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Reverse total shoulder arthroplasty for cuff tear arthropathy: the clinical effect of deltoid lengthening and center of rotation medialization

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Background: Reverse total shoulder arthroplasty (RSA) for cuff tear arthropathy improves shoulder function and reduces pain. Implant position and soft tissue balancing are important factors to optimize outcome. Tensioning the deltoid and increasing the deltoid moment arm by medializing the center of rotation are biomechanically advantageous. The purpose of this study was to correlate RSA functional outcomes with deltoid lengthening and center of rotation medialization.

Materials and methods: This prospective cohort study enrolled 49 consecutive patients who underwent RSA for cuff tear arthropathy. Preoperative and serial postoperative physical examinations, radiographs, and American Shoulder and Elbow Surgeons and Simple Shoulder Test scores were evaluated. Deltoid lengthening and medialization of the center of rotation were measured radiographically and correlated with functional outcome scores, range of motion, and complications.

Results: At final follow-up (average, 16 $\pm$ 10 months), 37 of 49 patients (76%) were available for analysis. Deltoid lengthening (average, 21 $\pm$ 10 mm) correlated significantly ($P = .002$) with superior active forward elevation (average, 144° $\pm$ 19°). Medialization of the center of rotation (average, 18 $\pm$ 8 mm) did not correlate with active forward elevation or subjective outcomes. Deltoid lengthening that achieved an acromion−greater tuberosity distance exceeding 38 mm had a 90% positive predictive value of obtaining 135° of active forward elevation. Two patients (4%) required revision surgery, and 68% of patients developed scapular notching (average grade, 1.3 $\pm$ 1.2) at final follow-up.

Conclusion: Deltoid lengthening improves active forward elevation after RSA for cuff tear arthropathy.

Level of evidence: Level II, Prospective Cohort Design, Treatment Study.

Keywords: Reverse; shoulder; arthroplasty; deltoid; lengthening; medialization; outcome

Neer described the clinical findings, pathology, and distinguishing features of cuff tear arthropathy.[26] He established ''limited goals'' of treatment with hemiarthroplasty, and many authors have demonstrated variable achievement of pain relief, progression of glenoid arthritis, and continued poor function.[8,9,13,29,32,45,46] The reverse

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prosthesis was developed for the treatment of cuff tear arthropathy with the intent to replace the painful glenoid and humeral arthritic joint surfaces and to optimize deltoid function in the face of a deficient rotator cuff.[14]

The modern generation of semiconstrained reverse total shoulder arthroplasty (RSA) designs, beginning with Grammont's Delta prosthesis,[14] which medialized the center of rotation (COR) and reduced the shear forces on the glenoid implant−bone interface, have shown favorable outcomes and superior functional results to those of hemiarthroplasty.[3,4,19,35,41,44] The central biomechanical principles of Grammont's design, as described by Boileau et al,[3] are the retensioning of the deltoid, and medialization of the COR to increase the deltoid lever arm length and increase the proportion of deltoid fibers that function as shoulder abductors. Patients with preoperative inability to forward elevate their arm have predictably gained significant forward elevation postoperatively.

The biomechanical advantages of RSA have been simulated in computer models,[6,7,17,22,31] demonstrated in cadavers,[1,28] and modeled with sawbones,[18] but no study to date has evaluated the clinical effect of lengthening the deltoid and increasing the deltoid moment arm by medializing the COR. Deltoid lengthening is recognized empirically as an important clinical attribute, and preoperative contralateral radiographs can help plan deltoid lengthening.[24] Inferior glenosphere placement has also been identified to decrease scapular notching and improve forward elevation.[33] Perhaps the improved forward elevation is the consequence of added deltoid lengthening by inferior placement of the glenosphere. This study hypothesizes that deltoid lengthening and medialization of the COR are primary determinants of functional outcome and the ability to forward elevate after RSA for cuff tear arthropathy.

Materials and methods

This prospective cohort study included 49 consecutive patients who underwent RSA for cuff tear arthropathy from January 2004 to October 2009. Twelve patients were excluded, leaving 37 patients (10 men, 27 women) with complete follow-up who were included in the analysis. Four surgeons at a single institution implanted 27 Zimmer trabecular metal reverse shoulder system prostheses (Zimmer Inc, Warsaw, IN, USA), 7 Delta III reverse shoulder system prosthesis (DePuy Orthopedics, Warsaw, IN, USA), and 3 Aequalis reversed prostheses (Tornier Inc., Houston, TX, USA). Indications included painful cuff tear arthropathy confirmed by shoulder radiographs,[43] less than 90° of active forward elevation, absence of septic arthritis, and evidence of chronic cuff tear arthropathy on magnetic resonance imaging (or computed tomography if magnetic resonance imaging was contraindicated) if there was any uncertainty of the diagnosis.[11,15]

The dominant arm was affected in 24 of the 37 shoulders. The average age was 76 years (range, 60-95 years). Prior rotator cuff surgery had failed in 10 patients. Exclusion criteria included any patient who had prior fracture, arthroplasty, neurologic dysfunction, or deltoid dysfunction in the operative shoulder. The analysis excluded patients who did not have at least 6 months of clinical and radiographic follow-up. Preoperative data collected included prior surgical procedures, preoperative Simple Shoulder Test (SST) and American Society of Shoulder and Elbow Surgery (ASES) questionnaires, and measurement of active range of motion (ROM) and passive ROM with a goniometer.

A deltopectoral approach was used in every case, and the subscapularis was tenotomized and repaired if found intact. During humeral head osteotomy, the teres minor tendon attachment was preserved if found intact. The prostheses were implanted as described in the techniques published by each implant company, with the humeral stem set at 10° retroversion. The triceps was not released or recessed from the infraglenoid tubercle.

During the course of the study, the position of the baseplate and glenosphere was attempted to be placed in a more inferior position with slight inferior tilt because of the early reports of notching and adduction impingement with a central placement.[28] Soft tissue tension and implant stability was assessed with liner trials by having the arthroplasty demonstrate little shuck <5 mm with longitudinal traction, the joint was stable without subluxation or impingement during a full passive range of motion, the prosthesis was difficult to reduce and dislocate, and if the deltoid felt palpably taut with the arm in full adduction. No cases required a spacer or a retentive polyethylene liner. Intraoperative data collected included the sizes of the prosthesis, thickness of polyethylene liners, and intraoperative complications.

At the follow-up visits, the ASES and SST questionnaires were completed, and postoperative ROM was measured with a goniometer by a research assistant and confirmed by the surgeon. The minimum clinical follow-up required in this study was 6 months, because improvement in active ROM plateaued by 6 months. Forward elevation, external rotation with the arm at the side, and internal rotation to the highest vertebral level were recorded. Care was taken to ensure that patients remained seated upright during internal and external rotation testing to avoid use of their body weight or momentum to increase rotational gains.

Complete preoperative and postoperative radiographs were collected. These included a true anteroposterior view of the glenohumeral joint in neutral rotation, a scapular-Y view, and an axillary view. Analysis of radiographs was blinded and not performed by the treating surgeon. Initial postoperative radiographs were used to measure lengthening and medialization, and the longest follow-up postoperative radiographs were used to grade scapular notching, as described by Nerot and Sirveaux.[35] TraumaCad 2.0 software (Orthocrat Ltd, Petah Tikva, Israel) was used for measurement and calibration of the radiographs. A representative measurement is illustrated in Figure 1.

The deltoid length was defined as the distance between the inferolateral tip of the acromion to the midpoint of the deltoid tuberosity with the arm in neutral rotation and 0° abduction. This deltoid length measurement has been described by De Wilde et al[6] for representing the length of the middle deltoid. This method does not account for any wrapping of the middle deltoid over the greater tuberosity,[21] which we found has a small effect (<2%) on deltoid length in shoulders without added humeral lateralization. The acromion−greater tuberosity distance was between the inferolateral tip of the acromion and the most prominent superolateral point of the greater tuberosity. There were 9 incomplete radiographs, and lengthening was calculated by the increase of the