanism (n)		
Traumatic	22	2
Degenerative	44	3
Number of compromised tendons (n)		
2 tendons	10	1
3 tendons	3	0
4 tendons	53	4
Follow-up (months)	14 ± 6	43 (35 - 54)*
VAS	0 (0 - 8)*	0 (0 - 10)*
CM shoulder score operated side	82.2 ± 8.3	88 (65 - 89)*
CM shoulder score contralateral side	82.6 ± 10.2	88 (69 - 89)*
Percentage of contralateral shoulder	98.4 (68.5 - 188.6)	100 (90.3 - 125.8)
Complications (adhesive capsulitis)	3	0
Satisfaction		
Very satisfied	60	
Somewhat satisfied		
Nor satisfied nor unsatisfied		5
Somewhat unsatisfied	5	
Very unsatisfied	1	

*Values expressed as medians (range min – max)

There were three complications (4.2%), all of them adhesive capsulitis and no re-ruptures. In general, 65 patients (91.5%) manifested feeling very satisfied with the outcomes, 5 (7%) felt somewhat unsatisfied, and one (1.4%) felt very unsatisfied (table 2).

The very unsatisfied patient was a 58-year-old woman who was operated on for a degenerative MRCT that compromised 4 tendons and who, 10 months after the surgery, had no complications but severe or permanent pain and a CM shoulder score of 64.

Table 2. Differences in the outcomes according to patient satisfaction

	Very satisfied (n=65)	Somewhat unsatisfied (n=5)	Very unsatisfied (n=1)	*p value*
Follow-up (months)	16.5 ± 9.9	12.4 ± 5.9	10	0.544
Pain level (VAS)	0.40 ± 1.5	3.8 ± 2.8	8	0.000*
CM shoulder score	82.9 ± 7.9	77.4 ± 10.7	64	0.032*
Complications	One adhesive capsulitis	Two adhesive capsulitis	None	

*Statistically significant. CM: Constant-Murley

Discussion

The double Mac surgical technique for MRCT was designed to improve the anatomical fixation of the tendon to the insertional footprint and reduce retearing. In the present study, we showed that in the short and mid-terms, this technique allows for excellent functional recovery to the same level of the contralateral non-affected shoulder with no or mild pain in most patients and a zero incidence of retears. Most patients were very satisfied with the outcomes, mainly due to the absence of pain and complete shoulder functionality.

Massive rotator cuff tears results in disturbed dynamic stability of the glenohumeral joint by creating an unstable hinge for overhead motion and limited active rotation[4]. Some MRCT are deemed "irreparable," and the surgical approach differs from the rest of massive tears[39,40]. Surgical methods for irreparable MRCT include tailored procedures for diverse indications such as partial repair, ideal for patients with low preoperative function[11,41]; graft or mesh augmentation, for improving stability and biologic healing in partial repairs[13–17]; arthroscopic superior capsular reconstruction, as an alternative for patients with pseudoparalysis[42–45]; subacromial balloon spacers, for patients without arthropathy but preserved passive range of motion[46]; and tendon transfer, for younger patients with high activity level[10]. RTSA is mainly indicated in older patients with a low activity level[18,19].

In contrast, for the repairable MRCT, the surgical treatment remains controversial. Still, all the proposed alternatives, such as debridement[8] and biceps tenotomy or tenodesis[9], aim to restore near-normal biomechanics, create a stable glenohumeral fulcrum, and reduce pain and incidence of retear. In times when we can expect patients to live active lives for many years after undergoing these procedures, the most durable and functional outcomes must be achieved. Careful patient selection warrants optimal clinical and functional results and minimizes mid- and long-term retearing risks.

In agreement with Sellers (2018)[47], for patients with anterosuperior escape and muscle atrophy at physical examination, a Hamada ≥3 in the x-rays, a tendon retraction stage 3 in the MRI (Patte classification), an advanced age (65 or older), and those with signs of arthropathy and pseudoparalysis, the main author of this study, elects RTSA, given the foreseeable and often excellent results. Therefore, patients not complying with the aforementioned criteria are ideal for the double Mac technique

proposed in this study. We believe that the precise selection of our patients permitted satisfactory functional results in the short and mid-terms in the absence of pain in most cases and the occurrence of retearing.

The biomechanical advantages of both DR repair and suture bridge repair (SB) over the SR regarding retear incidence have been demonstrated by several authors [48–50]. Even more, the SB and independent DR techniques have shown comparable clinical results and retear rates for medium to massive posterosuperior rotator cuff tears; however, the DR technique is perhaps more cost-effective due to the shorter surgical times and fewer anchors needed for the repair[51]. On the other hand, the Mac stitch, a combination of a horizontal and vertical loop at the site of the rotator cuff repair, was proposed by MacGillivray and Ma (2004) to increase the strength of tissue fixation and limit pull-out[29]. The Mac stitch configuration displays the biomechanical properties of the modified Mason-Allen -usually performed in open repairs due to its technical difficulty- and is three times stronger than the simple and horizontal stitches, representing an alternative for arthroscopic rotator cuff repairs[52]. However, despite improving the existing or incorporating new fixation methods for rotator cuff repair in clinical practice, the primary studies and meta-analyses still demonstrate a high incidence of retearing, ranging from 5% to 70%[28,30,53–56].

An ideal MRCT repair should have high fixation strength, preserve mechanical stability over time, and have good biological properties. In the double Mac technique, the biomechanical benefits of the better footprint coverage of the DR and the higher strength of the Mac stitch are combined. This rotator cuff suturing technique uses a row with two anchors loaded with double sutures and a configuration that allows a much more anatomical fixation of the tendon to the insertion footprint since the tendon adheres completely and without folds between the sutures towards the subacromial space. With the double Mac technique, in both the short and mid-term follow-ups, at a median of 14 months after the operation, objective outcome measures demonstrated that function and pain in the operated shoulder were equal to the nonsurgical side, indicating preserved anatomical stability. Furthermore, there were no events of retearing, which accounts for the strength of the fixation. Even though our results are mainly for a short-term follow-up, it has been shown that retears occur mainly between one to six months after the repair[57] and that the short-term outcomes are not likely to change in the long-term as demonstrated in a pooled analysis by Shah et al.[53] We are confident these results will be maintained in time; however, we will continue with periodic follow-ups and plan to report the long-term outcomes.

Additionally, in a MRCT repair, the amount of suture anchors and their cost are usually a major burden. With the double Mac technique, the number of anchors is optimized to no more than four, and the surgical time is comparable to that reported for SR[58], SB, and DR[51]; hence, it possibly constitutes a cost-effective surgical alternative.

Most patients reported being very satisfied with the outcomes that correlated to low pain levels and high CM shoulder scores, indicating that these patients fully regained their shoulder function without pain. Also, no

complications required revision surgery; only three patients presented adhesive capsulitis that resolved easily with physical therapy.

This study is limited by the retrospective part of its methodological design, which made it impossible to obtain a preoperative CM shoulder score, a restricted sample size, and the lack of a control group. Additionally, of the 71 patients, only 5 had a follow-up of more than 34 months (mid-term) after surgery. Therefore, a larger cohort and longer follow-up would be required before making conclusions regarding the long-term success of the double Mac surgical technique. The strict selection criteria could have introduced a bias, contributing to the excellent results. However, more than a bias, the careful selection of the patients constitutes a requirement for the success of this technique.

We believe that the existing best evidence has not definitively answered the question of which technique provides the greatest long-term benefit for patients with MRCT. There is a need for further high-powered and long-term comparative studies before determining the best intervention. We consider that the proposed suturing configuration for arthroscopic repair of MRCT provides surgeons with a reliable and reproducible technique that not only delivers good short-term outcomes but may theoretically offer long-term benefits, including reduced long-term retear incidence and maintenance of the biomechanical advantages demonstrated for other configurations.

Conclusions

The authors conclude that a MRCT repair with the double Mac technique is an arthroscopic alternative for carefully selected patients in whom satisfactory functional outcomes without the occurrence of retearing can be obtained in the short and mid-terms.

Conflicts of Interest Statement:

The authors have no conflicts of interest to declare.

Acknowledgements Statement:

None

Funding Statement:

No funding was received.

ORCID:

ORCID 0000-0003-2071-3422
ORCID 0009-0001-1438-1524
ORCID 0000-0002-7382-5631

References:

1. Kim HM, Teefey SA, Zelig A, Galatz LM, Keener JD, Yamaguchi K. Shoulder Strength in Asymptomatic Individuals with Intact Compared with Torn Rotator Cuffs. *The Journal of Bone and Joint Surgery-American Volume*. 2009; 91(2):289-296. doi:10.2106/JBJS.H.00219

2. Harryman DT, Mack LA, Wang KY, Jackins SE, Richardson ML, Matsen FA. Repairs of the rotator cuff. Correlation of functional results with integrity of the cuff. *J Bone Joint Surg Am*. 1991; 73(7):982-989.

3. Bedi A, Dines J, Warren RF, Dines DM. Massive Tears of the Rotator Cuff. *Journal of Bone and Joint Surgery*. 2010;92(9):1894-1908. doi:10.2106/JBJS.I.01531

4. Sheth MM, Shah AA. Massive and Irreparable Rotator Cuff Tears: A Review of Current Definitions and Concepts. *Orthop J Sports Med*. 2023;11(5). doi:10.1177/23259671231154452

5. Gerber C, Fuchs B, Hodler J. The Results of Repair of Massive Tears of the Rotator Cuff*†. *The Journal of Bone and Joint Surgery-American Volume*. 2000; 82(4):505-515. doi:10.2106/00004623-200004000-00006

6. DeOrio JK, Cofield RH. Results of a second attempt at surgical repair of a failed initial rotator-cuff repair. *J Bone Joint Surg Am*. 1984; 66(4):563-567.

7. Schumaier A, Kovacevic D, Schmidt C, et al. Defining massive rotator cuff tears: a Delphi consensus study. *J Shoulder Elbow Surg*. 2020;29(4):674-680. doi:10.1016/j.jse.2019.10.024

8. Berth A, Neumann W, Awiszus F, Pap G. Massive rotator cuff tears: functional outcome after debridement or arthroscopic partial repair. *Journal of Orthopaedics and Traumatology*. 2010;11(1):13-20. doi:10.1007/s10195-010-0084-0

9. Walch G, Edwards TB, Boulahia A, Nové-Josserand L, Neyton L, Szabo I. Arthroscopic tenotomy of the long head of the biceps in the treatment of rotator cuff tears: Clinical and radiographic results of 307 cases. *J Shoulder Elbow Surg*. 2005; 14(3):238-246. doi:10.1016/j.jse.2004.07.008

10. Cartucho A. Tendon transfers for massive rotator cuff tears. *EFORT Open Rev*. 2022; 7(6):404-413. doi:10.1530/EOR-22-0023

11. Duralde XA, Bair B. Massive rotator cuff tears: The result of partial rotator cuff repair. *J Shoulder Elbow Surg*. 2005; 14(2):121-127. doi:10.1016/j.jse.2004.06.015

12. Bond JL, Dopirak RM, Higgins J, Burns J, Snyder SJ. Arthroscopic Replacement of Massive, Irreparable Rotator Cuff Tears Using a GraftJacket Allograft: Technique and Preliminary Results. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*. 2008; 24(4):403.e1-403.e8. doi:10.1016/j.arthro.2007.07.033

13. de Campos Azevedo CI, Ângelo ACLPG, Vinga S. Arthroscopic Superior Capsular Reconstruction With a Minimally Invasive Harvested Fascia Lata Autograft Produces Good Clinical Results. *Orthop J Sports Med*. 2018; 6(11):232596711880824. doi:10.1177/2325967118808242

14. Rosales-Varo AP, Zafra M, García-Espona MA, Flores-Ruiz MA, Roda O. Reconstrucción de la cápsula superior en las roturas irreparables del manguito mediante injerto autógeno de isquiotibiales. *Rev Esp Cir Ortop*

Traumatol. 2019; 63(1):1-6. doi:10.1016/j.recot.2018.08.004

15. Pennington WT, Bartz BA, Pauli JM, Walker CE, Schmidt W. Arthroscopic Superior Capsular Reconstruction With Acellular Dermal Allograft for the Treatment of Massive Irreparable Rotator Cuff Tears: Short-Term Clinical Outcomes and the Radiographic Parameter of Superior Capsular Distance. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*. 2018; 34(6):1764-1773. doi:10.1016/j.arthro.2018.01.009

16. Denard PJ, Brady PC, Adams CR, Tokish JM, Burkhart SS. Preliminary Results of Arthroscopic Superior Capsule Reconstruction with Dermal Allograft. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*. 2018; 34(1):93-99. doi:10.1016/j.arthro.2017.08.265

17. Kholinne E, Kwak JM, Kim H, Koh KH, Jeon IH. Arthroscopic Superior Capsular Reconstruction With Mesh Augmentation for the Treatment of Irreparable Rotator Cuff Tears: A Comparative Study of Surgical Outcomes. *American Journal of Sports Medicine*. 2020; 48(13):3328-3338. doi:10.1177/0363546520958708

18. Sershon RA, Van Thiel GS, Lin EC, et al. Clinical outcomes of reverse total shoulder arthroplasty in patients aged younger than 60 years. *J Shoulder Elbow Surg*. 2014;23(3):395-400. doi:10.1016/j.jse.2013.07.047

19. Ernstbrunner L, Suter A, Catanzaro S, Rahm S, Gerber C. Reverse Total Shoulder Arthroplasty for Massive, Irreparable Rotator Cuff Tears Before the Age of 60 Years. *Journal of Bone and Joint Surgery*. 2017; 99(20):1721-1729. doi:10.2106/JBJS.17.00095

20. Henry P, Wasserstein D, Park S, et al. Arthroscopic Repair for Chronic Massive Rotator Cuff Tears: A Systematic Review. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*. 2015; 31(12):2472-2480. doi:10.1016/j.arthro.2015.06.038

21. Denard PJ, Jiwani AZ, Lädermann A, Burkhart SS. Long-Term Outcome of Arthroscopic Massive Rotator Cuff Repair: The Importance of Double-Row Fixation. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*. 2012; 28(7):909-915. doi:10.1016/j.arthro.2011.12.007

22. Vaishnav S, Millett PJ. Arthroscopic rotator cuff repair: Scientific rationale, surgical technique, and early clinical and functional results of a knotless self-reinforcing double-row rotator cuff repair system. *J Shoulder Elbow Surg*. 2010; 19(2):83-90. doi:10.1016/j.jse.2009.12.012

23. Grasso A, Milano G, Salvatore M, Falcone G, Deriu L, Fabbriciani C. Single-Row Versus Double-Row Arthroscopic Rotator Cuff Repair: A Prospective Randomized Clinical Study. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*. 2009; 25(1):4-12. doi:10.1016/j.arthro.2008.09.018

24. Park MC, ElAttrache NS, Tibone JE, Ahmad CS, Jun BJ, Lee TQ. Part I: Footprint contact characteristics for a transosseous-equivalent rotator cuff repair technique compared with a double-row repair technique. *J Shoulder Elbow Surg*. 2007; 16(4):461-468. doi:10.1016/j.jse.2006.09.010

25. Hohmann E, König A, Kat CJ, Glatt V, Tetsworth K, Keough N. Single- versus double-row repair for full-thickness rotator cuff tears using suture anchors. A systematic review and meta-analysis of basic

biomechanical studies. *European Journal of Orthopaedic Surgery & Traumatology*. 2018; 28(5):859-868. doi:10.1007/s00590-017 -2114-6

26. Barber FA, Herbert MA, Schroeder FA, Aziz-Jacobo J, Mays MM, Rapley JH. Biomechanical Advantages of Triple-Loaded Suture Anchors Compared With Double-Row Rotator Cuff Repairs. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*. 2010; 26(3):316-323. doi:10.1016/j.arthro. 2009.07.019

27. Lorbach O, Kieb M, Raber F, Busch LC, Kohn D, Pape D. Comparable Biomechanical Results for a Modified Single-Row Rotator Cuff Reconstruction Using Triple-Loaded Suture Anchors Versus a Suture-Bridging Double-Row Repair. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*. 2012; 28(2):178-187. doi:10.1016/j.arthro.2011.08.298

28. Kim KC, Shin HD, Lee WY, Han SC. Repair Integrity and Functional Outcome After Arthroscopic Rotator Cuff Repair. *Am J Sports Med*. 2012; 40(2):294-299. doi:10.1177/0363 546511425657

29. MacGillivray JD, Ma CB. An arthroscopic stitch for massive rotator cuff tears: the mac stitch. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*. 2004; 20(6):669-671. doi:10.1016/j.arthro.2004.04.065

30. Cheon SJ, Lee HY, Ahn SJ. A Modified Mac Suture Bridge Technique: Clinical and Radiological Outcomes of the Treatment of Rotator Cuff Tear with Poor Tissue Quality. *The Journal of the Korean Orthopaedic Association*. 2017; 52(5):392. doi:10.4055/ jkoa.2017.52.5.392

31. Arismendi Montoya A, Gallego Eusse HD, Ramírez Montoya JF. Roturas masivas del manguito de los rotadores: resultados clínicos de la reparación artroscópica con técnica doble MAC. *Revista Colombiana de Ortopedia y Traumatología*. 2018; 32(2):100-107. doi:10.1016/j.rccot.2017.08.006

32. Tokish JM, Alexander TC, Kissenberth MJ, Hawkins RJ. Pseudoparalysis: a systematic review of term definitions, treatment approaches, and outcomes of management techniques. *J Shoulder Elbow Surg*. 2017; 26(6):e177-e187. doi:10.1016/j.jse.2017.02.024

33. Hamada K, Fukuda H, Mikasa M, Kobayashi Y. *Roentgenographic Findings in Rotator Cuff Tears A Long-Term Observation Massive*. http://journals.lww.com/clinorthop

34. Patte D. Classification of rotator cuff lesions. *Clin Orthop Relat Res*. 1990;(254):81-86.

35. Lopiz Y, Garríguez-Pérez D, Scarano-Pereira JP, et al. The Spanish version of the Constant-Murley Shoulder Score: translation, cultural adaptation, and validity. *J Shoulder Elbow Surg*. 2023; 32(7):1348-1356. doi:10.10 16/j.jse.2023.01.032

36. Kim SH, Ha KI. The SMC knot - A new slip knot with locking mechanism. *Arthroscopy*. 2000; 16(5):563-565. doi:10.1053/jars.2000.4821

37. Ahmad SS, Hoos L, Perka C, Stöckle U, Braun KF, Konrads C. Follow-up definitions in clinical orthopaedic research. *Bone Jt Open*. 2021; 2(5):344-350. doi:10.1302/2633-1462. 25.BJO-2021-0007.R1

38. McLean A, Taylor F. Classifications in Brief: Bigliani Classification of Acromial Morphology. *Clin Orthop Relat Res*. 2019; 477(8):1958-1961. doi:10.1097/CORR.00000 00000000770

39. Kucirek NK, Hung NJ, Wong SE. Treatment Options for Massive Irreparable

Rotator Cuff Tears. doi:10.1007/s12178-021-09714-7/Published

40. Hazra MED, Hazra ROD, Hanson JA, et al. Treatment options for massive irreparable rotator cuff tears: a review of arthroscopic surgical options. *EFORT Open Rev*. 2023; 8(1):35-44. doi:10.1530/EOR-22-0015

41. Descamps J, Kierszbaum E, Protais M, Marion B, Bouché PA, Aïm F. Outcomes of Isolated Biceps Tenodesis/Tenotomy or Partial Rotator Cuff Repair Associated with Biceps Tenodesis/Tenotomy for Massive Irreparable Tears: A Systematic Review. *J Clin Med*. 2023; 12(7). doi:10.3390/jcm12072565

42. Li H, Liao Y, Jin B, Yang M, Tang K, Zhou B. Dynamic Superior Capsular Reconstruction for Irreparable Massive Rotator Cuff Tears: Histologic Analysis in a Rat Model and Short-term Clinical Evaluation. *American Journal of Sports Medicine*. 2023; 51(5):1255-1266. doi:10.1177/03635465231156619

43. Noyes MP, Haidamous G, Spittle NE, Hartzler RU, Denard PJ. Surgical Management of Massive Irreparable Cuff Tears: Superior Capsular Reconstruction. *Curr Rev Musculoskelet Med*. 2020; 13(6):717-724. doi:10.1007/s12178-020-09669-1

44. Cheppalli NS, Purudappa PP, Metikala S, et al. Superior Capsular Reconstruction Using the Biceps Tendon in the Treatment of Irreparable Massive Rotator Cuff Tears Improves Patient-Reported Outcome Scores: A Systematic Review. *Arthrosc Sports Med Rehabil*. 2022; 4(3):e1235-e1243. doi:10.1016/j.asmr.2022.04.003

45. Altintas B, Scheidt M, Kremser V, et al. Superior Capsule Reconstruction for Irreparable Massive Rotator Cuff Tears: Does It Make Sense? A Systematic Review of Early Clinical Evidence. *American Journal of Sports Medicine*. 2020; 48(13):3365-3375. doi:10.1177/0363546520904378

46. Savarese E, Romeo R. New Solution for Massive, Irreparable Rotator Cuff Tears: The Subacromial "Biodegradable Spacer." *Arthrosc Tech*. 2012; 1(1):e69-e74. doi:10.1016/j.eats.2012.02.002

47. Sellers TR, Abdelfattah A, Frankle MA. Massive Rotator Cuff Tear: When to Consider Reverse Shoulder Arthroplasty. *Curr Rev Musculoskelet Med*. 2018; 11(1):131-140. doi:10.1007/s12178-018-9467-2

48. Pauly S, Gerhardt C, Chen J, Scheibel M. Single versus double-row repair of the rotator cuff. *Knee Surgery, Sports Traumatology, Arthroscopy*. 2010; 18(12):1718-1729. doi:10.1007/s00167-010-1245-7

49. Millett PJ, Warth RJ, Dornan GJ, Lee JT, Spiegl UJ. Clinical and structural outcomes after arthroscopic single-row versus double-row rotator cuff repair: a systematic review and meta-analysis of level I randomized clinical trials. *J Shoulder Elbow Surg*. 2014; 23(4):586-597. doi:10.1016/j.jse.2013.10.006

50. Hein J, Reilly JM, Chae J, Maerz T, Anderson K. Retear Rates After Arthroscopic Single-Row, Double-Row, and Suture Bridge Rotator Cuff Repair at a Minimum of 1 Year of Imaging Follow-up: A Systematic Review. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*. 2015; 31(11):2274-2281. doi:10.1016/j.arthro.2015.06.004

51. Chen P, Yeh HW, Lu Y, et al. Comparison of suture-bridge and independent double-row techniques for medium to massive posterosuperior cuff tears: a two-year retrospective study. *BMC Musculoskelet*

Disord. 2023; 24(1):154. doi:10.1186/s12891-023-06256-6

52. Ma BC, MacGillivray JD, Clabeaux J, Lee S, Otis JC. Biomechanical Evaluation of Arthroscopic Rotator Cuff Stitches. *The Journal of Bone and Joint Surgery-American Volume*. 2004; 86(6):1211-1216. doi:10.2106/00004623-200406000-00013

53. Shah NS, Suriel Peguero E, Umeda Y, Crawford ZT, Grawe BM. Long-Term Outcomes of Massive Rotator Cuff Tear Repair: A Systematic Review. *HSS Journal*. 2022; 18(1):130-137. doi:10.1177/15563316211008137

54. Heuberer PR, Kölblinger R, Buchleitner S, et al. Arthroscopic management of massive rotator cuff tears: an evaluation of debridement, complete, and partial repair with and without force couple restoration. *Knee Surgery, Sports Traumatology, Arthroscopy*. 2016; 24(12):3828-3837. doi:10.1007/s00167-015-3739-9

55. Rhee YG, Cho NS, Parke CS. Arthroscopic Rotator Cuff Repair Using Modified Mason-Allen Medial Row Stitch. *Am J Sports Med*. 2012; 40(11):2440-2447. doi:10.1177/0363546512459170

56. Duquin TR, Buyea C, Bisson LJ. Which Method of Rotator Cuff Repair Leads to the Highest Rate of Structural Healing? *Am J Sports Med*. 2010; 38(4):835-841. doi:10.1177/0363546509359679

57. Iannotti JP, Deutsch A, Green A, et al. Time to Failure After Rotator Cuff Repair. *Journal of Bone and Joint Surgery*. 2013; 95(11):965-971. doi:10.2106/JBJS.L.00708

58. Carbone S, Razzano C, Passaretti D, Mezzoprete R. Arthroscopic single-row repair of massive potentially irreparable postero-superior cuff tear. *Musculoskelet Surg*. 2018; 102:13-19. doi:10.1007/s12306-018-0555-7