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Reverse shoulder arthroplasty for the treatment of three-part and four-part proximal humeral fractures in the elderly

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Background: The purpose of this study was to review the survivorship, radiologic and clinical outcomes of reverse shoulder arthroplasty (RSA) used for the treatment of 3-part and 4-part proximal humeral fractures in the elderly.

Methods: Between 2003 and 2009, 29 shoulders in 28 elderly patients (87% female) with a 3-part or 4-part fractures were managed with RSA in Brisbane, Australia. Clinical and radiologic outcomes of this continuous cohort were retrospectively reviewed at an average follow-up of 54.9 months. Average age at surgery was 79 years. Survivorship and radiologic outcome assessment for all patients was undertaken. Seven patients died, and 1 was unavailable for clinical review, leaving 21 shoulders in 20 patients available for clinical review.

Results: There were no revisions of the reverse prosthesis. Mean average pain was 2.19 of 100 (standard deviation [SD], 6.97). Mean American Shoulder and Elbow Surgeons score was 89.3 (SD, 13.65). Mean normalized Constant score was 88.03 (SD, 11.24). Grade 1 scapular notching was observed radiologically in 4 shoulders. A scapular spur was observed in 7 shoulders. Class 1 heterotopic ossification was seen in 4 shoulders. Nonprogressive lucent lines were seen in 2 shoulders. Nonprogressive radiolucency was observed around the superior screw in 3 shoulders. No loosening of the glenoid baseplate or of the humeral component was observed. There was 1 complication of an axillary nerve palsy, which spontaneously resolved by 12 months after surgery.

Conclusion: RSA using the shoulder technique described in this series provides good clinical and radiologic outcomes in elderly patients with 3-part and 4-part fractures.

The Mater Health Services Human Research Ethics Committee approved this study (Protocol Ref No. 1911E).

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Fractures of the proximal humerus are relatively common, accounting for between 4% and 5% of all fractures.⁷ The incidence increases with age, peaking in the ninth decade.⁷ Most fractures in elderly individuals are the result of a fall from standing height.⁷ The severity ranges from minimally displaced 2-part fractures to displaced 4-part fracture-dislocations,²⁰ with most fractures categorized as minimally displaced and responding well to conservative treatment, and only approximately 20% requiring an operation.^{11,26}

Three-part and 4-part fractures may be complicated by avascular necrosis,² particularly when associated with glenohumeral dislocation.¹⁰ There are also technical challenges in performing osteosynthesis of complex fracture patterns involving osteoporotic bone, as encountered in the elderly. These factors make prosthetic replacement of the humeral head an attractive alternative. Hemiarthroplasty is a well-recognized treatment for 3-part and 4-part fractures of the proximal humerus, particularly in older patients⁷; however, the results are mixed.^{3,17,19,25,26}

Acceptable pain relief is usually achieved, but functional outcomes vary.^{13,22} The functional result after hemiarthroplasty relies heavily on rotator cuff function. Not only is tuberosity healing critical, but also in the elderly there are frequently varying levels of pre-existing cuff dysfunction and structural compromise. Complications after hemiarthroplasty relating to tuberosity nonunion or malunion have been reported,^{2,25} and each of these is more prevalent in the presence of osteoporotic bone.¹⁷ In addition, the quality of glenoid articular cartilage in this age group is also less predictable and may be less resilient when articulating with a metallic humeral head. These factors all contribute to the fact that outcomes from hemiarthroplasty for fracture deteriorate significantly in elderly patients.^{11,23}

The reverse shoulder arthroplasty (RSA) was originally designed to treat rotator cuff tear arthropathy (CTA).^{14,24} RSA can compensate for deficient rotator cuff function by medializing the center of rotation and distalizing the deltoid insertion. These factors increase the deltoid lever arm and allow recruitment of a greater number of muscle fibers for elevation and abduction. The potential advantages of RSA in the elderly population compared with hemiarthroplasty may lead to more predictable outcomes in managing these difficult fractures.^{5,25}

In 2003, we began to undertake RSA as a treatment of 3-part and 4-part fractures and fracture dislocations in patients aged 70 years and older. We hypothesized that with careful attention to aspects of surgical technique to reproduce the biomechanical situation encountered in RSA for

rotator CTA, we could achieve similar results to those achieved in that group of patients. The purpose of this retrospective study was to establish the clinical and radiologic outcomes of a series of patients who received RSA for management of an acute 3-part or 4-part fracture of the proximal humerus using a consistent surgical technique.

Materials and methods

In this retrospective study, we performed survivorship, clinical, and radiologic review of all consecutive patients who had RSA for treatment of an acute 3-part or 4-part fracture of the proximal humerus between April 2003 and December 2009.

Patients were included in the study if they were at least 24 months since the date of surgery and the operation was performed by one of the senior authors (M.R. or P.F.R.D.) within 6 weeks of the fracture. For the patients who died, their most recent x-ray images before their death were used (even if less than 24 months). All patients except 1 were chronologically 70 years or older, although physiologic status was considered when this treatment was offered to a patient aged 67 years. During the period (2003 to 2009), if the operating surgeon believed that internal fixation was technically possible with sound fixation and a low risk of avascular necrosis (as determined from a subjective assessment of previously published criteria²), then internal fixation was undertaken in preference to RSA. All patients were offered hemiarthroplasty and RSA as treatment options. However, only patients who chose RSA were included in the retrospective review.

Participants

We studied 29 RSAs in 28 patients with traumatic fractures. Participants received unconstrained RSA using the SMR Modular Shoulder System (Lima Corporate, Udine, Italy) prosthesis (n = 28), or the Delta III Reverse (DePuy Companies, Leeds, UK) prosthesis (n = 1). Uncemented stems were used in 15 (52%). Types of liners included 31.4% with +3 mm (n = 9), 34.4% with +6 mm, and 34.4% standard liners.

Data for the 29 shoulders were obtained from the participant's medical file and the Australian National Joint Replacement Registry (ANJRR). X-ray images were obtained at the most recent follow-up for the 29 shoulders. Of the 28 patients included in the study, 7 had died. Clinical examination was performed for 96.67% of the live patients (n = 21). One patient resided overseas and could not be reviewed clinically.

Twenty participants with 21 shoulders were examined clinically with a mean follow-up interval of 54.8 months (standard deviation [SD], 20.6; range, 25-107 months). Eighty-seven percent were women. Mean age at surgery was 79 years (range, 67-90 years). Mean age at follow-up was 83.5 years.



Figure 1 Glenoid exposure is made simple by the metaphyseal fracture.

Operative technique

A deltopectoral approach was used in all cases. The long head of biceps was divided and tenodesed at the end of the procedure using the tails of the sutures for the tuberosity reconstruction. The head fragment was removed, and the tuberosities were tagged and debulked as required. Any remaining supraspinatus tendon was excised.

A standard capsular release around the glenoid rim was performed. The long head of triceps was partially released to expose the scapular neck for accurate baseplate and inferior screw placement and to prevent impingement on inferior soft tissues.

Glenoid exposure is easily achieved as a result of the metaphyseal fracture (Fig. 1) and the absence of capsular contracture. The glenoid was prepared by gentle reaming to remove cartilage. Care was required not to ream too aggressively because the subchondral bone is not sclerotic as it is in CTA. The baseplate was implanted, ensuring low placement at least flush with the inferior margin of the glenoid. Inclination of the base plate was neutral or tilted inferiorly, depending on surgeon preference.

The humeral body (Fig. 2) was routinely placed in 0° to 10° of retroversion to increase the safe internal rotation range and decrease anteroinferior notching. The prosthesis used was the SMR or the Delta III, based on surgeon preference.

The SMR RSA prosthesis used in this series has a medial chamfer in the metal humeral body and in the polyethylene liner. The intention by the designers was to decrease the likelihood of medial impingement against the inferior glenoid leading to polyethylene wear, debris generation, and notching due to mechanical and polyethylene particle factors. The problem is that the chamfer decreases the capture of the glenosphere and decreases the jump distance required for dislocation in the position of instability—adduction, extension, and axial load. In revision situations and in trauma situations where there is less capsular contracture, instability may pose a risk.¹² The risk is amplified because the SMR prosthesis has a neck/shaft angle of 150° , which is already less stable in adduction than the Delta III prosthesis with a neck/shaft angle of 155° . Accordingly, in those patients where the SMR prosthesis was used, we inserted the polyethylene liner with the chamfer rotated 180° to face the lateral aspect. This effectively increased the capture of the glenosphere, and we believe it



Figure 2 Body of the reverse shoulder implant.

augmented stability. Certainly, no instability occurred in this series of 29 implants.

After excision of the supraspinatus tendon and the portion of the greater tuberosity to which the supraspinatus attaches, the subscapularis/lesser tuberosity and the infraspinatus/inferior portion of greater tuberosity were reconstructed around the reverse body using 2 size 2 FiberWire sutures (Arthrex Inc, Naples, FL, USA) in a cerclage “round-the-world” configuration as well as superoinferior figure-of-8 sutures from the tendon/tuberosity interface to the shaft or suture holes, or both, in the prosthesis. Cancellous bone graft harvested from the humeral head was packed under the reconstructed tuberosities. The rotator interval was left widely open after the excision of the supraspinatus. This technique was used in all but the first 3 patients in this report, although those patients are included in the outcome reporting. The first 3 patients differed only in that they had rotator interval closure around the prosthesis without supraspinatus excision or tuberosity debulking.

Rehabilitation

Although one of the additional advantages of the reverse prosthesis in rotator CTA is that early active rehabilitation can be commenced, we have some concerns with this in the trauma situation. All current reverse prosthesis designs use an uncemented fixation of the glenosphere to the glenoid and often require no cuff reconstruction. There are concerns that osteoporosis may compromise the quality of primary stability of an uncemented glenoid prosthesis in this situation. Although we did not see any loosening in this series of patients, we have been somewhat less aggressive in our rehabilitation than we have been with our patients with a reverse prosthesis for CTA.

Postoperative rehabilitation included protection in a sling for 6 weeks, with commencement of passive mobilization immediately postoperatively. Passive flexion to 90° and external rotation to 20° , as tolerated, was commenced in the first week. Active range of motion was commenced at 6 weeks. Resisted activity and strengthening was not commenced until 12 weeks. Patients were advised to avoid axial loading in adduction and extension,

particularly in the early postoperative period, when this position is associated with risk of dislocation.

Implant survival, clinical, and radiologic outcomes

Data regarding implant survival and any revision surgery was cross-checked with the ANJRR. A complete set of radiographs preoperatively until most recent follow-up (clinical study review, most recent postoperative review, or most recent review before death) was available for all 29 shoulders. All clinical and radiologic evaluations were completed by an independent observer (ie, not one of the primary surgeons) who was a fellowship-trained upper limb orthopedic surgeon.

Demographic data, including gender, age, operative side, mechanism of injury, and operative details, were retrieved from the medical records of all participants included in the review. Perioperative data and complications⁸ were also recorded. The type of fracture was determined by x-ray imaging. A follow-up review specifically for the purpose of this study was conducted.

Clinical examination included a 100-mm visual analog scale (VAS) to rate the patient's pain intensity and satisfaction with the shoulder. For pain, 0 represented "no pain" and 100 represented "extreme pain." For satisfaction, 0 represented "very dissatisfied" and 100 "very satisfied." Disability and functional impairment was evaluated using the pain, function, stability subscales of the American Shoulder and Elbow Surgeons Score (ASES), the 11-item version of the Disabilities of Arm, Shoulder and Hand (QuickDASH), and the pain, functional, mobility, and strength subscales of the Constant Score. The strength test for the Constant Score was measured using a Chatillion isometric strength dynamometer (Ametek Inc, Largo, FL, USA) according to the method described by Constant and Murley, in which the patient stands with the shoulder abducted to 90° in the scapular plane, the elbow extended, and the forearm pronated. A Jamar EZ Read shoulder goniometer (Patterson Medical, Warrenville, IL, USA) was used to measure shoulder range of motion.

Radiographs included anteroposterior (AP) neutral, AP internal rotation, AP external rotation, axial, and axillary views. Notching was defined using the Nerot classification.²¹ No heterotopic ossification (HO) classification currently exists for the shoulder. In the absence of a formal grading scale for HO in the shoulder, we applied the Brooker Classification developed for hip HO⁴ to grade HO in the shoulder. Class I represents islands of bone within the soft tissues; class 2 represents bone spurs of at least 1 cm between the opposing bone surfaces; class 3 represents bone spurs that extend and reduce the space between the opposing bone surfaces to less than 1 cm; and class 4 represents radiographic ankylosis.

Statistical analysis

Descriptive statistical analysis was performed using SPSS 21 software (IBM Corp, Armonk, NY, USA). We normalized the constant score for age and gender using the method described by Katolik et al.¹⁵

Results

The study comprised 29 RSAs for traumatic humeral fractures in 28 patients.



Figure 3 A neutral x-ray view shows the status of the implant in an 81-year-old woman 5 years after reverse shoulder arthroplasty repair of a 3-part fracture.

Survivorship and complications

All shoulder implants were included in the survivorship analysis (data obtained from direct patient review, clinical notes, and the ANJRR). None of the 29 shoulders required revisions of the reverse prosthesis. The ANJRR uses hospital separation data to ensure successful capture of any activity. We can be confident that of those patients who died and could not be specifically reviewed clinically or radiographically for this review, no revisions occurred between the last documented clinical and radiographic review and the time of death.

One complication was reported (combining clinical review, file review, and the ANJRR), which was a postoperative axillary nerve palsy that completely resolved spontaneously within 12 months. No implant loosening or infection was documented. [Figure 3](#) depicts a radiograph of an 81-year-old woman at 5 years post-RSA for a 3-part humeral fracture.

Clinical evaluation

The clinical evaluation included 21 shoulders. Seven patients had died, and 1 was unavailable for follow-up. All patients were satisfied with their shoulder. Mean average pain with normal activities was 2 of 100 total (SD, 7; range, 0-28). The mean ASES score was 89.3 (SD, 13.6; range, 44.3-100), the mean QuickDASH score was 13.2 (SD, 18.1; range, 0-65.9), and the mean average Constant score was 70.9 (SD, 9.9; range, 54.3-83.9). The mean Constant score, after being normalized for age and gender,¹³ was 88 (SD,



Figure 4 Case example of heterotopic ossification.

11.2; range, 67.1-103.3). Average results for range of motion were 130° (range 90°-150°) for forward flexion, 30° (range 0°-70°) for external rotation, and 113° (range 70°-145°) for abduction. Internal rotation ranged from the lateral thigh to T4.

Radiologic outcomes

Twenty-nine shoulders were available for radiographic evaluation. The most recent x-rays were evaluated for the patients who died and the woman who was unavailable for follow-up.

Inferior scapular notch: Notching was observed as grade 0 in 25 shoulders and grade 1 in 4 shoulders.

Scapular spur: A spur was observed in 7 shoulders.

HO: Class 1 HO (adapted Brooker Classification⁴) was seen in 4 shoulders (Fig. 4).

Glenoid radiolucency: No loosening of the glenoid base plate was observed. Nonprogressive radiolucency around the superior screw >2 mm was seen in 3 shoulders.

Humeral radiolucency: No loosening of the humeral component was observed. Nonprogressive lucent lines were seen in 2 shoulders. Lucent lines <2 mm were present in zones 1, 2, and 7 in 1 patient with a cemented stem and in zones 2 and 6 in 1 patient with an uncemented stem (Fig. 5).

Tuberosities: Partial lysis of the greater tuberosity was seen in 10 shoulders and in the lesser tuberosity in 5 shoulders.

Discussion

We used the deltopectoral approach because it did not require detachment of the deltoid from the acromion. The deltoid is the primary motor in RSA. This approach also assisted in inferior placement of the glenosphere. Furthermore modified tuberosity fixation is easier through a

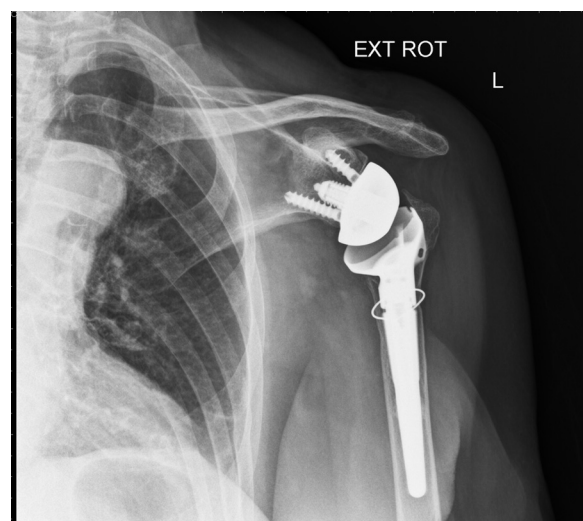


Figure 5 Case example of non-progressive radiolucency around superior screw.

deltopectoral approach. A further potential benefit of the deltopectoral approach may be the possibility of a lower infection rate. Some previous studies on reverse prostheses have reported a higher infection rate than is normally seen in shoulder arthroplasty.⁹ A proposed reason for this has been the larger dead-space more closely related to the skin incision of the superior approach.⁷ No infections were observed in this series.

Exposure of the glenoid was aided by the fractured metaphyseal region of the humerus and the lack of capsular contracture compared with the situation in CTA.

Our practice in routine RSA has been to preferentially use an uncemented humeral stem, and we have seen few problems with loosening. We do, however, have some concerns with the use of an uncemented stem in this setting. We are not suggesting that these concerns would preclude the use of an uncemented stem, but would recommend caution and attention to detail.

These patients are often osteoporotic. In addition, fracture lines of the proximal humerus may extend into the proximal shaft. Sometimes, these extensions can be difficult to identify, and the risk of causing an inadvertent intraoperative fracture or separation of a pre-existing occult fracture line, when impacting an uncemented stem into the humerus, exists. Further, the lack of any metaphyseal support places greater emphasis on middle to distal stem fixation. Given the critical aspects of achieving the correct height of the stem, as well as good primary stability, there is little margin for error. As such, our practice is to use a cemented prosthesis when there is any doubt regarding the quality of the bone or the potential for occult fracture lines. When an uncemented prosthesis was used, if a split in the humerus was identified, it was treated intraoperatively with cerclage wires (Fig. 6). In 3 of 15 uncemented stems, cerclage wires were used for intraoperative identification of a shaft fracture. There were no long-term issues with stem

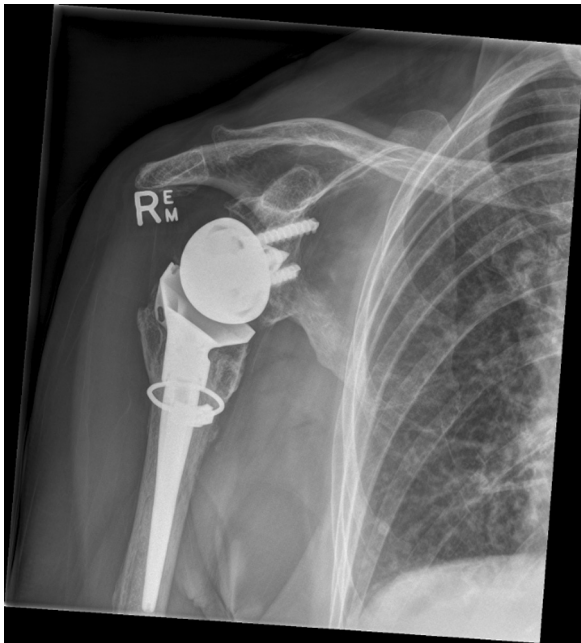


Figure 6 Cerclage wiring was performed intraoperatively to manage a split in the humerus.

fixation in these 3 shoulders. This is in line with literature from hip arthroplasty, which suggests that intraoperative identification and management of a split in the shaft does not lead to long-term compromise.¹ Humeral height was judged by attempting to place the humeral implant such that the medial lip of the humeral articular surface could be placed just caudal to the inferior margin of the native glenoid, before glenoid preparation. Subsequent adjustments in tension could be achieved using polyethylene humeral liner height. No retentive liners were used in our series.

Some of the patients in our early experience developed a degree of stiffness somewhat analogous to the difficulties we had previously observed with prosthetic hemiarthroplasty. This was in the first 3 patients of the series, as discussed in the operative technique section. This was at odds with our experience in RSA for rotator CTA. One of the major differences between the 2 situations is that there is a greater potential for scarring, particularly in the region of the rotator interval, when a full cuff reconstruction has been performed around the prosthesis. The humeral reverse body is more bulky than a fracture-specific hemiarthroplasty, and we had concerns that the additional bulk, combined with full tuberosity and cuff reconstruction, was leading to stiffness. Given that CTA patients have no significant supraspinatus tendon, we hypothesized that excision of the supraspinatus tendon and the anterior part of the greater tuberosity would mimic the situation seen in the CTA patients. This would be achieved by avoiding a full cuff reconstruction with rotator interval closure, thereby possibly allowing a more predictable restoration of range of motion. Since we adopted this technique, we have observed this has been the case in our experience over a number of

years and have noticed a more rapid return of function with easier rehabilitation. We did, however, believe that reconstruction of subscapularis and infraspinatus function were quite important for restoration of rotation. Our results for active external rotation range support this contention. Restoration of the force couple also contributes to stability. We had no cases of instability, although we have seen anecdotal reports from other centers of problems with instability when some form of tuberosity reconstruction was not undertaken at the time of reverse implants for trauma.

In our series, 29 RSA were implanted for 3-part or 4-part fractures, with 21 available for clinical evaluation at a mean follow-up of 54 months. No revisions were required. The mean Constant score was 70.9 (range, 54.3 -83.9), and when normalized for age and gender, was 88 (range, 67.1-103.3). These results compare favorably with the average Constant scores of 44 to 68 reported in the literature.^{5,16} Our series had an average ASES score of 89.3 (range, 44.3-100). This also compared favorably with the series by Garrigues et al,⁹ who reported an average of 47.4 (range, 30-81) for their hemiarthroplasty group and 81.1 (range, 75-88) for their RSA group. Furthermore, Young et al²⁵ reported an average of 67 (range, 26-100) for their hemiarthroplasty group and 65 (range, 40-88) in their RSA group. Range of movement measurements in our series were also comparable, or better, than those reported in case series.^{9,25} As a result, our patient group demonstrates encouraging results, which have led us to continue this technique.

Given the average age of the patients at the time of surgery (79 years) and the expected life expectancy in this demographic, we believe this study has achieved a significant follow-up duration. In addition, the challenges presented in relation to follow-up in this demographic have been at least partially mitigated by the rigorous tracking afforded by the ANJRR. Our results concurred with the results received from the ANJRR. We can confidently conclude that there was no revision activity in this group of 29 implants. Review of the clinical notes confirmed even for the 7 patients who died, no concerns were reported by the patients at their latest follow-up.

We believe that the results of the 21 patients available for clinical review are comparable or better than outcomes reported by other authors for reverse shoulder replacement in this setting. In a prospective study of 44 patients with an average follow-up of 48 months, Martinez et al¹⁸ reported a high complication (27%), dislocation (13.6%), and revision rate. In a similarly sized sample of 36 patients with longer follow-up of 6.6 years, Cazeneuve and Cristofari⁶ found a similarly high complication and dislocation rate. Young et al²⁵ reported 20% complications in their hemiarthroplasty group (n = 2), whereas none were reported in the RSA group. In comparison, the patients in our RSA series had no dislocations, infections, or revisions.

Our study's limitations include its retrospective nature. Although the patients were a consecutive series, the sample size was small ($n = 29$ shoulders). However, the strengths of this study included that no surviving patients were lost to follow-up, although 1 contactable participant could not attend because she resided overseas. All patients could be reviewed radiologically from x-ray images, with the x-ray images from those who died being those that were the most recent before death. All revision and complication data could be cross-checked with our national joint registry to ensure accuracy of reporting. Even though our study had a smaller sample than those previously published, our study found fewer complication rates and had better functional outcomes. Future research would benefit from a longer prospective cohort or randomized clinical trial examining the survivorship, clinical, and radiologic, outcomes of this implant.

Conclusions

This series demonstrates excellent outcomes in the use of a reverse total shoulder arthroplasty for the treatment of 3-part and 4-part fractures in elderly patients. The clinical outcomes of this group were superior to most of the previously published studies and the complication rate was also extremely low, with no dislocations, infections, or prosthetic revisions. We believe that careful attention to the very specific aspects of the surgical technique and rehabilitation that we have used in this cohort of patients may have contributed to these results. This surgical technique allows us to reliably offer these patients pain relief and restoration of functional range. Our decision to undertake this treatment modality was based on the good results that we observed in patients with rotator CTA treated with reverse total shoulder arthroplasty. Our strategy for partial reattachment of the rotator cuff is based on the premise that we were trying to recreate a similar biomechanical situation to that which exists in the rotator CTA patient group.

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