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ORIGINAL ARTICLE

Determining glenoid component version after total shoulder arthroplasty

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Background: Glenoid component loosening after total shoulder arthroplasty (TSA) may occur if retroversion is not corrected to <10°. However, accurately measuring postoperative glenoid component version has been difficult without postoperative computed tomography (CT), adding cost and radiation exposure outside of the standard radiographic follow-up. We present a new method to assess glenoid component version after TSA using only routine preoperative CT and postoperative radiographs (x-rays).

Methods: Preoperative glenoid version was measured using established methods with an axillary x-ray, 2-dimensional CT, and Glenosys software (Imascap, Plouzané, France). Postoperative glenoid component version and inclination were measured for 61 TSA patients using Mimics software (Materialise, Leuven, Belgium) with preoperative CT and postoperative x-rays. Four patients also had postoperative CTs. Glenoid implantation and imaging were performed on 14 cadavers, allowing validation of results against the gold standard postoperative CT glenoid retroversion measurement.

Results: Compared with the gold standard, retroversion and inclination measurement error was 2° ± 1° and 2° ± 1°, respectively. Average postoperative version correction was 6° ± 7°, with 35 of 61 patients (57%) corrected to <10° of retroversion. Correlation between preoperative version measurement methods was good to very good, except on the axillary x-ray. Patients not corrected to <10° of retroversion had significantly higher preoperative retroversion (14° ± 6°) than those corrected to <10° (6° ± 7°; $P < .00001$).

Conclusions: Glenoid component retroversion after TSA can be accurately measured with a method using only routine preoperative CT and postoperative x-rays, validated to within 1.9° of the gold standard postoperative CT measurement. Future studies using this method may correlate glenoid retroversion correction with glenoid component longevity to help optimize shoulder arthroplasty outcomes.

Level of evidence: Level III; Diagnostic Study

Keywords: Glenoid; version; total shoulder arthroplasty; mimics; 3D model; retroversion; shoulder; replacement

Total shoulder arthroplasty (TSA) routinely has excellent outcomes with low revision rates.[7] When failure does occur, one of the most common reasons is glenoid loosening.[3,5,7-9,12,19] Although glenoid component failure as low as 0.2% has been reported,[7] short-term loosening rates have been reported between 10% and 15.5%.[1,20] Reasons for glenoid

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component loosening include preoperative retroversion, incomplete correction of retroversion,[12,32] eccentric component loading from rotator cuff tear or imbalance,[8,29] and other factors, including infection, poor cementation, or failure of bony integration. Patients with primary glenohumeral osteoarthritis may have increased glenoid retroversion beyond the normal range of 5° anteversion to 15° retroversion, and those with significant glenoid component retroversion may have inferior outcomes.[6,11,12,16,31]

In particular, cadaveric studies and finite element analyses have shown that glenoid component implantation in retroversion with eccentric humeral head loading can lead to uneven distribution of cement and bone stresses and to glenoid component loosening.[15,17,18,22,24,26-28] Moreover, Ho et al[12] showed that glenoid component retroversion of 15° or greater after TSA resulted in increased odds of osteolysis. Farron et al[6] likewise stated that "glenoid retroversion exceeding 10° should be corrected during total shoulder arthroplasty" to decrease loosening risk. In severe cases of retroversion, correcting to neutral version may not be possible. In a 3-dimensional (3D) simulation model, Nowak et al[21] demonstrated that glenoids with greater than 18° of retroversion could not be corrected to neutral without component peg penetration of the glenoid vault.

Although consensus among shoulder specialists may be that correcting excessive glenoid version during TSA is a surgical goal, precise measurement of postoperative glenoid component version itself has been challenging. Multiple studies have shown that measurements on radiographs (x-rays) and even computed tomography (CT) measurements can be unreliable preoperatively and postoperatively.[4,10,23,30]

Measurements on postoperative images are further affected by implant artifact. In addition, postoperative CT scans are outside the standard of care in the United States for an uncomplicated TSA postoperative course because they incur unnecessary cost and radiation exposure to the patient. Thus, much of the available literature regarding glenoid component version after TSA is inherently constrained by the ethical and practical limitations of available imaging.

One study that did use postoperative CT scans showed fair to moderate agreement between the postoperative x-ray and CT for humeral glenoid alignment in the superior-inferior plane and for glenoid version.[13] However, the results were influenced greatly by radiograph quality, with intraclass correlation coefficients ranging from 0.35 to 0.53, depending on the presence of acromioclavicular overlap or humeral rotation on imaging.

In this report, we present a new method of determining postoperative glenoid component retroversion by using routine preoperative CT scans and postoperative x-rays. This method allows for preoperative planning based on 3D CT models as well as determination of postoperative glenoid version without imaging outside the current standard of care. To our knowledge, this is the first study of this software application in total shoulder postoperative implant positioning. We hypothesize that coupling routine imaging with Mimics software (Materialise, Leuven, Belgium) is as accurate as a postoperative CT scan in determining glenoid component retroversion. Measuring postoperative glenoid component retroversion, and therefore determining how successful surgeons are in correcting excessive retroversion, will likely be an important step in understanding the factors that affect glenoid component longevity and loosening.

Materials and methods

Study cohort

This was a retrospective review of 61 patients (25 men and 36 women) who consecutively underwent primary TSA by 3 shoulder fellowship–trained surgeons at our institution. The average age at the time of surgery was 68.1 years (range, 40-87 years). Patients were included if they had a preoperative CT scan with slice thickness ranging from 0.625 to 3 mm and a minimum of 1 set of postoperative nonportable anteroposterior (AP) and axillary radiographs in our institution's Picture Archiving Communication System. A postoperative CT scan that was also performed in 4 of these patients to evaluate for rotator cuff tearing or lesser tuberosity osteotomy nonunion was used for validation of the method described in this study via comparison with the postoperative CT gold standard for glenoid component version measurement.

2D glenoid version measurement

Glenoid version was measured on an axillary x-ray (Fig. 1), as described by Nyffeler et al,[23] as well as on the midglenoid axial CT image and axial CT image just inferior to the coracoid. The midglenoid image was determined by counting the total number of

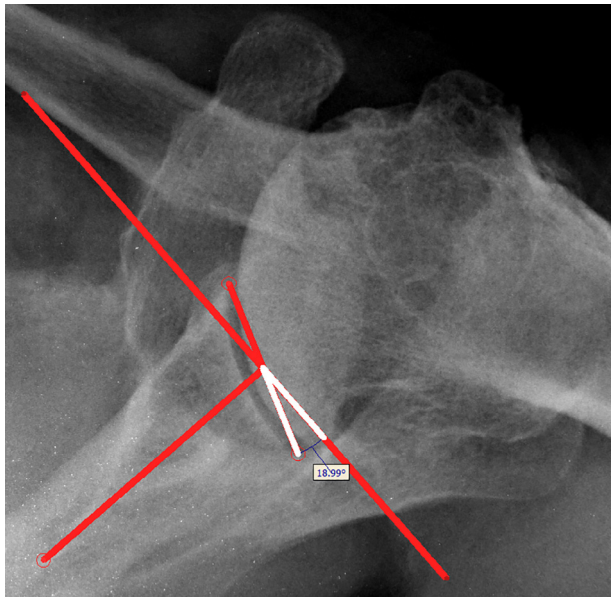

Figure 1 Preoperative glenoid retroversion (19°) measured on an axillary radiograph.