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A quantitative method for determining medial migration of the humeral head after shoulder arthroplasty: preliminary results in assessing glenoid wear at a minimum of two years after hemiarthroplasty with concentric glenoid reaming

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Hypothesis: Glenoid erosion and medial migration of the humeral head prosthesis have been observed after most types of shoulder arthroplasty. A method of measuring the change in humeral head position with time after shoulder prosthetic arthroplasty was applied it to 14 shoulders that underwent humeral hemiarthroplasty with concentric glenoid reaming. We hypothesized that the measurement technique would be reproducible and that the rate of wear would be small in the series of shoulders studied.
Materials and methods: Standardized anteroposterior and axillary radiographs were obtained after surgery. Two examiners measured the position of the humeral head center in relation to scapular reference coordinates for the anteroposterior and axillary projections and plotted these values against time after surgery. The change in position was characterized as the slope of this plot. Shoulders were included if there were at least 3 sets of postoperative films, the last being at least 2 years after surgery.
Results: The slopes measured by the 2 examiners agreed within 0.5 mm/y for the anteroposterior and the axillary projections. For the series of shoulder arthroplasties, the rate of movement of the head center toward the scapula was less than 0.4 mm/y for either examiner in either projection.
Discussion: Medial migration is a concern after any type of shoulder arthroplasty, whether a hemiarthroplasty, a biological interpositional arthroplasty, or a total shoulder arthroplasty. Quantifying the rate of medial migration over time after shoulder arthroplasty is an important element of clinical follow-up.
Conclusions: This is an inexpensive, practical, and reproducible method that can be used to determine the rate of medial migration of the humeral head on plain radiographs after shoulder arthroplasty. The average rate of medial migration in the shoulders in this study was small.

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The glenoid side of the articulation presents the major challenge in achieving a durable reconstruction in shoulder arthroplasty.[26] The published literature indicates substantial concern regarding glenoid component wear and loosening after total shoulder arthroplasty, joint space narrowing after interpositional arthroplasty, and glenoid bone erosion after humeral hemiarthroplasty.[1-3,5-8,10-12,14-17,19,24,26,29-31,33,34,37,42,46,48] In a recent article by Tauton et al,[41] obvious polyethylene component wear was identified on anteroposterior (AP) and axillary radiographs in 30 of 83 shoulders a minimum of two years after shoulder arthroplasty. The authors stated,

Radiographically, polyethylene wear was determined by visualization of obvious narrowing of the radiolucent gap between the humeral head and the metal portion of the glenoid. It must be noted that this represents only the components with severe polyethylene wear, and the actual polyethylene wear could be much higher.

These authors addressed factors that could increase the polyethylene wear rate, but did not indicate how this rate might be measured.

Cheung et al[8] identified polyethylene wear as "narrowing of the space between the prosthetic head and the metal backing of the glenoid component." Boileau et al[4] reported the same method and referred to "accelerated wear," but did not provide a method by which the rate of wear was measured.

The method used in these 3 recent articles involved comparing the distance between the metal back of the glenoid component and the metal prosthetic head. However, this method cannot be used to determine medial wear in cases of an all-polyethylene component, an interpositional arthroplasty, or where no interposition is used. Wirth et al[47] used standardized axillary lateral and AP radiographs to assess the glenohumeral joint space and posterior glenoid erosion after humeral hemiarthroplasty with meniscal allograft but did not determine the rate of medial migration. Collins et al,[11] Krishnan et al,[21,22] Parsons et al,[34] and Wirth[49] used basically similar approaches to measure thinning of the radiographic joint space after shoulder hemiarthroplasty, with or without soft tissue interposition, but did not determine the rate of this thinning.

The first purpose of this study was to describe a practical method for measuring the rate of medial migration of the humeral head center in relation to the scapula after shoulder arthroplasty that differed from those previously reported for that shoulder and that was analogous to the method used by McCaldren et al[28] for hip arthroplasty. The second purpose was to apply this method to a group of 14 shoulders over a 2-year period after hemiarthroplasty with concentric glenoid reaming. We hypothesized that the measurement technique would be reproducible and that the rate of wear would be small in the series of shoulders studied.

Materials and methods

Approval from the Institutional Review Board at the University of Washington (IRB No. 24667) was granted before review of patient records.

Radiographic method

Radiographs were taken in a standard manner with attention to control arm position and rotation, essentially identical to the method used by Wirth et al[44] in their study of humeral hemiarthroplasty and meniscal allograft resurfacing of the glenoid. The AP radiograph was taken with the patient relaxed and supine, with the scapula flat on the radiographic table to provide a view in the plane of the scapula. The humerus was positioned in 30° of external rotation from the x-ray beam. The axillary radiograph was taken with the patient relaxed and supine, with the arm passively abducted to 90° and in neutral rotation.[19]

Shoulder radiographs were included only if an acceptable pair of AP and axillary radiographs were available for the shoulder on the same date. Radiographs were acceptable if they showed the humeral head prosthesis and scapula with good contrast and resolution. Radiographs were analyzed on a Picture Archival and Communications System (PACS) monitor (General Electric). The humeral head center was determined as the center of a circle fit to the joint surface of the humeral prosthesis.

Although most methods for assessing the position of the head center relative to the scapula use as a scapular reference (*a*) only two points on the rim of the glenoid or (*b*) landmarks on metal backed glenoid components, such approaches are limited in application by (*a*) the changes in glenoid rim geometry that may occur during and after shoulder arthroplasty or (*b*) the absence of metal markers in many cases of shoulder arthroplasty. Instead, we sought a method that would use as much of the radiographically visible lateral scapular anatomy as possible to define the scapular reference. This approach would be applicable to shoulders with and without interposition and to shoulders with and without glenoid implants.

Transparent templates outlining the scapular anatomy (Fig. 1, *A* and *B*) were fit by eye to the outline of the lateral scapula in the AP and axillary views displayed on the PACS monitor and scaled

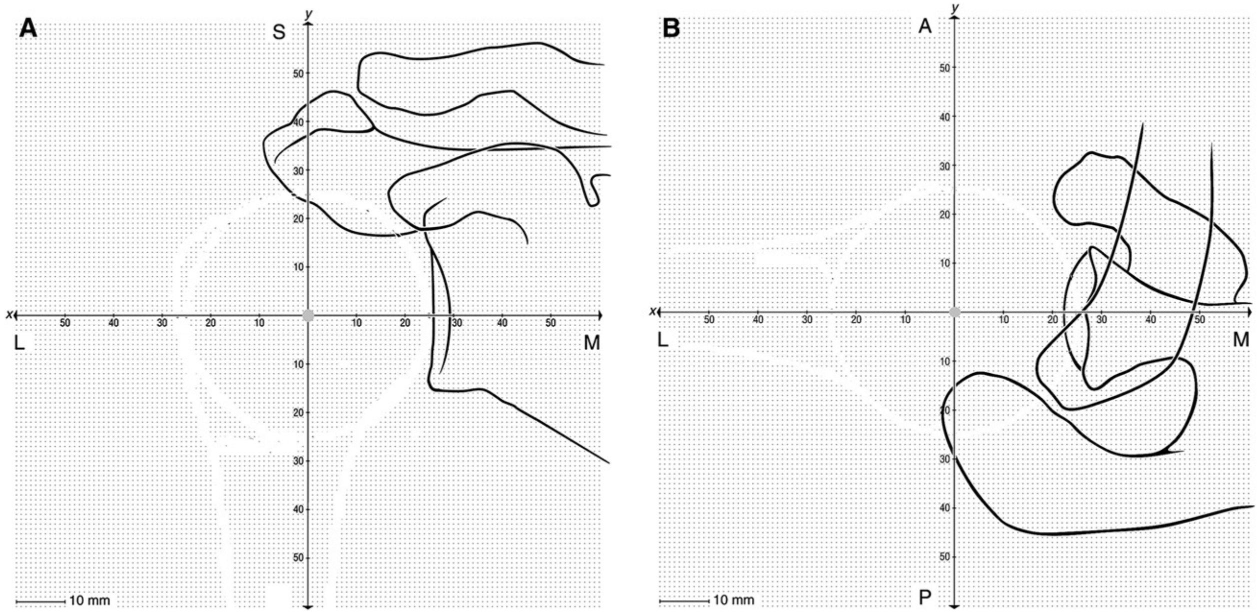

Figure 1 Templates show the outline of the scapular anatomy in the **(A)** anteroposterior and **(B)** axillary views. Each template orients a bidirectional coordinate system to the scapula. The *small circle* represents the origin of the coordinate system. These templates are superimposed by eye on scaled radiographs so that the position of the head center can be documented in relation to the coordinate origin.

to a common size. These templates defined bidirectional coordinates for each view (superior/inferior and medial/lateral in the AP view; medial/lateral and anterior/posterior in the axillary view). The position of the head center in relation to the origins of these coordinate systems was measured (Fig. 2). Head center positions medial, posterior, or inferior to the origin of the coordinate system were given a negative sign; head center positions lateral, anterior, or superior to the origin of the coordinate system were given a positive sign.

For each shoulder and for each AP and axillary view, the medial/lateral head center position was plotted as a function of time after surgery. The slope of this line indicated the rate of lateral or medial change in position of the humeral head; this slope was determined using the trend line function of Excel (Microsoft Inc, Redmond, Wash) in a manner analogous to the method of McCalden et al.[28] A positive slope indicates a trend of lateral movement of the head center away from the scapula. A negative slope indicates a trend of medial movement of the head center towards the scapula.

Study group

To demonstrate the application and the reproducibility of this method, we chose shoulders that had undergone humeral hemiarthroplasty but did not have a metallic reference (such as a metal-backed glenoid component) on the scapular side of the articulation. We recognized that previous studies of metal-backed glenoids or glenoids with embedded metal markers may not be applicable to shoulders without these markers. The study population consisted of 14 shoulders that had (1) a humeral hemiarthroplasty with concentric glenoid reaming between 2001 and 2007,[9] (2) a minimum of 2 years of radiographic follow-up, and (3) at least 3 sets standardized AP and axillary radiographs available for review between 6 weeks after surgery and the final follow-up. The immediate postoperative films were not used because of the possibility that effects of anesthesia, analgesics, muscle tone, and presence of blood within the joint could not be standardized. Thus, we followed the precedent of McCalden,[28] "a six week postoperative radiograph as well as one made at a minimum of two years postoperatively were deemed necessary for inclusion." Fourteen shoulders met our inclusion criteria. The age, gender, and duration of follow-up for these shoulders are reported in Table I. The diagnosis in all shoulders was primary or secondary degenerative joint disease; no patients with inflammatory arthritis were included. All shoulders had intact rotator cuffs.

Although previously published studies of medial wear have included measurements by only 1 observer, we wished to assess the consistency between an inexperienced examiner (a junior resident relatively new to the measurement method), examiner 1, and an experienced examiner (a faculty member specialist in shoulder surgery with substantial experience in the measurement of the head center position), examiner 2. The 2 sets of data were analyzed independently. The examiners were blinded to the time between the surgery and the follow-up radiographs.

Statistical analysis

The slopes were determined by linear regression.

Results

The average follow-up was 3.4 ± 1.1 years. Typical results are shown in Fig. 3 and summarized in Table I. The slopes of the head center position in the AP view were 0.0 ± 0.4 mm/y for examiner 1 and 0.2 ± 0.5 mm/y for examiner 2.

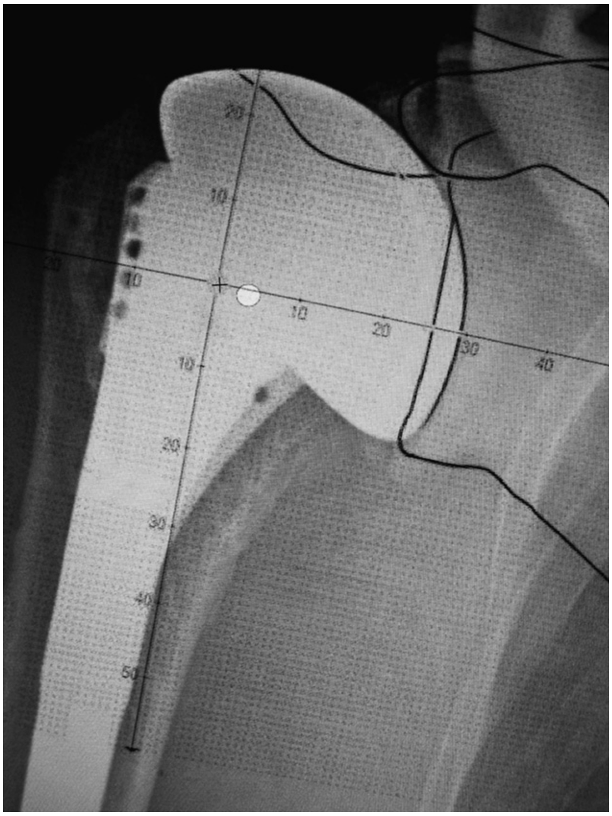

Figure 2 The transparent anteroposterior (AP) template is superimposed on the radiographic image of an AP view of the shoulder so that the outline of the scapula on the template *(dark lines)* corresponds to the scapular outline on the radiograph. This superimposition orients a coordinate system to the scapular anatomy, the center of which is indicated by the *X*. The center of curvature the humeral head prosthesis *(white dot)* is the center of a circle fit to the articular surface of the prosthesis. The medial/lateral position of the head center relative to the scapular coordinate system is measured on the horizontal axis.

The average difference in these measurements by the two examiners was 0.2 ± 0.6 mm/y. The slopes of the head center position in the axillary view averaged −0.3 ± 0.6 mm/y for examiner 1 and 0.1 ± 0.7 mm/y for examiner 2. The average difference in these measurements by the 2 examiners was 0.4 ± 0.6 mm/y. In both views and for both examiners, some shoulders showed lateral movement of the head center over time, whereas others showed medial migration. In none of these shoulders was anterior or posterior luxation observed on the axillary radiographs, nor was any radiographic evidence noted of anterior/posterior wear or superior/inferior wear. Therefore, only medial/lateral position change was included in the analysis.

Discussion

We have described a simple, practical, and reproducible radiographic method for documenting the rate of change of the position of the humeral head in relation to the scapula after shoulder arthroplasty. This method uses plain radiographs rather than computed tomography scans or magnetic resonance images that may have difficulties related to the presence of a metal humeral prosthesis. The described method did not require metal landmarks on the scapula, such as metal backing, metal markers within glenoid components, or stereophotogrammetric markers placed with the bone.

Documentation of wear rates is important because it provides a method for (1) defining changes in the arthroplasty before they become advanced to the point where remedial action may be no longer possible, (2) correlating wear with clinical outcome, and (3) comparing wear rates among different techniques of shoulder arthroplasty, for example, total shoulder vs interpositional arthroplasty vs hemiarthroplasty without interposition.

As is the case for hip arthroplasty, the concave side of shoulder arthroplasty provides one of the greatest challenges in prosthetic reconstruction, whether the reconstruction involves a hemiarthroplasty, a total shoulder arthroplasty, or a hemiarthroplasty with soft tissue interposition.[24] Glenoid bone wear has been observed after humeral hemiarthroplasty alone.[9,27,45] Sperling et al[38,39] noted erosion of the glenoid in 68% of hemiarthroplasties. Hasan et al[18] found substantial glenoid erosion in 42% of shoulders with a failed hemiarthroplasty. In their study on glenoid wear after shoulder hemiarthroplasty, Parsons et al[34] found progressive glenoid wear in all 8 patients. Although wear of glenoid polyethylene after total shoulder arthroplasty occurs and is of clinical concern,[4,6,17,19,20,32,33,36,37,40,41,43,47] the rate of wear in vivo has yet to be determined.

Wirth[45] noted medial humeral head migration after humeral hemiarthroplasty with a meniscal allograft. Elhassan et al[13] reviewed soft-tissue resurfacing of the glenoid in the treatment of glenohumeral arthritis in 13 active patients aged younger than 50 years. Radiographic evaluation at the time of revision surgery in 10 patients demonstrated loss of joint space and glenoid erosion in all cases. Krishnan et al[22] reported an average of 7 mm of glenoid erosion in humeral hemiarthroplasty with biologic resurfacing of the glenoid for glenohumeral arthritis. Lee et al[23] described cementless surface replacement arthroplasty of the shoulder with biologic resurfacing of the glenoid and found moderate to severe glenoid erosion in 56% of the shoulders. Uncertainty regarding the management of the glenoid side of the articulation led to the recent statement, "The most appropriate treatment for advanced glenohumeral osteoarthritis remains controversial."[35]

A literature review indicates that although medial erosion has been commonly observed after all types of shoulder arthroplasty, a quantitative, practical, and reproducible method for measuring the amount and rate of this erosion has yet to be described. This article presents such a method and applies it to shoulders undergoing humeral

Table I Age, gender, years of follow-up, and slopes of change in head center position relative to the scapula for 14 shoulders that underwent humeral hemiarthroplasty and concentric glenoid reaming*

Pt	Age	Sex	Years F/U	AP slope†			Ax slope†		
				Ex 1	Ex 2	Diff	Ex 1	Ex 2	Diff
1	57.8	M	4.5	0.3	−0.1	0.4	0.4	−0.1	0.5
2	67.7	M	2.3	0.2	−0.3	0.5	−1.7	−1.0	−0.7
3	60.5	F	4.5	0.3	0.5	−0.2	−0.7	−0.2	−0.5
4	59.1	M	3.5	0.4	0.0	0.4	−0.3	−0.3	0.0
5	59.3	M	5.8	0.2	0.1	0.1	−0.2	−0.6	0.4
6	63.2	M	3.3	0.3	0.9	−0.6	0.4	0.5	−0.1
7	58.6	F	2.4	−0.6	−0.1	−0.5	0.3	1.0	−0.7
8	63.1	M	2.0	−1.1	0.3	−1.4	−1.5	−0.4	−1.1
9	52	M	2.0	0.2	0.3	−0.1	−0.7	0.0	−0.7
10	55.7	M	2.8	0.4	1.6	−1.2	0.0	1.4	−1.4
11	54.3	M	3.7	0.1	0.4	−0.3	−0.6	−0.1	−0.5
12	55.5	M	3.0	−0.3	−0.3	0.0	−0.2	−0.4	0.2
13	59.4	M	4.5	0.2	0.2	0.0	0.2	1.5	−1.3
14	54	M	2.8	−0.1	0.0	−0.1	−0.5	−0.2	−0.3
Avg	58.6		3.4	0.0	0.2	−0.2	−0.3	0.1	−0.4
SD	4.2		1.1	0.4	0.5	0.6	0.6	0.7	0.6

AP, Anteroposterior; *Ax,* axiliary; *Diff,* difference; *Ex,* examiner; *F,* female; *M,* male; *SD,* standard deviation.

* Included are the results from 2 examiners (Ex 1 and Ex 2), and the differences in their measurements are shown.

† The negative slopes indicate movement of the humeral head center toward the scapula, and positive slopes indicate movement away from the scapula.

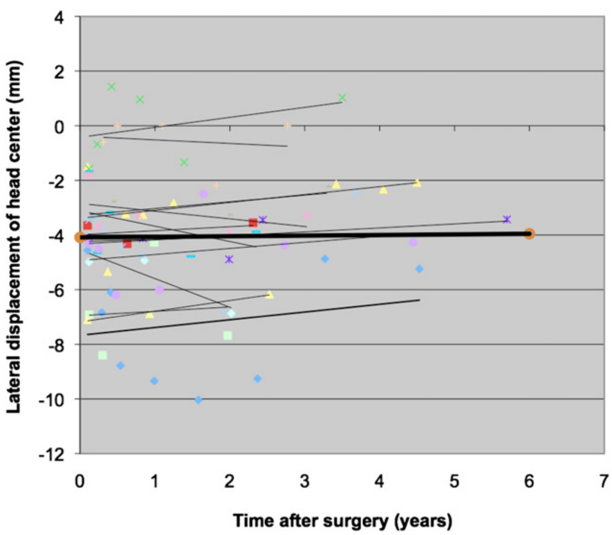

Figure 3 Trend in medial/lateral displacement on the anteroposterior projection for 14 shoulders that underwent humeral hemiarthroplasty and concentric glenoid remaining as determined by examiner 1. Each data point represents the position of the humeral head center in relation to the origin of the scapular coordinates at a point in time after humeral hemiarthroplasty with nonprosthetic glenoid arthroplasty. The *fine lines* indicate the trend lines for each patient. The *dark line* represents the trendline for all data points ($y = 0.0x - 4.1$). Positive slopes represent lateral movement of the humeral head with respect to the scapula. Similar plots were created for the axillary projection for examiner 1, and for the anteroposterior and axillary projections for examiner 2.

hemiarthroplasty with concentric glenoid reaming. The method presented here is simple in concept and practical in application. A coordinate system is oriented to the scapula on plain radiographs scaled to a common size. The position of the center of the humeral head is measured in relation to the origin of this coordinate system. The results obtained using this system were consistent between 2 examiners, even though the 2 examiners differed in terms of their experience with the method.

It is of note that some of the shoulders demonstrated lateral movement of the humeral head with respect to the scapula over time rather than medial wear. This finding was associated with the development of a radiolucent space between the glenoid bone and the humeral prosthesis. This space may represent the development and growth of a fibrocartilaginous surface as was identified in our laboratory study of this procedure.[25]

These data from the sample set of shoulders should be viewed in light of limitations in that they were included primarily to demonstrate the application and the reproducibility of the method. These cases were confined to the experience of an individual surgeon. The length of follow-up was insufficient to determine whether the position of the humeral head stabilized over time or continued to slowly drift medially or laterally. These shoulders did not constitute a consecutive case series—many of the shoulders undergoing this procedure could not be included because they had an insufficient number of acceptable postoperative radiographs. There was no control group or gold standard for comparison. Despite these limitations, we observed that these shoulders undergoing humeral arthroplasty with concentric glenoid reaming were relatively free of medial glenoid erosion at 2 or more years after the procedure.

Conclusions

A practical and reproducible method for quantifying the rate of migration of the humeral head in relation to the scapula after shoulder arthroplasty has been presented and applied to a group of shoulders with humeral hemiarthroplasty and concentrically reamed glenoid bone.

Disclaimer

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