Reverse Total Shoulder Arthroplasty Can Significantly Change the Shoulder Center of Rotation

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Disclosures: D.R. Walker: None. A. Struk: None. T. Wright: 1; Exactech Inc. S.A. Banks: 1; DJO surgical, Mako Surgical.

Introduction: Reverse total shoulder arthroplasty (RTSA) has had rapidly increasing utilization since its approval for U.S. use in 2003. RTSA accounted for 11% of extremity market procedure growth in 2011. Although RTSA is widely used, there remain significant challenges in determining the location and configuration of implants to achieve optimal clinical and functional results. A few studies have quantified coronal-plane (lowering and lateralization) joint center placement post-RTSA, but there are no reports of the three-dimensional (3D) changes in shoulder joint center resulting from placement of RTSA. The goal of this study was to measure the 3D position of the shoulder joint center, relative to the center of the native glenoid face, in 16 subjects with RTSA of three different implant designs, and in 12 healthy young shoulders.

Methods: CT scans of 12 healthy and 16 pre-operative shoulders were segmented to create 3D models of the scapula and humerus. A standardized bone coordinate system was defined for each bone (Figure 1). For healthy shoulders, the location of the humeral head center was measured relative to the glenoid face center. For the RTSA shoulders, a two-step measurement was required. First, 3D models of the pre-operative bones were reconstructed and oriented in the same manner as for healthy shoulders. Second, 3D model-image registration was used to determine the post-operative implant positioning relative to the bones. The 3D position and orientation of the implants and bones were determined in a sequence of six fluoroscopic images of the arm during abduction, and the mean implant-to-bone relationships were used to determine the surgical positioning of the implants (Figure 2). The RTSA center of rotation was defined as the offset from the center of the implant glenosphere to the center of the native glenoid face.

Results: The center of rotation in RTSA shoulders varied over a much greater range than the native shoulders (Figure 3). Lateral offset of the joint center in RTSA shoulders was at least 6 mm smaller than the smallest joint center offset in the healthy shoulders. The center of rotation in RTSA shoulders was significantly more inferior than in healthy shoulders. The range of anterior/posterior placement of the rotation center for RTSA shoulders was bounded by the range for normal shoulders.

Discussion: How to best position RTSA implants for optimal patient outcomes remains a topic of great debate and research interest. A first step towards addressing this issue is to understand the range of configurations achieved with current implant systems and surgical techniques. We found that the 3D joint center position can vary over a supraphysiologic range in shoulders with RTSA, and that this variation is primarily in the coronal plane. By relating these geometric variations to muscle, shoulder and clinical function, we hope to establish methods and strategies for predictably obtaining the best clinical and functional outcomes for RTSA patients on a per-subject basis.

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Figure 1. Bone coordinate systems were defined according to the International Society for Biomechanics recommendations.
Figure 2. 3D Model-Image registration was used to determine the 3D position/orientation of the implants relative to the bones.

<table>
<thead>
<tr>
<th></th>
<th>Medial(-)/Lateral (mm)</th>
<th>Superior(-)/Inferior (mm)</th>
<th>Anterior(-)/Posterior (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTSA -JC</td>
<td>0 mm – 14 mm</td>
<td>-3 mm – 14 mm</td>
<td>-6 mm – 6 mm</td>
</tr>
<tr>
<td>RTSA - HO</td>
<td>21 mm – 40 mm</td>
<td>11 mm – 35 mm</td>
<td>-12 mm – 12 mm</td>
</tr>
<tr>
<td>Normal- HO</td>
<td>22 mm – 28 mm</td>
<td>-3 mm – 7 mm</td>
<td>-12 mm – 7 mm</td>
</tr>
</tbody>
</table>

ORS 2015 Annual Meeting
Poster No: 0986