Inter and Intra-Rater Reliability of Using Computed Tomography to Assess Prosthesis Position Post Shoulder Arthroplasty

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Abstract

**Background:** Computer models and cadaveric studies have demonstrated that humeral version has a significant impact on the impingement, stability, and range of motion of the prosthetic shoulder joint. Computed tomography (CT) has been used to measure native humeral version, however the reliability of using CT to measure humeral version post reverse total shoulder replacement has not yet been established.

**Aims:** To investigate the inter and intra-rater reliability of using CT to assess the post-operative humeral version following shoulder arthroplasty.

**Methodology:** Patients underwent a limited CT scan of the operative limb; positioned and protocoled by one consultant radiologist on one machine. The humeral version of the prostheses was calculated individually by two experienced, board certified consultant radiologists. They were blinded to each other’s measurements. The humeral version was calculated using the epicondylar axis.

**Data:** Overall, 20 shoulders are included; 12 females (60%), and 10 left-sided (50%). The median anteversion was 0° (range 33° retroversion–27° anteversion; IQ 6.75° retroversion–4.75° anteversion). The inter-rater reliability was 0.985 (95% CI: 0.964–0.994). The intra-rater reliability for radiologist A was 0.988 (95% CI: 0.969–0.995), and the intra-rater reliability for radiologist B was 0.976 (95% CI: 0.942–0.991).

**Conclusion:** The use of post operative CT has excellent inter and intra-rater reliability in measuring humeral version following shoulder arthroplasty. This study will facilitate future research regarding impact of the humeral version on patient outcomes.

**Keywords**
Arthroplasty, computed tomography, humerus, shoulder, validation, version

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Introduction

The surgical techniques and implant designs for reverse total shoulder arthroplasty have progressed significantly in recent years. However, despite the increasing literature and information on shoulder arthroplasty, there remains debate regarding optimal implant position.

Native humeral version is varied and has been reported between 2° anteversion and 60° retroversion (mean 26° ± 11° retroversion). It is influenced by

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gender, hand dominance, overhead throwing activity and ethnicity.1–4

In reverse total shoulder arthroplasty, humeral version has been proved to have implications on prosthesis impingement and range of motion.5–9 Specifically, increased retroversion on the humeral prosthesis permits greater range of external rotation at the sacrifice of internal rotation. Furthermore 20–40 degrees of retroversion offers the greatest functional arc of movement5,7,9–11 and retroversion of 0 degrees leads to less impingement in functional activities of daily living.7,11

This prior research has used computer modelling or intended version at implantation in cadavers to estimate the humeral version without radiographic correlation. The use of computed tomography (CT) allows for accuracy in determining the humeral version in the native shoulder, by referencing the epicondylar axis2,12–15 This method however has not yet been utilised in determining the humeral version post reverse total shoulder replacement.

The intra-operative surgical technique for estimating humeral version during reverse shoulder arthroplasty involves referencing bony landmarks at the proximal humerus and/or an external jig aligned with the axis of the forearm. Individual variation in native version, degenerative joint disease, and the position of the forearm during humeral stem implantation limit the accuracy of this technique.

There is a paucity of information in the literature regarding techniques on achieving intended humeral version accurately, and how it may affect patient outcomes. As such, we designed this study to establish the inter and intra-rate reliability of using CT in measuring humeral prosthesis version following reverse total shoulder arthroplasty.

**Materials and Methods**

Patients with glenohumeral osteoarthritis who had undergone a reverse total shoulder replacement (Equinoxx; Exactech) by a single fellowship trained orthopaedic surgeon were consented to participate in this study at their post-operative review. All patients underwent an Equinox reverse total shoulder replacement. Intra-operatively the glenoid was navigated. The humerus was conventionally broached and the uncremented stem inserted at 10° of retroversion referencing the forearm axis with the elbow at 90 degrees. The arm was held in a hydraulic arm holder with the humerus vertical, adducted and the forearm externally rotated approximately 80 degrees.

All consenting subjects underwent a CT scan of their operative shoulder positioned and protocolled by one consultant radiologist on one machine using metal artefact reduction (GE Discovery 750 HD 1.25 mm slices).

The patients were positioned supine with their arm by their side, neutral glenohumeral rotation, elbow in slight flexion, and the forearm in supination. The scan included the reverse prosthesis as well as a limited series at the distal humerus to capture the epicondyles. Two images were overlayed to calculate the humeral version: one image showed the humerus capturing the tray at the tip of the stem proximally, and the other image showed the epicondyles distally (Figure 1).

Two experienced, accredited radiographers measured the humeral version at day 0 (SKD1 & DYD1) and day 14 (SKD14 & DYD14) post CT. The radiographers results were blinded. The day 0 results were also blinded at the conduction of the day 14 measurements.

Data was extracted into SPSS (version 24; IBM), and the interclass correlation coefficient was calculated using two-way random absolute agreement method of reliability analysis. Ethical approval was granted from The Human Research Ethics Committee of Joondalup Health Campus, reference number 1817.

**Results**

We recruited and scanned 20 shoulders in 19 patients, 12 female (60%), 10 left shoulders (50%), humeral version as seen in Figure 2. We calculated a median of 0° of anteverision and range between 33° retroversion to 27° anteverision (IQ 6.75° retroversion to 4.75° anteverision).

The median retroversion for males was 5.5° (range 33° retroversion – 23° anteverversion) and females the median retroversion was 1° (Range 11° retroversion to 27° anteverversion).

Inter-rater reliability analysis was conducted and determined the following:

Interclass correlation coefficient for SKD1 and DYD1 = 0.985 (95% CI: 0.964–0.994) and interclass
Intra-rater reliability analysis was conducted and determined the following:

Intraclass correlation coefficient for SKD1 and SKD14 = 0.988 (95% CI: 0.969–0.995) and Intraclass correlation coefficient for DYD1 and DYD14 = 0.976 (95% CI: 0.942–0.991).

Discussion

CT has been highly validated in measuring humeral version in the native shoulder. There are however limitations in using CT to measure humeral version including the identification of articular margins and the anatomic neck proximally, the variability of patient position in reference to the CT gantry, and the impact of anatomic deformity associated with degenerative joint disease.12–14

We adopted patient positioning and distal landmarks used by Cassagnaud et al to measure the humeral version of the reverse prosthesis. Proximally the widest point of the tray of the humeral prosthesis was used to define the humeral version.

Identification of both the bony and prosthetic landmarks were easily captured and identified by the radiologists. The procedure was well tolerated by all patients and no specific positioning devices or demanding postures were required. We hypothesized that the inter and intra-rater reliability of measuring humeral version on CT would be excellent.

Native humeral version is highly variable. It is well known that humeral version affects range of motion and stability post arthroplasty. However, it remains unclear if individual native/pathologic humeral version should be restored, as compared to setting a fixed version intra-operatively.16 In our cohort of patients, the humeral prosthesis was inserted at 10 degrees of retroversion, referencing the forearm axis. There was however a wide variability in the humeral version measured post-operatively on the CT.

The discrepancy between intended intra-operative humeral version actual achieved position of the humeral stem warrants further investigation as it can not be explained by our current study. There is a paucity of evidence in the published literature of measured humeral version post operatively because until now the much of the attention has been placed on accuracy of glenoid placement. Prior studies on humeral version have been based on the intra-operative assessment compared with the forearm axis, and did not include the use of post-operative CT scans.17

The implication of this variability is felt to be clinically significant given among 7 of the 20 patients (35%), the humeral version was more than 10° off the intended version. A shift of this magnitude changes the arc of movement and can lead to impingement in activities of daily living.4,6,7

The limitations of this study include our inability to explain the variability between intended and achieved...
humeral version. The number of patients included in this study is consistent with prior studies of inter and intra-rater reliability assessment\textsuperscript{2,12} but a prospective study with a larger sample size, pre-operative measurements, patient demographics, and post-operative outcomes would be beneficial. The use of CT involves exposure to ionising radiation which must be considered. Other imaging modalities such as MRI\textsuperscript{18} have been used to measure humeral version however cost and access are limitations. The use of three-dimensional CT reconstructions may be more favourable, however two dimensional CT scans have been well established in the literature in the use calculating humeral version.\textsuperscript{3,13,15}

**Conclusion**

The use of post operative CT for measuring humeral version in reverse total shoulder arthroplasty has excellent inter and intra-rater reliability. This study should facilitate future research into actual achieved version of the humeral prosthesis, and the implication this has on patient outcomes.

**Declaration of Conflicting Interests**

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

**Ethics**

The Human Research Ethics Committee of Joondalup Health Campus granted approval for this project: #1817.

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