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The influence of fatty infiltration and muscle atrophy of the rotator cuff muscles on mid-term functional outcomes in total shoulder resurfacing at 6 years follow up.

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Keywords: Glenohumeral osteoarthritis; rotator cuff tear; total shoulder arthroplasty, fatty infiltration, muscle atrophy, MRI

Abstract:

Background: We report functional outcomes at six years in patients with varying degrees of fatty infiltration and atrophy of the rotator cuff muscles who have undergone anatomic total shoulder replacement (TSR).

Methods: A retrospective analysis of case notes and magnetic resonance imaging (MRI) scans of patients undergoing TSR for primary gleno-humeral arthritis was performed. Patients were grouped based upon their pre-operative MRI findings for fatty infiltration, muscle area and tendinopathy. Post-operative functional outcomes were assessed using the Oxford Shoulder Score (OSS) and Quick Disabilities of the Arm, Shoulder and Hand score (Quick DASH). Post-operative measurements were made for active shoulder movements.

Results: Thirty-two patients were reviewed at a mean of 67 months following surgery. All patients demonstrated fatty infiltration on their pre-operative MRI scan. Muscle atrophy was shown in 22 patients and 12 had tendinopathy.

Multiple regression analysis showed no correlation between the OSS (p=0.443), the Quick DASH (p=0.419), forward flexion (p=0.170), external rotation (p=0.755) and any of the preoperative independent variables.

Discussion: The degree of fatty infiltration, muscle atrophy and tendinopathy of the rotator cuff muscle on pre-operative MRI scanning is not associated with functional outcome score or functional movement at medium term follow up following TSR.

Level of evidence: IV

Introduction:

Total shoulder replacement (TSR) is an effective treatment for gleno-humeral arthritis. The anatomic TSR aims to restore the normal shoulder biomechanics by replicating the native anatomy.[1] The majority of patients who undergo this procedure achieve both a reduction in pain and an improvement in range of motion. The stability of the joint and the restoration of joint kinematics is thought to be reliant on an intact and functional rotator cuff.[2] Aside from the commonly noted complications of joint arthroplasty such as infection, aseptic loosening, dislocation and peri-prosthetic fracture, anatomic shoulder replacement is unique in that the gradual attrition of the surrounding rotator cuff poses one of the greatest risks for subsequent revision.[1, 3-6] Furthermore, it is the functionality of these muscles that will dictate the behaviour of the implant in-situ. Hence an understanding of the integrity of the rotator cuff is critical prior to undertaking surgery.

Rotator cuff fatty infiltration and muscle atrophy are both indicative of chronic rotator cuff dysfunction and have been shown to increase the likelihood of a poor outcome in the treatment of rotator cuff tears.[7-11] Thus, the management of patients who have a concomitant rotator cuff tendinopathy at the time of arthroplasty remains controversial.[12-14] It is perceived that the degree of fatty infiltration and atrophy in the rotator cuff muscles in the pre-operative osteoarthritic shoulder affects functional outcome and has perhaps attributed to the rise in the use of reverse geometry prosthesis for gleno-humeral

osteoarthritis.[14] However, recent investigation has suggested that fatty infiltration of the rotator cuff is a reversible process in patients undergoing elective anatomic shoulder replacement for arthritis at 12 month follow up suggesting that restoration of active movement negates the effects of chronic immobilisation secondary to joint arthropathy.[8]

Appropriate patient selection is essential prior to TSR to optimise outcomes and reduced the risk of complication. It requires careful pre-operative assessment of the quality of the rotator cuff tendon and muscle. Magnetic resonance imaging (MRI) is a critical investigation that allows for the assessment of multiple parameters relevant to the procedure. It not only permits accurate appreciation of the soft tissue integrity and quality, but s also valuable for the analysis of, glenoid bone stock and orientation.[15]

The aim of this study was to investigate whether the presence of rotator cuff muscle atrophy, fatty infiltration and rotator cuff tendinopathy, on pre-operative MRI scanning was associated with functional outcome measurement and active shoulder movements following anatomic total shoulder replacement at medium term follow up.

Materials and Methods:

The STROBE methodology for observational studies was followed.[16]

A retrospective analysis was performed on a group of 51 consecutive patients with primary gleno-humeral arthritis who had undergone elective TSR between June 2006 and August 2011. Patients were identified by operative procedure code from computerised theatre records. The radiological investigations were available via the Picture Archiving and Communications System (PACS) Centricity® Web software (GE Healthcare, Chalfont St Giles, UK). The inclusion criteria for this study was primary anatomic TSR for gleno-humeral osteoarthritis. Exclusion criteria included hemiarthroplasty, reverse total shoulder replacement for cuff tear arthropathy and TSR for fracture. All surgeries were performed by, or under the direct supervision of the senior author using the EPOCA (Synthes, Paoli, Pennsylvania, USA) modular prosthesis via a standard operative technique utilising a lesser tuberosity osteotomy and a standard postoperative rehabilitation programme (See figure 1). At the time of surgery an assessment of the integrity of the rotator cuff tendon was made; if the tendons were macroscopically torn then the operative plan was changed and then a reverse geometry prosthesis used instead.

All patients underwent a pre-operative MRI scan of the affected shoulder, reported by consultant musculoskeletal radiologists. The imaging and reports were reviewed for the presence and grade of tendinopathy, fatty infiltration and rotator cuff atrophy.

The patients were grouped by their MRI findings as per the Fuchs grading system for fatty infiltration (See table 1), the Warner atrophy grade (See figure 2) and finally in to either normal rotator cuff, rotator cuff tendinopathy or partial thickness tear of the rotator cuff tendons. [17, 18] The Warner atrophy grade is a four-category scale describing atrophy as none, mild, moderate or severe.[18] None indicates that the supraspinatus muscle extends superior to a line extending between the superior tip of the coracoid and the superior tip of the scapular spine; mild indicates that the supraspinatus muscle extends to but not beyond this line; moderate and severe indicate higher degrees of muscle atrophy. These scales were converted to numerical scales for the purposes of statistical analysis. (1=none, 4=severe)

The muscles were graded on the most lateral parasagittal image on which the scapular spine was in contact with the scapular body. Adjacent images were used to clarify the anatomic relationships where required. The cross-sectional area of the supraspinatus fossa was assessed at this point as per the grading system described by Fuchs. [17] (See figure 3)

The degree of muscle atrophy was also assessed on the same sagittal slice as per the grading system described by Warner.[18] (See figure 4)

Demographic data was collected for patients as regard to sex and age. Shoulder range of movement was recorded at the time of review for elevation, external rotation, abduction and internal rotation. Patient reported outcome measures (PROMS) were obtained post operatively by an Oxford Shoulder Score (OSS) and Quick Disabilities of the Arm, Shoulder and Hand score (quick-DASH).[19,20] PROMS and range of motion measurements were collected at a mean of 67 months following surgery.

Statistical analyses were performed using Graph Pad InStat and Prism (GraphPad Software Inc, La Jolla, CA, USA). The distribution of continuous data was assessed with a Kolmogorov-Smirnov test. Where the data was found to be normally distributed, it is described with the mean and standard deviation (SD). Data that was not normally distributed is described with the median and interquartile ranges (IQR). In order to determine the effect of preoperative predictors (Fuchs grade, Warner grade, Tendinopathy grade, patient age at procedure and gender) on outcome (OSS, Quick DASH, forward flexion, external rotation, abduction and internal rotation), a multiple regression analysis was performed. Significance was determined when $p < 0.05$. The R2 values were inspected to determine if multicollinearity was a problem in the model, all

R2 values were <0.75 indicating that multicollinearity was not a problem and therefore no rationalization of the independent variables was required. A post hoc power calculation was performed to determine the calculated power achieved for the model.

Results:

51 patients met the inclusion criteria and underwent anatomic TSR for primary gleno-humeral osteoarthritis.

At the review point, a mean time of 67 months (range 48-94 months), six patients had died of unrelated illness, six patients had incomplete data, seven patients had been lost to follow up, and a full set of data and case notes, PACS images and PROMs was available for 32 patients. No post-operative complications were noted as of the final review date.

Procedures were carried out for 19 females and 13 males, the mean age was 70 years (SD 7.3). Demographic details for patients included are shown in table 2.

Within the cohort the presence of tendinopathy, fatty infiltration and muscle atrophy was a common finding with 12 patients demonstrating tendinopathy and seven a partial tear which was debrided at time of surgery. All thirty-two patients showed either mild or moderate fatty infiltration of their rotator cuff muscles, with twenty-two demonstrating mild changes. Fatty infiltration was noted to be broadly similar throughout the cuff muscles of each patient in keeping with previous studies, but supraspinatus was specifically analysed statistically as we believe it is clinically the most important to good

outcome following TSR.[8] Twenty-Two patients were reported to have muscle atrophy on their MRI scans, ten had normal muscle bulk.

The median OSS was 47 (IQR 42.5-48) and the median Quick DASH 8 (IQR 0-13.6). The median forward flexion was 150 degrees (IQR 127.5-170), external rotation 55 degrees (IQR 45-60), abduction 100 degrees (IQR 90-130) and median internal rotation 90 degrees (IQR 90-100).

The multiple regression analysis showed no correlation between the OSS (p=0.443), the Quick DASH (p=0.419), forward flexion (p=0.170), external rotation (p=0.755), abduction (p=0.058), internal rotation (p=0.523) and any of the preoperative independent variables (Outcome scores: table 3 and post-operative movements: Table 4).

The calculated R^2 for the model with abduction as the dependent variable and Fuchs grade, Warner grade, Tendinopathy grade, patient age at procedure and gender as the independent variables was 32.3% giving a calculated effect size of 0.477. For a multiple regression model with an alpha value of 0.05, 32 patients and 5 predictor variables, this gives a calculated power of (1-beta) of 0.78 which is reasonable for this type of analysis of a retrospective cohort.

Discussion:

This study investigates the effect of pre-operative rotator cuff fatty infiltration, muscle atrophy and tendinopathy on post-operative TSR functional scores and active range of motion. We postulated that infiltration of the rotator cuff muscles with fat, atrophy of the rotator cuff musculature and/or presence of tendinopathy on pre-operative MRI scanning would adversely affect the functional outcome measurements and movements following anatomic TSR. However, this study has shown that the presence of fatty infiltration, muscle atrophy and tendinopathy on pre-operative MRI has no significant effect on post-operative functional scores following TSR and that post-operative movement is well preserved at medium term follow up.

Fatty degeneration or infiltration of the rotator cuff muscles is a degenerative condition of the tendon-muscle unit, which is defined by atrophy of the muscle fibres, fibrosis and fatty accumulation within and around the muscles.[21] Fatty infiltration is observed after tears of the rotator cuff tendons.[17] Originally described by Goutallier, it is most commonly seen in the elderly and is most often associated with age related reduction of the healing potential of the rotator cuff tendons.[22] It is also seen in the arthritic shoulder resulting from inactivity and reduced range of motion secondary to the arthritic pain and loss of joint congruity.[8]

The prevalence of partial cuff tearing in this series of almost a quarter of the patients is significantly lower than previously reported studies for patients of a similar age both in an asymptomatic population and also in a similar population to that reported here undergoing TSR.[23, 24]

Fatty infiltration or degeneration of the muscle and atrophy influence several clinical parameters such as outcome and strength and has been associated with adverse outcome measurements following rotator cuff repair.[25-29] The association between the condition of the rotator cuff muscles preoperatively and function and quality of life post shoulder replacement in the arthritic shoulder are less well understood.[8] Many previous studies have suggested that the presence of rotator cuff pathology is associated with a higher risk of failure in TSR, however these studies to date have included multiple diagnoses and variable pathology.[1, 6, 30]

An association between increasing degree of infraspinatus fatty infiltration and poorer Constant scores in patients undergoing shoulder replacement was noted by Edwards et al.[31] The authors of this study demonstrated on CT scans that moderate and severe fatty degeneration of the infraspinatus, in the presence of partial and full thickness rotator cuff tear were associated with poorer outcomes, satisfaction and movement.[31] This finding is supported by Moineau et al who noted that patients with post traumatic humeral head

collapse or necrosis with fatty infiltration of the rotator cuff muscles treated with anatomic shoulder replacement had poorer functional outcome.[32] Lapner demonstrated that the fatty infiltration of the rotator cuff muscles on post-operative CT scanning may decrease following shoulder replacement but that the muscle area did not change significantly.[8] However the presence of moderate to high pre-operative fatty infiltration did not correlate with poorer patient reported outcome scores at 1 year follow up.[8]

Choate et al demonstrated that the presence of rotator cuff pathology, including tear status and Goutallier grade did not correlate with postoperative functional outcome scores, however the presence of fatty infiltration of the infraspinatus negatively correlated with post-operative forward elevation and external rotation.[24] The current study supports their findings that pre-operative fatty infiltration has no significant association with post-operative patient reported outcome measures, however our study found no significant correlation between fatty infiltration of the rotator cuff and post-operative elevation and external rotation. This may be explained by our analysis of fatty infiltration being of supraspinatus rather than infraspinatus or the longer period of our follow up. Furthermore, it is important to note that the study by Choate et al and other studies with similar findings did not have a standardised operative technique, analysed multiple surgeons and implants and included patients with rheumatoid arthritis and significant partial or full thickness supraspinatus tendon tears, none of which the current study does.[8,24,31] Our study presents

a single surgeon series with the same implant, rather than multiple surgeons using variable implants which was noted by Choate et al as being a potential confounding variable as regard to the results in their study.[24]

There are several limitations of this study, including those associated with a retrospective analysis of data with potential selection bias being acknowledged. The nature of the study design means that we can explore association, but it is not possible to definitively establish causation. Furthermore, only 63% of our original cohort had full data available for analysis, however the achieved power from the power calculation is reasonable for consideration of association in a retrospective cohort such as this. Another limitation is that we do not have post-operative imaging to allow quantitative and qualitative analysis of the rotator cuff musculotendinous junction over time following TSR.

Conclusion:

Our study demonstrates that total shoulder replacement is an effective treatment option for patients with primary gleno-humeral osteoarthritis despite the presence of fatty atrophy and muscle wasting of the rotator cuff muscles. Mild to moderate fatty infiltration and mild to moderate muscle wasting of the rotator cuff muscles shoulder not preclude patients from undergoing total shoulder replacement for primary gleno-humeral osteoarthritis. Longer term follow up is ongoing and may provide an insight into the rate of rotator cuff attrition following total shoulder replacement.

Reference:

1. Hawkins RJ, Bell RH, Jallay B. Total shoulder arthroplasty. Clin Orthop Relat Res. 1989(242):188-94. ISSN 0009-921X.

2. Matsen FA, Boileau P, Walch G, et al. The reverse total shoulder arthroplasty. J Bone Joint Surg Am. 2007;89(3):660-7. ISSN 0021-9355.

3. Khan A, Bunker TD, Kitson JB. Clinical and radiological follow-up of the Aequalis third-generation cemented total shoulder replacement: a minimum ten-year study. J Bone Joint Surg Br. 2009;91(12):1594-600. ISSN 0301-620X

4. Sperling JW, Cofield RH, Rowland CM. Neer hemiarthroplasty and Neer total shoulder arthroplasty in patients fifty years old or less. Long-term results. J Bone Joint Surg Am. 1998;80(4):464-73. ISSN 0021-9355.

5. Franklin JL, Barrett WP, Jackins SE, et al. Glenoid loosening in total shoulder arthroplasty. Association with rotator cuff deficiency. J Arthroplasty. 1988;3(1):39-46. ISSN 0883-5403.

6. Mestdagh H, Petroff E, Maynou C, et al. [Effect of the rotator cuff condition on the results of shoulder arthroplasty]. Rev Chir Orthop Reparatrice Appar Mot. 1997;83(6):522-30. ISSN 0035-1040.

7. Goutallier D, Postel JM, Bernageau J, et al. Fatty muscle degeneration in cuff ruptures. Pre- and postoperative evaluation by CT scan. Clin Orthop Relat Res. 1994(304):78-83. ISSN 0009-921X.

8. Lapner PL, Jiang L, Zhang T, et al. Rotator cuff fatty infiltration and atrophy are associated with functional outcomes in anatomic shoulder arthroplasty. Clin Orthop Relat Res. 2015;473(2):674-82. ISSN 1528-1132.

9. Melis B, DeFranco MJ, Chuinard C, et al. Natural history of fatty infiltration and atrophy of the supraspinatus muscle in rotator cuff tears. Clin Orthop Relat Res. 2010;468(6):1498-505. ISSN 1528-1132.

10. Nakagaki K, Ozaki J, Tomita Y, et al. Function of supraspinatus muscle with torn cuff evaluated by magnetic resonance imaging. Clin Orthop Relat Res. 1995(318):144-51. ISSN 0009-921X.

11. Shen PH, Lien SB, Shen HC, et al. Long-term functional outcomes after repair of rotator cuff tears correlated with atrophy of the supraspinatus muscles on magnetic resonance images. J Shoulder Elbow Surg. 2008;17(1 Suppl):1S-7S. ISSN 1532-6500.

12. Galasso O, Familiari F, Gasparini G. Treatment options for irreparable postero-superior cuff tears in young patients. World J Orthop. 2015;6(10):770-5. ISSN 2218-5836.

13. Flurin PH, Roche CP, Wright TW, et al. A Comparison and Correlation of Clinical Outcome Metrics in Anatomic and Reverse Total Shoulder Arthroplasty. Bull Hosp Jt Dis (2013). 2015;73 Suppl 1:S118-23. ISSN 2328-5273.

14. Chalmers PN, Keener JD. Expanding roles for reverse shoulder arthroplasty. Curr Rev Musculoskelet Med. 2016;9(1):40-8. ISSN 1935-973X.

15. Feeley BT, Gallo RA, Craig EV. Cuff tear arthropathy: current trends in diagnosis and surgical management. J Shoulder Elbow Surg. 2009;18(3):484-94. ISSN 1532-6500.

16. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet. 2007;370(9596):1453-7. ISSN 1474-547X.

17. Fuchs B, Weishaupt D, Zanetti M, et al. Fatty degeneration of the muscles of the rotator cuff: assessment by computed tomography versus magnetic resonance imaging. J Shoulder Elbow Surg. 1999;8(6):599-605. ISSN 1058-2746.

18. Warner JJ, Higgins L, Parsons IM, et al. Diagnosis and treatment of anterosuperior rotator cuff tears. J Shoulder Elbow Surg. 2001;10(1):37-46. ISSN 1058-2746.

19. Dawson J, Fitzpatrick R, Carr A. Questionnaire on the perceptions of patients about shoulder surgery. J Bone Joint Surg Br. 1996;78(4):593-600. ISSN 0301-620X.

20. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). Am J Ind Med. 1996;29(6):602-8. ISSN 0271-3586.

21. Osti L, Buda M, Del Buono A. Fatty infiltration of the shoulder: diagnosis and reversibility. Muscles Ligaments Tendons J. 2013;3(4):351-4. ISSN 2240-4554.

22. Gumucio JP, Korn MA, Saripalli AL, et al. Aging-associated exacerbation in fatty degeneration and infiltration after rotator cuff tear. J Shoulder Elbow Surg. 2014;23(1):99-108. ISSN 1532-6500.

23. Sher JS, Uribe JW, Posada A, et al. Abnormal findings on magnetic resonance images of asymptomatic shoulders. J Bone Joint Surg Am. 1995;77(1):10-5. ISSN 0021-9355.

24. Choate WS, Shanley E, Washburn R, et al. The incidence and effect of fatty atrophy, positive tangent sign, and rotator cuff tears on outcomes after total shoulder arthroplasty. J Shoulder Elbow Surg. 2017. ISSN 1532-6500.

25. Gazielly DF, Gleyze P, Montagnon C. Functional and anatomical results after rotator cuff repair. Clin Orthop Relat Res. 1994(304):43-53. ISSN 0009-921X.

26. Harryman DT, Mack LA, Wang KY, et al. Repairs of the rotator cuff. Correlation of functional results with integrity of the cuff. J Bone Joint Surg Am. 1991;73(7):982-9. ISSN 0021-9355.

27. Iannotti JP, Zlatkin MB, Esterhai JL, et al. Magnetic resonance imaging of the shoulder. Sensitivity, specificity, and predictive value. J Bone Joint Surg Am. 1991;73(1):17-29. ISSN 0021-9355.

28. Nakagaki K, Ozaki J, Tomita Y, et al. Alterations in the supraspinatus muscle belly with rotator cuff tearing: Evaluation with magnetic resonance imaging. J Shoulder Elbow Surg. 1994;3(2):88-93. ISSN 1058-2746.

29. Thomazeau H, Boukobza E, Morcet N, et al. Prediction of rotator cuff repair results by magnetic resonance imaging. Clin Orthop Relat Res. 1997(344):275-83. ISSN 0009-921X.

30. Torchia ME, Cofield RH, Settergren CR. Total shoulder arthroplasty with the Neer prosthesis: long-term results. J Shoulder Elbow Surg. 1997;6(6):495-505. ISSN 1058-2746.

31. Edwards TB, Boulahia A, Kempf JF, et al. The influence of rotator cuff disease on the results of shoulder arthroplasty for primary osteoarthritis: results of a multicenter study. J Bone Joint Surg Am. 2002;84-A(12):2240-8. ISSN 0021-9355.

32. Moineau G, McClelland WB, Trojani C, et al. Prognostic factors and limitations of anatomic shoulder arthroplasty for the treatment of posttraumatic cephalic collapse or necrosis (type-1 proximal humeral fracture sequelae). J Bone Joint Surg Am. 2012;94(23):2186-94. ISSN 1535-1386.

Figure and table legends:

Table 1: Fuchs grading system

Table 2: Patient demographic data classified by Fuchs Fatty infiltration

Table 3: Multiple regression models investigating the association of outcome measures (OSS, Quick DASH) with preoperative state of rotator cuff (Fuchs grade, Warner grade, Tendinopathy grade), age and gender.

Table 4: Multiple regression models investigating the association of post-operative movement (Forward elevation, External rotation, Abduction and Internal rotation) with preoperative state of rotator cuff (Fuchs grade, Warner grade, Tendinopathy grade), age and gender.

Figure 1: Plain radiograph demonstrating Epoca resurfacing prosthesis

Figure 2: Warner atrophy grade

Figure 3: Sagittal MRI sequence demonstrating normal supraspinatus muscle bulk in supraspinatus fossa

Figure 4: Sagittal MRI sequence demonstrating fatty infiltration of supraspinatus muscle and loss of muscle bulk.