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The rotator cuff muscles are antagonists after reverse total shoulder arthroplasty

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Introduction: There is disagreement regarding whether, when possible, the rotator cuff should be repaired in conjunction with reverse total shoulder arthroplasty (RTSA). Therefore, we investigated the effects of rotator cuff repair in RTSA models with varying magnitudes of humeral and glenosphere lateralization.
Methods: Six fresh frozen cadaveric shoulders were tested on a validated in vitro muscle-driven motion simulator. Each specimen was implanted with a custom adjustable, load-sensing RTSA after creation of a simulated rotator cuff tear. The effects of 4 RTSA configurations (0 and 10 mm of humeral lateralization and glenosphere lateralization) on deltoid force and joint load during abduction with and without rotator cuff repair were assessed.
Results: Deltoid force was significantly affected by increasing humeral lateralization (–2.5% ± 1.7% body weight [BW], $P = .016$) and glenosphere lateralization (+7.7% ± 5.6% BW, $P = .016$). Rotator cuff repair interacted with humeral and glenosphere lateralization ($P = .005$), such that with no humeral lateralization, glenosphere lateralization increased deltoid force without cuff repair (8.1% ± 5.1% BW, $P = .012$). This effect was increased with cuff repair (12.8% ± 7.8% BW, $P = .010$), but the addition of humeral lateralization mitigated this effect. Rotator cuff repair increased joint load (+11.9% ± 5.1% BW, $P = .002$), as did glenosphere lateralization (+13.3% ± 3.7% BW, $P < .001$). These interacted, such that increasing glenosphere lateralization markedly increased the negative effects of cuff repair (9.4% ± 3.2% BW [$P = .001$] vs. 14.4% ± 7.4% BW [$P = .005$]).
Conclusion: Rotator cuff repair, especially in conjunction with glenosphere lateralization, produces an antagonistic effect that increases deltoid and joint loading. The long-term effects of this remain unknown; however, combining these factors may prove undesirable. Humeral lateralization improves joint compression through deltoid wrapping and increases the deltoid's mechanical advantage, and therefore, could be used in place of rotator cuff repair, thus avoiding its complications.
Level of evidence: Basic Science Study; Biomechanics

Keywords: Reverse total shoulder arthroplasty; RTSA; RSA; shoulder; rotator cuff; simulator; cuff tear arthropathy

Institutional Review Board approval was not required for this in vitro biomechanical investigation.

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Reverse total shoulder arthroplasty (RTSA) is primarily indicated for the treatment of rotator cuff tear arthropathy or massive rotator cuff tears that are deemed irreparable.[9,15,17,20] Despite these indications, it is often possible to repair portions of the subscapularis and infraspinatus/teres minor; however, there is disagreement regarding whether these tissues should be repaired because their effects on RTSA biomechanics and outcomes remain unclear.[6,7,10,16] In addition, the indications for RTSA have expanded to include surgical conditions with an intact rotator cuff, such as the management of A2, B2, or C glenoid erosions.[8,22] The surgeon thus has the option to preserve or release the rotator cuff in these scenarios.

Some have advocated repair of these tissues on the basis that they increase RTSA stability and decrease the incidence of dislocation,[6,10,21,23] but clinical series by Clark et al[7] and Wall et al[24] have disputed this effect. However, a review by Wall et al[24] found that repair of the subscapularis may still be warranted because it significantly improves postoperative internal rotation (IR). In contrast, Boulahia et al[5] suggested that subscapularis repair may detrimentally affect external rotation (ER) through antagonistic loading against the already weakened posterior cuff. Other reports that specifically investigated subscapularis repair have not confirmed this finding, however.[7,24]

Although to date the discussion of whether to repair the rotator cuff has primarily focused on postoperative joint stability, the potential effect on muscle and joint loading must also be considered. As is the case in the native glenohumeral joint, the concentric loads applied by a repaired rotator cuff can be expected to counter the deltoid's eccentric joint loads. However, in an in vitro study of one RTSA implant configuration, Ackland et al[1] demonstrated that the function of the subscapularis is markedly shifted toward adduction—especially early in motion—compared with its native role. This finding suggests that repair of the subscapularis may resist abduction and thus increase muscle and joint loading, but whether this change in function holds across the full range of RTSA configurations used clinically is unclear.

With the conflicting clinical information and the relative paucity of biomechanical evidence in mind, we sought to investigate the effects of rotator cuff repair or preservation in glenoid erosion cases on functional shoulder outcomes and joint kinetics. We also investigated how these effects are influenced by changes in 2 geometric implant parameters that have a strong influence on shoulder biomechanics. Specifically, we wanted to clarify how rotator cuff repair affects active IR and ER range of motion (ROM) and ER strength, while also determining whether it has a detrimental effect on deltoid and joint loading.

We hypothesized that rotator cuff repair would resist abduction, thus increasing deltoid muscle force requirements and the resulting joint load. As well, we hypothesized that glenosphere lateralization would have no effect on IR and ER but would exacerbate the negative effects of rotator cuff loading and that humeral lateralization would improve IR and ER and mitigate the effects of rotator cuff repair.

Materials and methods

Instrumented RTSA implant

In this in vitro biomechanical study, it was possible to measure joint loads and investigate the effects of systematic adjustments to implant geometry using a previously described custom modular implant system with a built-in load sensor (Fig. 1).[14,19] Four combinations of humeral and glenosphere lateralization were investigated (respectively: 0 and 0 mm, 0 and 10 mm, 10 and 0 mm, and 10 and 10 mm) where the configuration is considered to be neutral when both variables are at 0 mm, corresponding to a traditional Grammont-style implant.

Specifically, neutral was defined as the glenoid baseplate level with the inferior glenoid rim, the glenosphere center of rotation coincident with the glenoid surface, neutral humeral version with a 155° head-neck angle, and a 12.5-mm lateral offset between the humeral stem and deepest point of the cup. The 10-mm offset configurations were achieved by making mechanical adjustments to the custom implant without altering the surgical fixation.

To ensure accurate mechanical properties, commercially available 38-mm Delta Xtend polyethylene humeral cups (DePuy, Warsaw, IN, USA) were used. The glenosphere was custom fabricated to accommodate a 6 degree-of-freedom Nano25 load cell (ATI-IA, Apex, NC, USA) that attached medially to a glenoid fixation baseplate, which was recessed into the glenoid vault to allow neutral glenosphere positioning.

Active motion simulator and specimen preparation

Six fresh frozen cadaveric shoulders (aged 60 ± 21 years) without signs of cuff deficiency or prior surgery were prepared, and the humerus was transected distal to the deltoid tuberosity. To enable repeated access to the glenohumeral joint throughout the testing protocol, the subscapularis muscle was elevated from the scapula and reflected laterally without disrupting its insertion on the lesser tuberosity. A full-thickness superior rotator cuff tear was simulated by releasing the entire supraspinatus and upper portion of the infraspinatus from the greater tuberosity.

The specimens were implanted with the above-described custom adjustable RTSA implant positioned in the neutral configuration, including 0° retroversion relative to the transepicondylar axis and with humeral distalization dictated by aligning the superior humeral cup with the superior aspect of the greater tuberosity for all specimens. After implantation, the 3 deltoid heads were sutured at their insertion, and the subscapularis and inferior infraspinatus/teres minor musculotendinous junctions were sutured across their width using a running locking stitch.

Specimen preparation was completed as described by Giles et al,[12] including fixation of Optotrak Certus optical trackers (NDI, Waterloo, ON, Canada) to the scapula and insertion of an instrumented intramedullary humeral rod that could provide optical motion tracking and data regarding the loads applied to the rod by the experimenter. These data were recorded using a 6 degree-of-freedom Mini45 load cell (ATI-IA) interposed between the proximal rod, which was inserted into the humeral canal, and the distal rod