Analysis of Radial Head Implant Length with Use of Contralateral Elbow Radiographs

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Introduction

This article describes a technique in which measurements are obtained from radiographs of the contralateral, normal elbow to predict the magnitude of overlengthening resulting from use of a metallic radial head prosthesis.

Clinical studies have demonstrated that radial head arthroplasty is safe and effective in restoring stability in the setting of comminuted unreconstructable radial head fractures associated with instability. Biomechanical studies have shown that insertion of a correctly sized metallic radial head implant can reliably restore elbow and forearm kinematics and stability to nearly normal levels¹⁻³. A primary technical goal during radial head arthroplasty is placement of an implant that closely replicates the dimensions of the native radial head. Insertion of an implant that is too thick, which lengthens the radius axially or “overstuffs” the radiocapitellar joint, has been associated with pain, loss of elbow motion, capitellar articular cartilage erosions, and posttraumatic arthritis⁴⁻⁶.

Several intraoperative landmarks have been identified to assist surgeons in selecting an implant of correct length⁷⁻⁹. Knowledge of these guidelines is especially important when the radial head is highly comminuted and cannot be used to approximate implant size, or in revision situations where the native radial head is absent. Despite the known importance of correct radial head implant length, insertion of an incorrectly sized prosthesis is not uncommon¹⁰. A postoperative radiographic method to diagnose and to determine the magnitude of overlengthening is an important diagnostic tool when a patient has persistent pain or stiffness following a radial head arthroplasty.

A radiographic technique was developed and validated to calculate the length of a radial head implant with use of radiographs of the contralateral, normal elbow. The technique is based on a previous cadaveric study by Frank et al.⁸ on radial head im-

plant overlengthening, which demonstrated that thicker implants resulted in increasing varus angulation of the elbow with hinging open of the lateral ulnohumeral joint (Fig. 1). The technique utilizes measurements obtained from radiographs of the contralateral, normal elbow to predict the magnitude of overlengthening resulting from the radial head implant. The technique requires bilateral standardized anteroposterior elbow radiographs. The radiograph of the contralateral, normal elbow is used as a surrogate to calculate the virtual length of the native radial head. A radiograph of the radial head prosthesis is used to calculate the virtual length of the implant, from which the virtual length of the native radial head is subtracted to obtain the magnitude of implant overlengthening.

The technique consists of four major steps:

- Step 1: Obtain bilateral elbow radiographs
- Step 2: Perform radiographic measurements of the contralateral, normal elbow
- Step 3: Perform radiographic measurements of the radial head implant
- Step 4: Calculate radial head implant length

Step 1: Obtain Bilateral Elbow Radiographs

- Obtain bilateral digital anteroposterior radiographs of the elbows that are orthogonal to the forearm in 45° of flexion and neutral forearm rotation. This position for the radiographs is used as it should be attainable by most patients after radial head arthroplasty, since some flexion contracture and rotational motion loss is not uncommon.
- View the radiographs on any commercially available picture archiving and communication system (PACS), where measurements and angles can be annotated.

Step 2: Perform Radiographic Measurements of the Contralateral, Normal Elbow

Draw the angle on the radiograph of the normal elbow.

- Mark the osseous lateral edge of the lateral ulnohumeral joint on both the humerus (*h*) and the ulna (*u*) (Fig. 2-A).
- Create an angle with an apex starting at the most medial aspect of the coronoid on the anteroposterior radiograph, bisecting the points *h* and *u* (Fig. 2-B).
- Draw a line in the coronal plane that bisects the native radial head in half. This line starts at a point in the center of the radial neck (*cRN*) and bisects a point at the center of the radial head (*cRH*) (Fig. 2-C).
- The portion of this line that lies between the limbs of the angle is the virtual length of the native radial head (*L-NRH*).

Step 3: Perform Radiographic Measurements of the Radial Head Implant

Draw the same lines and angle and perform the same measurements on the implant radiograph.

- Mark the points *h* and *u* on the lateral aspect of the lateral ulnohumeral joint (Fig. 2-D).
- An angle is created with its apex at the most medial edge of the coronoid process.
- Draw a line that bisects the radial head implant in half. This line starts at the distal center point of the radial implant stem (*cRS*) and bisects a point at the center of the radial head implant (*cRHI*).
- The portion of this line that lies between the limbs of the angle is the virtual length of the radial head implant (*L-RHI*).

Step 4: Calculate Radial Head Implant Length

The virtual length of the native radial head implant (*L-NRH*) is subtracted from the virtual length of the radial head implant (*L-RHI*), which results in the magnitude of the radial head implant overlengthening in millimeters: $(L-RHI) - (L-NRH) = \text{overlengthening}$.

Results

The radiographic measurement technique was validated in a cadaveric study¹¹. Eight fresh-frozen human cadaveric upper extremities (four pairs) were tested under simulated loading of the biceps, triceps, and brachialis muscles. Each specimen was mounted on a custom radiolucent rig to control elbow flexion/extension and forearm rotation. A radial head prosthesis with a correct length and those overlengthened by 2, 4, 6, and 8 mm were then implanted.

After implantation of the radial head prosthesis, anteroposterior radiographs relative to the forearm were obtained of the elbow in 45° of flexion, with neutral forearm rotation. Radiographs were obtained of the native elbow, with an implant of correct length, and with implants resulting in 2, 4, 6, and 8 mm of overlengthening. For the eight specimens, a total of forty-eight radiographs were made; these consisted of eight native specimen radiographs and forty implant radiographs (eight for each the five testing conditions [correct length implant and implants resulting in 2, 4, 6, and 8 mm of overlengthening]). The forty implant radiographs with varying degrees of overlengthening and their corresponding radiographs of the contralateral, normal elbow were blinded, and the testing formula was applied to calculate the magnitude of overlengthening. Examiner 1 tested the set of forty implant radiographs twice (eighty observations) and examiner 2 tested the set once (forty observations), for a total of 120 observations.

The radiographic measurement method was successful in calculating the magnitude of radial head implant overlengthening within ± 1 mm in 104 (87%) of the 120 radial head implant scenarios tested. The method was effective in calculating the implant size within ± 2 mm in all radial head implant scenarios tested. The overall diagnostic accuracy of the test to correctly identify overlengthening, when it was present, within 1 mm, was excellent. The ability of the test to precisely calculate the magnitude of overlengthening was 92% when the overlengthening was set at 2 mm ($n = 24$), 96% when it was 4 mm ($n = 24$), 87% when it was 6 mm ($n = 24$), and 54% when it was 8 mm ($n = 24$).

What to Watch For

Indications

- A patient who has pain, restricted elbow and forearm motion, or wear of the capitellar articular cartilage after metallic radial head arthroplasty.

- Anteroposterior radiographs demonstrating increased varus angulation, compared with preoperative or contralateral normal radiographs, after metallic radial head arthroplasty.
- Anteroposterior radiographs demonstrating excessive gapping open of the lateral ulnohumeral joint or medial subluxation of the joint after metallic radial head arthroplasty.

Contraindications

- Pre-existing deformity in the elbow that underwent metallic radial head arthroplasty. The results obtained in the cadaveric study were based on specimens without pre-existing disease or deformity; therefore, they may not apply to patients with congenital, developmental, or degenerative elbow conditions.
- Patients with abnormal radiographic findings in the contralateral elbow. The described measurement technique is premised on measurements obtained from radiographs of a contralateral normal elbow; therefore, pre-existing disease or deformity may result in incorrect calculations and findings.

Pitfalls & Challenges

- An undersized radial head implant. The described technique cannot be used to deter-

mine if a radial head implant is of insufficient length.

- Interosseous membrane injury. This technique depends on an intact interosseous membrane. Injury to the interosseous membrane will likely lead to incorrect calculations.

Clinical Comments

Overlengthening of a radial head implant can be prevented by appropriate surgical technique. Several intraoperative landmarks exist to assist with correct implant length determination. Doornberg et al.⁷ and van Riet et al.⁹ described referencing the radial head implant to the proximal edge of the lesser sigmoid notch, 2 mm distal to the tip of the coronoid. Frank et al.⁸ diagnosed implant overlengthening by identifying a visible gapping open of the lateral ulnohumeral joint. What intraoperative measures have you found useful in the prevention of radial head implant overlengthening?

Radial head implant overlengthening has been associated with capitellar articular cartilage erosions, pain, and restricted elbow and forearm motion. What has been the primary symptom of patients in whom you have performed revision due to implant overlengthening?

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Figures

Fig. 1

An anteroposterior radiograph of an incorrectly sized metallic radial head implant inserted into a cadaveric specimen. The implant is overlengthened by 6 mm, leading to excessive gapping of the lateral ulnohumeral facet.

Fig. 2-A

Fig. 2-B

Fig. 2-C

Fig. 2-D

Figs. 2-A through 2-D The measurement technique to estimate radial head implant length is based on comparing the radiograph of the contralateral, normal elbow with the radiograph of the radial head implant. The virtual length of the native radial head (*L-NRH*) is calculated on the anteroposterior radiograph of the contralateral, normal elbow (**Figs. 2-A, 2-B, and 2-C**). The same method is used to determine the virtual length of the radial head implant (*L-RHI*) (**Fig. 2-D**). Then, to calculate the magnitude of overlengthening, the *L-NRH* is subtracted from *L-RHI*.

Fig. 1

Fig. 2-A Fig. 2-B

Fig. 2-C Fig. 2-D