How Does Scapula Motion Change after Reverse Total Shoulder Arthroplasty?

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Background: The elevation of the arm is composed of glenohumeral and scapulothoracic component. Many reports have addressed changes in scapular position in many shoulder disease spectrum. However, no study has examined changes in scapular position after reverse total shoulder arthroplasty (RTSA). The purpose of this study was to evaluate the changes in scapula motion after RTSA versus contralateral sides.

Methods: Seven patients that underwent reverse total shoulder replacement for cuff tear arthropathy from July 2007 to October 2008 were enrolled. The distance between the long axis of the thoracic spine and the inferior pole of the scapula (lateralization of the scapula) was measured on shoulder A-P radiographs at 0 degrees (the neutral position) and at 30, 60, 90, and 120 degrees of shoulder abduction. In addition, the angle between the long axis of the thoracic spine and medial border of the scapula was measured and compared with contralateral sides.

Results: Scapulohumeral rhythm was 2.4:1 on operated sides and 4.1:1 on contralateral sides at 120 degrees of abduction. The distance between the line of the interspinous process of upper thoracic vertebra and the inferior pole of the scapula showed a negative slope at 0 to 30 degrees section on the operated side, but beyond 30 degrees of abduction, this distance showed a more sudden increase than in contralateral sides. The angle between the vertical vertebral line and the scapular medial border also showed greater increase beyond 30 degrees abduction on operated sides.

Conclusions: The pattern of scapular motion after RTSA, was found to differ from that of contralateral sides, and showed a more scapular upward rotation. Therefore, rehabilitation
programs should be designed to prevent periscapular muscle fatigue after reverse total shoulder arthroplasty.

**Keywords:** Scapula Motion, Scapulohumeral rhythm, Reverse Total Shoulder Arthroplasty
Background

Elevation of the arm is composed of the glenohumeral (GH) and scapulothoracic (ST) components. This was first called scapulohumeral rhythm (SHR) by Codman [1] and the normal ratio was reported by Inman et al. [2] as 2:1. The motion of the scapular is affected by GH joint motion, and according to Inman, the setting phase is in 0 to 60 degrees of abduction, where the scapular is stabilized. In the setting phase, according to Yano et al. [3], scapular motion is reduced, and beyond 60 degrees, scapulohumeral rhythm is decreased, which means more scapular motion.

Several reports have addressed changes in scapular position in many shoulder diseases, such as, impingement, rotator cuff tear, instability, and frozen shoulder [4-9]. Also, some research has been conducted on scapulohumeral rhythm after total shoulder arthroplasty [10]. However, biomechanics concept of reverse total shoulder arthroplasty differs from normal shoulder and conventional arthroplasty. Reverse total shoulder arthroplasty medializes the center of rotation, distalizes the humerus, and elongates the deltoid. The lever arm of the deltoid muscle is lengthened so that for any given angular displacement of the humerus, shortening of the deltoid is greater than for total shoulder arthroplasty. Furthermore, no study has previously reported changes in scapular motion after reverse total shoulder arthroplasty.

Accordingly, the purpose of this study was to evaluate the changes in scapula motion after reverse total shoulder arthroplasty versus contralateral sides during abduction in the scapular plane.

Methods

This study was approved by our institutional review board, and informed consent was obtained from all patients. We reviewed seven primary reverse total shoulder arthroplasties
conducted in seven patients between July 2007 and October 2008. The study cohort consisted of two men and five women of mean age 67.4 years (range, 63 to 77 years) at surgery. We included the patient who did not have a history of shoulder disease in the contralateral side, and all had normal active arm elevation and abduction, and active abduction over 120 degrees in operated sides at their follow ups (mean 22.3 months postoperatively). In these seven shoulders, five shoulders had pseudoparalysis with cuff tear arthropathy, one shoulder had osteoarthritis of the glenohumeral joint and a massive rotator cuff tear, and one shoulder had avascular necrosis of humeral head.

All patients were implanted with the Aequalis Reverse Shoulder Prosthesis (Tonier, Edina, MN) with a 6.5mm stem, a 36-mm glenosphere, and a 25mm glenoid baseplate. The component sizes were chosen because they were the most commonly used sizes of the Aequalis Reverse Shoulder system. All patients were operated on in a beach chair position and the deltopectoral approach was used. In those cases where the inferior third of the subscapularis tendon was intact, it was released from the lesser tuberosity and preserved for reinsertion at the end of the procedure with transosseous sutures. The humeral cut was performed with a jig to achieve retroversion of 20 degree and an inclination of about 150 degree using the forearm as a reference. Next, sequential reamers were used to open and prepare the humeral canal. The trial prosthesis was kept in place to protect the proximal humerus during glenoid preparation. The guide wire for the glenoid reamer was positioned (as is essential) so that the glenoid baseplate was as low as possible. Reaming was performed manually and upper and lower divergent locking screws and anterior, posterior non-locking screws were used to provide primary stability. An appropriately size glenoid hemisphere (glenosphere) was then mounted on the baseplate. Polyethylene insert thickness was chosen based on soft-tissue tension during trial reduction. After surgery, patients were placed in an
abduction sling for 6 weeks. The initiation of passive range of motion with low intensity supervised physical therapy was started 4 weeks after surgery, and progressed from active assist range of motion to full active range of motion. Passive external rotation was initially avoided to protect subscapularis tendon repair.

To identify scapular motion at last follow up, shoulder AP view of scapular plane at 0, 30, 60, 90 and 120 degrees was checked on standing. To evaluate scapular upward rotation, the length of the line between the interspinous process of upper thoracic vertebra and the inferior pole of scapula was measured (Figure 1A), and the angle between the vertical vertebral line and scapular medial border was measured (Figure 1B). The increasing rate on each section was then compared with that of the contralateral side.

**Results**

Mean active forward elevation after operation was 138.6 degrees, and abduction was 131.2 degrees. Mean VAS (visual analog scale) improved from 8.4 preoperatively to 0.8 points postoperatively. In addition, mean ASES (American Shoulder and Elbow Surgeons) score improved from 30.0 to 83.3 points, and KSS (Korean Shoulder Surgeons) score improved from 37.4 to 76.5 points.

Mean scapulohumeral rhythm was 2.4:1 on operated sides and 4.1:1 on contralateral sides at 120 degrees of abduction (Table 1), showing more scapular motion on operated sides.

The distances between the interspinous process of the upper thoracic vertebra and the inferior pole of the scapula on operated sides were 85.2mm at 0 degrees, 73.1mm at 30 degrees, 91.4mm at 60 degrees, 110.1mm at 90 degrees and 138.5mm at 120 degrees of abduction. On contralateral sides, these distances between the vertical vertebral line and the inferior pole of the scapula were 81.4, 90.5, 104.4, 111.8, and 131.1mm at 0, 30, 60, 90 and
120 degrees of abduction, respectively. The difference of each section were -12.1, 18.3, 18.7, and 28.4mm on operated sides, 9.1, 13.9, 7.4, and 19.3mm on contralateral sides. At 0 to 30 degree section on operated sides, the slope was negative. However, beyond 30 degrees of abduction, slope of distance showed more sudden increase of distance than the contralateral side (Figure 2).

The angles between the vertical vertebral line and the scapular medial border on operated sides were 5.5, 6.3, 20.1, 26.4, and 39.0 degrees at 0, 30, 60, 90, and 120 degrees of abduction, respectively, and on the contralateral sides, these angles were 7.7, 9.7, 16.2, 22.0, and 30.0 degrees, respectively. The difference of each section were 0.8, 13.8, 6.3, and 12.6 degrees on operated sides, and 2, 6.5, 5.8, and 8 degrees on contralateral sides. The slope of the angle also showed more increase beyond 30 degrees abduction on the operated side (Figure 3).

Discussion
Scapular motions are described in three planes: upward and downward rotation in scapular plane, anterior and posterior tilting in the sagittal plane, and internal and external rotation in the transverse plane [5]. In the present study, scapular upward and downward rotations were evaluated in the scapular plane during abduction.

The movement of the scapula under the influence of glenohumeral motion aids the understanding of the mechanics and pathology of the shoulder joint. Cathcart [11] was the first to recognize the contribution made by the scapulothoracic motion to normal shoulder complex kinematics. Codman [1] termed this synchronous motion as scapulohumeral rhythm. Inman et al. [2] reported a SHR of 2:1 in healthy subjects. Since, much research on shoulder kinematics has been directed toward the study of SHR [2, 12, 13]. Braman et al. [10] reported
that shoulder motions differed between patients with advanced glenohumeral osteoarthritis and healthy individuals, and that total shoulder arthroplasty, restored SHRs to normal values. In the present study, SHR was 2.4:1 on operated sides and 4.1:1 on contralateral sides at 120 degrees of abduction. This means that scapular motion on operated sides is greater than on contralateral sides. We consider this postoperative change a useful adaptation of scapular mechanics to maintain the tension of the deltoid muscle to generate the forces necessary for shoulder motion, as was mentioned by Mell et al. [7].

In particular, because the function of deltoid muscle is important and the rotator cuff has no function in patients with an implanted reverse total shoulder system, this scapular motion represents a highly meaningful change. However, after long term follow up, increased scapular motion can lead to periscapular muscle fatigue. Therefore, rehabilitation programs should be designed to prevent periscapular muscle fatigue after reverse total shoulder arthroplasty.

In the present study, during 0 to 30 degrees of abduction, distance between vertical vertebral line and inferior pole of scapula was decreased on operated sides, which means downward rotation of the scapula on initial abduction; described as motion of the glenohumeral type by Yano et al. [3]. Furthermore, the angle between the vertical vertebral line and scapular medial border increased less than in contralateral sides on initial abduction. However, beyond 30 degrees, changes in distance and angle were higher than in contralateral sides. Therefore, more scapular upward rotation occurred during middle and late abduction.

Yano et al. [3] proposed two types of upward rotation during the initial phase of elevation. For the glenohumeral type (much glenohumeral motion), the scapula slightly rotates downward and then progresses upward, and for the scapulothoracic type (much scapular motion), the scapular directly rotates upward. Inman et al. [2] used the term ‘the setting
phase’ to describe the early phase of shoulder motion over the 0 to 60 degrees of abduction range, indicating preparatory stabilization of the scapula to permit controlled humeral motion. Yano et al. [14] reported that SHR was generally greatest (less scapular motion) during the setting phase and that it then decreased beyond 60 degrees of abduction (more scapular motion). Furthermore, the SHR increased again below 60 degrees of abduction. They mentioned that muscular stabilization of the scapula increases while raising the arms, and thus, that less scapular motion is seen during the setting phase.

The present study has some limitations. The most obvious of which is the small number of cases enrolled. In addition, it considers only upward rotation, not internal, external rotation, or tilting. Nevertheless, the study has relevance in the context of evaluating changes of scapular upward rotation after reverse total shoulder arthroplasty. Because it is the main movement of the scapula, upward rotation is frequently addressed during treatment and research [15-17].

Conclusions

In conclusion, the pattern of scapular motion after reverse total shoulder arthroplasty was found to differ in operated and contralateral sides and to show more upward rotation after surgery. Therefore, rehabilitation programs should be designed to prevent periscapular muscle fatigue after reverse total shoulder arthroplasty.

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Authors' contributions

MSK designed this study, review the literatures and drafted the manuscript. KBL and KYL gave substantial intellectual ideas in drafting the manuscript. NYC participated in the acquisition of data of cases and gave substantial contributes to interpretation of literature review. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.
References

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**Figure 1** The measurement method of distance between line of inter-spinous process of upper thoracic vertebra and inferior pole of scapula (A) and angle between vertical vertebral line and scapular medial border (B).

**Figure 2** The distance between line of inter-spinous process of the upper thoracic vertebra and inferior pole of scapula.

**Figure 3** The angle between line of inter-spinous process of upper thoracic vertebra and scapular medial border.
Table 1 The degree of glenohumeral and scapulohumeral rhythm on operated and contralateral shoulder at 30°, 60°, 90°, 120° of abduction.

<table>
<thead>
<tr>
<th>Abduction</th>
<th>RTSR</th>
<th>Normal</th>
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<tbody>
<tr>
<td></td>
<td>G-H</td>
<td>S-T</td>
</tr>
<tr>
<td>30°</td>
<td>23.8°</td>
<td>0.7°</td>
</tr>
<tr>
<td>60°</td>
<td>39.9°</td>
<td>14.6°</td>
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<tr>
<td>90°</td>
<td>63.6°</td>
<td>20.9°</td>
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<tr>
<td>120°</td>
<td>81.0°</td>
<td>33.5°</td>
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RTSR = reverse total shoulder arthroplasty; G-H = glenohumeral motion; S-T = scapulothoracic motion.
Figure 3