Use of patient-specific guides and 3D planning to optimize glenoid implant positioning

Jean Chaoui, PhD
Marc-Olivier Gauci, MD
Gilles Walch, MD
Pascal Boileau, MD

Background: Glenoid component positioning is a key factor for success in total shoulder arthroplasty. Three-dimensional (3D) measurements of glenoid retroversion, inclination, and humeral head subluxation are a helpful tool for preoperative planning. The purpose of this study was to assess the reliability and precision of a novel surgical method for placing the glenoid component utilizing patient specific templates created using preoperative surgical planning and 3D modelling.

Methods: A preoperative computed tomography (CT) scan examination of each patient (N=20) was performed. The glenoid implants were virtually placed, and patient specific guides were created to direct the guide pin into the desired orientation and position on the glenoid. Three-dimensional orientation and position of the guide pin was evaluated by performing a postoperative CT scan for each patient. The differences between the preoperative planning and the achieved result were analysed.

A CT scan of each cadaveric scapula was performed on a Siemens machine (Siemens Healthcare, Mavern, PA). The CT kV was 140, mAs at 180, and image matrix of 512 x 512. The field of view (FOV) was adapted with a maximum of 180 mm, resulting in a pixel size of 0.6 mm. All the patients were scanned in a dorsal recumbent position with maximum 1.5-mm interval slices. The CT images of each scapula were imported under DICOM format (Digital imaging and Communications in Medicine) on standard compact disks (CDs). The CDs were introduced into a computer and processed through the Glenosys® software (Imascap™, Brest, France). This software is able to perform automatic segmentation, 3D reconstruction, and measurements of glenoid retroversion and inclination. It has been demonstrated previously that the Glenosys® software measurements have excellent reliability and reproducibility.

The first step performed by Glenosys planning software is fully automatic segmentation based on 3D shape recognition algorithms applied to each object detected in the volume. The second step is a specific processing that only treats the region between the humerus and the glenoid surface in order to separate possible contact areas. The third step is a full morphological analysis of the anatomical structure of the bone. The glenoid surface and the glenoid vault are detected, and 3D version and inclination angles of the glenoid surface are automatically computed. Our novel method determines a new scapular reference plane. It is based on all 3D points of the scapular body, and it is computed by fitting a plane using the mathematical principles of least-squares minimization. The same process is applied to define a glenoid sphere: the glenoid surface is detected automatically using a 3D watershed-based method applied on the 3D scapula model. Since the software uses all the points of the scapula and the glenoid, there is no need to manually define any point on the 3D model.

The parameters of glenoid version and inclination are extremely important to define an optimal path for implanting the guide wire and subsequent glenoid reaming. The surgeon can easily modify the position of the implant in three dimensions aided by 3D and two-dimensional (2D) views of the patient's anatomy in the software interface. The glenoid version and inclination angles as well as the glenoid vault are computed for each position in real time to help the surgeon evaluate the implant position and orientation.

After validation of these measurements, a second screen appears with the templates of the available glenoid prosthesis. The surgeon can then virtually implant a glenoid component into the desired position of retroversion and inclination. The software indicates the seating percentage and the reaming depth for each position. Once the implant and optimal positioning have been determined, the software generates the patient specific guide that will be used during the surgery. A second CT scan was performed after the surgery for each patient using the same protocol as the initial CT scan. The Post-op scapula is matched to the preop planning in order to compute the errors between the planned implant positioning and the obtained position.

Results: The mean error in 3D orientation of the guide pin was 2.39°, mean entry point position error was 1.05 mm, and mean inclination angle error was 1.42°. The average error in version angle was 1.64°. There were no technical difficulties or complications related to using patient specific guides for guide pin placement. Quantitative analysis of guide pin positioning demonstrated a good correlation between preoperative planning and the achieved position of guide pin fixation.

Discussion: Using the patient-specific guide to position and orient the guide-wire involved no particular technical difficulty. Quantitative analysis found good concordance between planned and achieved positioning. The technique allows ideal glenoid positioning (version and inclination) to be planned on 3D reconstruction of pre-operative CT, especially in difficult cases. The pre-operatively planned "ideal" position is reproduced peroperatively using specific guides that are reliable to within a very few degrees (version and inclination) and millimeters (wire entry point).

Conclusion: The present study demonstrated the gain in precision achieved by using pre-operative planning software and patient-specific guides in total shoulder replacement, and for positioning the glenoid component in particular.