Can Ulnar Variance Be Used to Detect Overstuffing After Radial Head Arthroplasty?

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Received: 21 May 2013 / Accepted: 29 August 2013 / Published online: 13 September 2013
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Abstract

Background Overstuffing of the radiocapitellar joint during metallic radial head arthroplasty has been reported to cause loss of elbow flexion, capitellar erosion, and early-onset osteoarthritis. Although this is known, there is no agreed-on measurement approach to determine whether overstuffing has occurred.

Questions/purposes We therefore hypothesized that overlengthening the radial head during radial head arthroplasty changes the ulnar variance in the wrist.

Methods Seven cadaveric radii were implanted with radial head prostheses of increasing thickness. Each specimen was implanted successively with increasingly thick radial head prostheses measuring 2, 4, and 6 mm thicker

than the native radial head, and radiographs were taken after implantation of each prosthesis. The ulnar variance with each prosthesis was measured using the method of perpendiculars.

Results The ulnar variance of the native and 2-mm ($p = 0.04$), 4-mm ($p = 0.008$), and 6-mm ($p = 0.008$) overly thick radial head prosthesis-implanted states decreased significantly with each incremental increase in prosthetic head thickness.

Conclusions Implantation of thicker radial head prostheses decreased the ulnar variance. Our results indicate ulnar variance could be used to detect overstuffing of radial head prostheses.

Clinical Relevance The simplicity and reliability of ulnar variance make it a potentially useful indicator of overlengthening after radial head arthroplasty.

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Introduction

In metallic radial head arthroplasty, the insertion of an overly thick prosthesis leads to overstuffing of the radiocapitellar joint and has been reported to cause loss of elbow flexion, capitellar erosion, and early-onset osteoarthritis [2]. Despite the known importance of maintaining radial length, overstuffing of the radial head prosthesis after radial head arthroplasty remains an important concern. Several radiographic methods for avoiding overstuffing have been described [1, 5, 15]. However, recent studies have found these previously described methods to be inadequate for identifying overlengthening of the radial head prosthesis [9, 10]. Furthermore, most of these methods rely on measuring the relationship between the radial head and proximal ulna, the latter of which is frequently fractured and thus difficult to use as a landmark [1, 5, 15].

The ulnar variance, or relative positions of the distal radius and ulna, has been used to assess the radioulnar relationship in the wrist [4, 12]. This parameter has been used not only for evaluation of wrist diseases such as Kienbock's disease, but also in surgical procedures to correct radial length. This prompted us to hypothesize that overlengthening the radial head may change the ulnar variance in the wrist and that this change could be used to assess radial head and neck height after radial head arthroplasty.

We therefore sought to determine whether overlengthening the radial head during radial head arthroplasty changes the ulnar variance in the wrist and whether decrease of ulnar variance correlates with the amount of overlengthening (2, 4, and 6 mm).

Materials and Methods

Seven fresh-frozen cadaveric upper extremities were used. No specimen showed evidence of macroscopic or radiographic pathology. All specimens were thawed overnight at room temperature. Their stability and ROM at the elbow and wrist were confirmed to be within normal limits. All specimens were considered stable and normal ROM when the passive flexion extension arc was more than 130°. Valgus and varus stress test under fluoroscopy was performed and considered stable when there was not excessive joint line opening. The arms were transected at the shoulder girdle with the elbow, wrist, and hand left intact. Before the surgical procedures, forearm AP radiographs including the elbow and wrist were taken in a position of full supination. These images provided the diameter of the radial head and medullary canal of each specimen for determination of the appropriate size for the radial head prosthesis. The radial head prosthesis used in this study was a cementless straight prosthesis (EVOLVE® Proline RH System; Wright Medical Technology, Inc, Arlington, TN, USA). This prosthesis is a modular implant design with head sizes ranging from 18 to 28 mm in diameter and stem sizes ranging from 4.5 to 9.5 mm in diameter. The system has three head heights (standard, +2 mm, and +4 mm) and three stem collar heights (standard, +2 mm, and +4 mm) to enable precise replication of the articulation of the native radial head with the proximal radioulnar joint. The 6-mm thick implant was built up using a 4-mm head and a 2-mm collar.

The humerus was fixed to a mount that allowed forearm motion. The radial head was approached through the standard Kocher interval (between the anconeus and extensor carpi ulnaris) with care not to damage the lateral ulnar collateral ligament (Fig. 1). The size of the implant was determined by measuring the diameters of the native radial head in situ with calipers, and then a thickness of the native radial head equal to the thickness of the implant was

Fig. 1 The Kocher approach allows access to the radial head, neck, and lateral collateral ligament.

resected with a microsagittal saw. When the maximum and minimum diameters of the native radial head differed, the minimum diameter was selected as per the manufacturer's protocol. The radial canal was reamed and prepared as per the manufacturer's technique manual, and an implant with an equal thickness and optimal diameter was inserted first. Then, the equal-thickness implant was subsequently replaced with implants 2, 4, and 6 mm thicker than the equal-thickness implant (Fig. 2).

The intact specimens were mounted on an x-ray tube, and standard AP radiographs of the forearm including the elbow and wrist were taken with the elbow in full extension and full supination. Additional radiographs were acquired after implantation of the equal thickness and 2-, 4-, and 6-mm overly thick prostheses. All radiographs were taken with the specimen in an unloaded state, and the x-ray beam was oriented perpendicular to the forearm. Each specimen was successively implanted with radial head prostheses of increasing thickness, and radiographs were taken after each insertion (Fig. 3).

The measurements were made from the digital radiographs using imaging software (PiViewSTAR™; INFINITT Software, Phillipsburg, NJ, USA). All radiographs were anonymized and randomized before measurement, and all were viewed on the same monitor (20-inch Dell LCD monitor; Dell, Round Rock, TX, USA) at a resolution of 1200 × 1600 pixels. The images were viewed in full-screen mode and zoomed to a magnification of approximately × 1.5 for ease of measurement. All measurements were performed by all observers at the same level of magnification. The observers used the software's set square tool to measure the distance between the top of the radial head and any given point to the nearest 0.1 mm.

The ulnar variance was measured using the "method of perpendiculars" [3]. A line perpendicular to the long axis

Fig. 2A–D A photograph shows (A) 0-, (B) 2-, (C) 4-, and (D) 6-mm thicker radial head implants, which assemble with 2-mm collars and 4-mm heads.

Fig. 3A–E An AP radiograph of (A) the native radial head; (B) after implantation with an equal-thickness prosthesis; and after (C) 2, (D) 4, and (E) 6 mm of overlengthening demonstrate decreasing ulnar variance.

of the radius was drawn through the distal ulnar aspect of the radius. Another line was drawn along the dorsal cortical rim of the ulna. The distance between these two lines was measured as the ulnar variance (Fig. 4). Ulnar variance is positive if the ulnar articular surface is distal to radial and negative if the ulnar articular surface is proximal to radial. The ulnar variance was assessed twice by two observers (J-HH, NB) to assess the inter- and intraobserver reliabilities of the measurement. Intraclass correlation coefficients were calculated for the radiographic measurement of ulnar variance by the two observers. The intraclass correlation coefficients were graded subjectively as described by Shrout and Fleiss [11], ie, a coefficient greater than 0.75 was considered excellent. The intraclass correlation coefficients demonstrated excellent intraobserver and interobserver reliability for measurement of ulnar variance. The interobserver reliability was 0.917 and the intraobserver reliability coefficients for the two observers were 0.964 and 0.967. The mean ulnar variance of the two measurements was used in the final analysis.

Statistical analyses were performed using MedCalc for Windows[®] (Version 12.5; MedCalc Software, Ostend, Belgium). The mean of the ulnar variance measurements

Fig. 4 The ulnar variance was measured using the method of perpendiculars. A line (L-U1) perpendicular to the long axis of the radius (L-R) was drawn through the distal ulnar aspect of the radius. Another line (L-U2) was drawn along the dorsal cortical rim of the ulna. The distance between these two lines was measured as the ulnar variance (UV).

by the two observers was used in the final analysis. For analysis of data, ulnar variances of each radial length were compared using one-way repeated-measures analysis of variance with length as a factor and a *p* value of < 0.05 considered significant. Significant main effects were then further analyzed using pairwise comparison tests.

Results

The mean ulnar variance with the native radial head was 0.5 mm (range, −0.9 to 2.6 mm). The mean ulnar variance was 0.1 mm (range, −1.4 to 1.4 mm) in the specimens with equal thickness, −0.5 mm (range, −1.9 to 1.4 mm) in the specimens overlengthened by 2 mm, −1.3 mm (range, −2.2 to 0.0 mm) in the specimens overlengthened by 4 mm, and −2.0 mm (range, −0.1 to −3.6 mm) in the specimens overlengthened by 6 mm.

The mean ulnar variance of the equal-thickness prosthesis was not different from that of native radial heads ($p = 0.96$). However, mean ulnar variance decreased in specimens with 2 ($p = 0.04$), 4 ($p = 0.008$), and 6 mm ($p = 0.008$) of overlengthening (Table 1). The multiple pairwise comparisons analysis showed significant differences among all of the incrementally thicker prosthetic heads used (Fig. 5).

Discussion

Radial head arthroplasty is the accepted treatment for nonunion and unreconstructable fractures of the radial head. Close replication of the native radial head dimensions by the inserted prosthesis is required for the restoration of near-normal stability and kinematics of the affected elbow [6, 8, 13]. The insertion of an incorrectly sized prosthesis is associated with instability, maltracking, and early degeneration of the joint. In an experimental study, Van Glabbeek et al. [14] demonstrated the importance of restoration of the radial head and neck height to within 2.5 mm of its original length. The use of an overly thick prosthesis may lead to lengthening of the radius and thus overstuffing of the joint, which may necessitate revision surgery. The presence of associated ligament injuries decreases the reliability of using soft tissue tension and stability to assess the implant length and increases the risk for inserting an overly thick prosthesis and overstuffing the joint. Despite the known adverse effects and reported outcomes, no well-defined criteria for addressing overstuffing have been described.

This study is limited by its small number of specimens and use of a cadaver model. There was an inherent difference in ulnar variance. This variability in specimens is presumably the result of differences in ulnar variance in overlengthened conditions. Another limitation is that we did not simulate the various soft tissue injuries that accompany radial fractures requiring arthroplasty. However, by maintaining the elbow in a stable position, we were able to demonstrate the effects of overlengthening on ulnar variance as they would occur in the clinical scenario of a radial head prosthesis with repaired ligaments.

Our results show that progressively increasing the radial head prosthesis thickness changes the ulnar variance at the wrist. The native radial head can be used as a reliable template, but its use is limited in cases of revision, grossly comminuted radial head fractures, and nonunion. Therefore, other methods to facilitate insertion of the correct-sized implant based on identification of local anatomic landmarks have been reported. Doornberg et al. [5] studied CT scans and recommended that the radial head should be on average 0.9 mm proximal to the lateral edge of the coronoid. The use

Fig. 5 A graph shows decreased mean ulnar variance with increases in the thickness of radial head prosthesis. Lowercase letters indicate the results of testing. Bars with the same letters are not statistically different. The error bars indicate the 95% CIs.

Table 1. The differences of the ulnar variance values with the 0-, 2-, 4-, and 6-mm overly thick radial head prostheses from that in the native state

Ulnar variance value	Difference in ulnar variance (mm)		p value	95% confidence interval
	Mean	Standard error		
Native–0 mm	0.32	0.16	0.96	−0.384–1.030
Native–2 mm	0.95	0.21	0.04	0.039–1.859
Native–4 mm	1.75	0.28	0.008	0.534–2.957
Native–6 mm	2.47	0.40	0.008	0.740–4.197

of this measurement is limited by its great variability from one patient to another; furthermore, that study did not take into account the thickness of the articular cartilage when establishing the relationship between the radial head and lateral coronoid. A cadaveric study by van Riet et al. [15] reported the proximal edge of the lesser sigmoid notch to be a reliable landmark for assessing radial length only in cases of isolated comminuted fracture of the radius. Rowland et al. [9] demonstrated divergent lateral ulnohumeral space in up to one-third of normal elbow radiographs, indicating that this measure is of limited use for assessing radial length. Fluoroscopic analysis of the medial ulnohumeral joint was found in two different studies to be insensitive for detecting overlengthening of less than 6 mm [1, 10]. The critical value of 2.5 mm for the restoration of radial length limits the clinical application of changes in the medial ulnohumeral joint as an indicator of overstuffing. Moon et al. [7] described the use of a simple overlay device to use the bicipital tuberosity as a reliable landmark for assessing overlengthening. This method is simple and easy to use, but its applicability in the clinical setting has yet to be established. Therefore, although several studies to date have focused on intraoperative assessment of radial overstuffing, few reliable postoperative radiographic parameters have been identified.

The ulnar variance is a common radiographic parameter with which most orthopaedic surgeons are familiar, but to our knowledge, its use as a diagnostic tool to assess intraoperative and postoperative changes in radial length has not been previously described. Ulnar variance describes the length of the ulna relative to the radius [4]. In the present study, the ulnar variance was assessed by the method of perpendiculars, which is a simple and reproducible method with good inter- and intraobserver reliability [12]. The interclass correlation coefficients demonstrated excellent interobserver and intraobserver reliability in our study. In conclusion, our study showed that increasing the thickness of the radial head process decreased the ulnar variance. Our results indicate that the ulnar variance can be used to detect overstuffing of radial head prostheses. However, there was variability in this measurement, presumably the result of differences in the size of the cadaver elbows tested. The simplicity and reliability of measurement of ulnar variance make it a potentially useful indicator of overlengthening after radial head arthroplasty. There are some further issues that require additional consideration before this technique

can be applied in the clinical setting. The effects of underlengthening of radial head prostheses on ulnar variance could be considered in a future study.

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