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ORIGINAL ARTICLE

Interdepartmental imaging protocol for clinically based three-dimensional computed tomography can provide accurate measurement of glenoid version

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Background: Conventional computed tomography (CT) is not accurate for glenoid version measurement. This study sought to examine the feasibility of an interdepartmental protocol implemented between orthopedic surgery and radiology departments for acquisition of anatomic axial CT images and to validate the glenoid version measured through such a protocol.

Materials and methods: Data of 30 conventional CT scans of 10 normal and 20 osteoarthritic glenoids were transferred to clinical 3-dimensional imaging software by a radiology technician trained for the study. The technician independently reoriented the scapulae to generate anatomic CT images. A separate team of orthopedic researchers used laboratory-based 3-dimensional reconstruction software (Mimics; Materialise, Leuven, Belgium) to generate anatomic axial images. Three independent examiners measured glenoid version on the conventional CT, reoriented anatomic CT, and Mimics images at the superior, middle, and inferior levels. Data were analyzed using the Mimics data as the "gold standard."

Results: Reoriented anatomic CT images generated by the technician resulted in almost identical version measurements to the Mimics images in both normal and arthritic glenoids. The conventional CT images had poor agreement with the Mimics images in normal glenoids but had good agreement in arthritic glenoids. Both normal and arthritic glenoids had increased retroversion superiorly ($P < .05$), and this phenomenon was significantly exaggerated on the conventional CT images ($P < .05$).

Conclusions: This study demonstrated that an interdepartmental protocol can produce reoriented anatomic axial CT images on which true glenoid version can be accurately measured. Such an institutional protocol would help surgeons accurately evaluate glenoid version preoperatively with reduced workload and expense.

The study was approved by Penn State College of Medicine Institutional Review Board: No. 00005535.

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Glenoid component loosening remains the most common cause of failure after total shoulder arthroplasty despite remarkable advances in implant material and design.[20,23] Preoperative factors related to glenoid morphology, such as excessive glenoid retroversion, eccentric glenoid wear, and posterior humeral head subluxation, are associated with an increased risk of glenoid loosening.[8,13,23] Therefore, accurate evaluation of glenoid morphology is a critical step during preoperative planning. Axillary radiographs are widely used as an initial tool for glenoid morphology in a clinical setting, and 2-dimensional (2D) computed tomography (CT) is often obtained for further evaluation if there is concerning glenoid morphology. However, conventional 2D CT has been shown to have poor accuracy, especially for glenoid version measurement.[2-5]

This problem stems from the fact that the axis of the CT gantry angle is aligned to the patient's body rather than to the plane of the scapula. In an anatomic position, the scapula is oriented 20°-30° internally rotated with respect to the coronal plane and 10°-40° anteriorly flexed on the sagittal plane with variable inclination.[11] In addition, depending on the patient's position in the CT scanner, the orientation of the scapula is subjected to further variations. In conventional CT protocols, the axial slices are made with respect to the cardinal axes of the body rather than to the scapular plane,[6] which leads to inaccurate glenoid version measurement. Other assessments of glenoid morphology, such as biconcavity and vault width, can also be skewed by this misalignment of CT slices. Studies have shown that using 3-dimensional (3D) reconstruction software to reorient and reslice the scapula in the anatomic scapular plane greatly improves the accuracy of glenoid version measurement.[5,12,16,22] However, the majority of 3D reconstruction software is proprietary and expensive, and surgeons often do not have access to such software unless they are affiliated with a properly equipped research laboratory or qualified collaborators. Furthermore, even if a surgeon is equipped with such software, the burden of work rests on the surgeon. One possible alternative to circumvent these obstacles is to establish an interdepartmental protocol whereby specially trained radiology technologists reorient the scapula using clinical 3D imaging software, reslice axial cuts in an accurate and precise fashion, and provide the surgeon with reformatted anatomic 2D axial CT images, from which version can be readily measured. Such a protocol would stand to improve patient outcomes by improving the surgeon's preoperative measurement of glenoid version for a more anatomic placement of the glenoid component.

The purpose of this study was to examine the feasibility of an interdepartmental protocol experimentally implemented between the orthopedic surgery and radiology departments at our institution and to examine the accuracy of glenoid version measured on the reoriented anatomic axial CT images obtained through such a protocol. We also sought to characterize how the glenoid version changes relative to the level of axial slices. We hypothesized that a well-established interdepartmental protocol would allow accurate glenoid version measurement that is comparable to the accuracy of a "gold standard" method using proprietary laboratory-based 3D reconstruction software. We also hypothesized that the superior part of the glenoid has increased retroversion compared with the middle and inferior parts, and this phenomenon is exaggerated in conventional CT.

Materials and methods

Patient CT scan selection

This study was a retrospective diagnostic test study. A total of 30 shoulder CT scans from 30 patients (ie, 10 with a normal glenoid and 20 with an arthritic glenoid) were used for the study. The 10 patients with a normal glenoid were selected from a pool of patients who had undergone a shoulder CT scan at our institution for a proximal humerus fracture sustained in an otherwise normal shoulder with no osseous abnormalities of the scapula. The 20 patients with an arthritic glenoid were selected from a pool of patients who had undergone a shoulder CT scan at our institution as part of preoperative evaluation for total shoulder arthroplasty for glenohumeral osteoarthritis. They were selected in such a way that similar numbers of patients were selected for each of the 3 common arthritic glenoid types (ie, A2, B2, and B3) of the modified Walch classification[1] on the basis of axillary plain radiographs. Each patient had a dedicated CT scan of the left or right shoulder girdle while positioned supine in a Philips MX8000 CT scanner (Philips Medical Systems, Bothell, WA, USA) in increments of 0.5 or 0.6 mm. In-plane pixel size was 0.4-0.7 mm.

Interdepartmental protocol for acquisition of reoriented anatomic 2D axial CT images

A radiology technician was recruited and specially trained for the study. The technologist was given a brief introduction of the study and instruction on how to orient the scapula for accurate glenoid version measurement. Shoulder CT scans of several patients who were not included in the study were used for training. The original 2D CT data were first imported into clinical 3D imaging software (Aquarius iNtuition; TeraRecon, Foster City, CA, USA), and a 3D model of the scapula was built by the technician. The scapula was then oriented anatomically with regard to its plane according to the methods described in previous studies.[4,5,16] Briefly, 3 anatomic landmarks were located on the 3D model images: the inferior tip