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# A method for documenting the change in center of rotation with reverse total shoulder arthroplasty and its application to a consecutive series of 68 shoulders having reconstruction with one of two different reverse prostheses

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**Background:** Reverse shoulder arthroplasty changes the center of rotation (COR) of the glenohumeral joint and in doing so affects the resting tension in the deltoid and residual cuff muscles, as well as their respective moment arms. The purpose of this study was to assess the change in COR from the preoperative to postoperative state in a group of patients undergoing reverse shoulder arthroplasty.

**Materials and methods:** The position of the COR in relation to a scapular coordinate system was determined for the anteroposterior and axillary radiographs before and after reverse total shoulder arthroplasty for 68 shoulders (63 patients) receiving either a Delta prosthesis or an Encore Reverse Shoulder Prosthesis.

**Results:** Preoperatively, the COR was superiorly displaced a mean of 9 ± 7 mm from the origin of the coordinate system. For all shoulders, the postoperative COR was inferiorly displaced by 12 mm to a position 3 ± 3 mm below the coordinate origin ($P < .001$) and medially displaced by 27 ± 4 mm from the coordinate origin ($P < .001$) in the anteroposterior projection. For the shoulders receiving the Delta prosthesis, the COR was inferiorly displaced by 2 ± 3 mm from the coordinate origin, whereas it was inferiorly displaced by 7 ± 3 mm with the Encore prosthesis ($P < .001$). The COR was medially displaced by 28 ± 4 mm with the Delta prosthesis and by 19 ± 3 mm with the Encore prosthesis ($P < .001$).

**Conclusions:** The position of the COR relative to the scapula is significantly altered by reverse shoulder arthroplasty and is significantly different for 2 different implant designs.

**Level of evidence:** Basic Science Study, Anatomic/Radiologic Study.



**Keywords:** Reverse; arthroplasty; glenohumeral; center of rotation

Reverse shoulder arthroplasty is used to treat conditions, such as anterosuperior escape and pseudoparalysis, in which the location of the center of rotation (COR) cannot be stabilized by anatomic arthroplasty.[3,8,9,17,25] In the

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reverse total shoulder, the COR is in the center of a spherical glenoid component fixed to the scapula,[17] whereas before surgery, the COR is in the center of the humeral head.[15] Changes in the COR affect the resting tension in the deltoid and residual cuff muscles as well as their respective moment arms. The position of the COR after a reverse total shoulder arthroplasty is determined by the design of the glenoid prosthesis and the position in which it is placed. Several studies have evaluated the effect of reverse total shoulder prosthesis design on range of motion,[12,13] implant micromotion,[11,14,23] and unwanted contact between the humeral component and the scapula,[12,20,22] but with 1 exception,[6] no studies to date have quantified the actual change in glenohumeral COR after reverse shoulder arthroplasty in patients.

In that the positioning of the COR is a variable under the control of the surgeon and is likely to have an important effect on the biomechanics of the reconstruction, it is desirable to have a method for documenting the preoperative and postoperative position of the COR so that future clinical research can correlate the outcome with this anatomic parameter. In this study we present a method for documenting the position of the COR before and after reverse total shoulder arthroplasty and use it to test the hypotheses that (1) the COR of the glenohumeral joint is changed in a characteristic manner by reverse shoulder arthroplasty and (2) the change in COR is different for different implant designs.

## Materials and methods

### Radiographic method

The method requires standardized radiographs in the anteroposterior (AP) and axillary projections.[18] For each radiograph, the COR is documented as either the center of the native humeral head or the center of the prosthetic humeral head for preoperative films and the center of the glenosphere for postoperative films (Figure 1). These centers were located by use of picture archiving and communication system tools (Centricity PACS; GE Healthcare Technologies, Waukesha, WI). First, a best-fit circle was drawn on the native humeral head, the prosthetic humeral head, or the glenosphere. Second, perpendicular diameter lines were drawn, and their intersecting point was marked as the COR. Next, transparent templates that define a coordinate system based on the position and orientation of the scapula in each projection were superimposed on the PACS images and fit by eye to the outline of scapula. The relationship of the COR to the origin of the coordinate system was then measured for each projection in each shoulder before and after surgery. Superior-inferior and medial-lateral distances of the head center from the origin of the coordinate system were measured on the AP projection (Figure 1, A). Anterior-posterior and medial-lateral distances of the head center from the origin of the coordinate system were measured on the axillary projection (Figure 1, B).

### Study shoulders

Institutional review board approval was obtained before we commenced this investigation. Patients undergoing reverse shoulder arthroplasty at our institution by 1 of 2 surgeons between 2004 and 2009 were included. Two patients were excluded because of poor-quality radiographs, leaving 63 patients (68 shoulders) for evaluation. The indication for surgery was cuff tear arthropathy in 28 shoulders, failed arthroplasty in 25, failed cuff surgery in 14, and post-traumatic deformity in 1. Of the shoulders, 59 received a Delta prosthesis (DePuy, Warsaw, IN) and 9 received an Encore Reverse Shoulder Prosthesis (Encore Medical, Austin, TX). Both surgeons made an effort to place the glenosphere as inferiorly as possible from 2007 to 2009 in an effort to avoid scapular notching.[22] A summary of patient demographics for both groups of patients is shown in Table I.

### Statistical analysis

For assessment of the significance of change in COR position between preoperative and postoperative states, a 2-tailed, paired $t$ test was used. For comparison of the 2 prosthesis designs, a 2-tailed, unpaired $t$ test was used, assuming unequal variance. The results were considered significant at $P < .05$.

## Results

Preoperatively, the COR was superiorly displaced a mean of 9 ± 7 mm from the coordinate origin and centered in the anterior-posterior and medial-lateral directions. When the results for both types of prostheses were combined, the postoperative COR was inferiorly displaced by 12 mm to a position 3 ± 3 mm below the coordinate origin ($P < .001$) and medially displaced by 27 ± 4 mm from the coordinate origin ($P < .001$) on the AP projection. On the axillary projection, the postoperative COR remained centered in the anterior-posterior direction and was medially displaced by 24 ± 8 mm from the coordinate origin ($P < .001$) (Table II). Our first hypothesis—that the COR of the shoulder is changed in a characteristic manner by reverse shoulder arthroplasty—was therefore supported.

Our second hypothesis—that the change in COR is different for different implant designs—was also supported. The postoperative position of the COR on the AP projection was significantly different for the Delta and Encore shoulders. Postoperatively, on the AP projection, the COR was displaced inferiorly by 2 ± 3 mm from the coordinate origin for the Delta prosthesis and displaced inferiorly by 7 ± 3 mm from the coordinate origin for the Encore prosthesis ($P < .001$). Postoperatively, on the AP projection, the COR was displaced medially by 28 ± 4 mm from the coordinate origin for the Delta prosthesis and displaced medially by 19 ± 3 mm from the coordinate origin for the Encore prosthesis ($P < .001$). Postoperatively, on the axillary projection, the COR remained centered in the anterior-posterior direction for both the Delta prosthesis