Glenoid Guide Pin Accuracy during Shoulder Arthroplasty using Mixed Reality Navigation versus Computer Navigation: Is there a Difference?

Ryan Gao, Cole Thomas Fleet, G Daniel G Langohr, James A Johnson[1], George S Athwal[2]
[1]Hand & Upper Limb Center, [2]St Joseph's Hand and Upper Limb Centre

INTRODUCTION: Accurate insertion of the glenoid guide pin in both total (TSA) and reverse (RSA) shoulder arthroplasty is important as glenoid component malposition can increase the risk of impingement, component loosening, and instability. The use of three-dimensional (3D) preoperative planning alone has been shown to yield large errors in guide pin position and orientation relative to the preoperative plan[1]. Increased guide pin insertion accuracy has been achieved using computer navigation (C-NAV). These systems allow the surgeon to register the glenoid intraoperatively to preoperative computer tomography (CT) scans and obtain real-time feedback of their guide pin position and orientation compared to the surgical plan. These systems however can be costly and cumbersome to use in the operating room due to their larger size. Recently, it has been proposed that mixed reality can be used for surgical visualization and holographic navigation (MR-NAV). However, few studies exist that evaluate such a system for guide pin insertion in shoulder arthroplasty. Therefore, the objective of this study was to compare glenoid guide pin insertion accuracy using C-NAV and MR-NAV methods.

METHODS: Twenty CT scans were obtained from patients (mean age 68±12 years) exhibiting glenohumeral arthritis or rotator cuff tear arthropathy according to the Walch and Favard classifications[2,3]. All scans were automatically segmented and planned for either TSA (n=5) or RSA (n=15) by the senior author using validated preoperative planning software. Each scapula was exported to a computer-aided design software, where the glenoid (with coracoid) was manually sectioned from the rest of the scapula. Two models of each glenoid with coracoid were then 3D printed. Two guide pin insertion methods were randomly evaluated under the guidance and supervision of the senior surgeon. The first method employed an in-house C-NAV system which utilized an optical tracking system with an accuracy of 0.1mm and a resolution of 0.01mm. The second method used an MR-NAV system comprised of a head mounted display. Both navigation systems were used to complete the glenoid model registration and guide pin insertion processes. The same registration process was utilized for both methods, with the surgeon digitizing 6 points on the glenoid and coracoid, followed by a trace of the glenoid surface, coracoid foot to knee, and coracoid tip. The C-NAV system provided real-time feedback through a monitor positioned beside the glenoid model (Figure 1), while the MR-NAV system provided real-time holographic visualization and guidance through the head mounted display (Figure 2). Once all guide pins had been inserted, an optical tracking system and custom digitization device was used to quantify the position and orientation of the guide pin relative to the glenoid model. The primary outcomes for this study were the absolute error in guide pin inclination, version, and entry point relative to the preoperative plan. The Total Global Error was also assessed, which is the sum of the absolute error in both guide pin orientation and position. Statistical analysis was performed using a one-way repeated measures analysis of variance.

RESULTS: No statistically significant differences ($p=0.362$) in glenoid inclination error were found between C-NAV (1.5±1.2°) and MR-NAV (1.9±1.0°). This was also true for the absolute version error ($p=0.086$) between C-NAV (1.9±1.5°) and MR-NAV (1.2±1.1°). The difference in entry point error between C-NAV (2.5±1.1mm) and MR-NAV (2.3±0.9mm) was not found to be statically significant ($p=0.316$). This was also observed with the difference in Total Global Error between both methods (C-NAV: 5.2±1.7 [mm+deg], MR-NAV: 4.7±1.2 [mm+deg], $p=0.322$, Figure 3).

DISCUSSION AND CONCLUSION:

This study showed both C-NAV and MR-NAV to be highly accurate methods in obtaining optimized glenoid guide pin position and orientation in shoulder arthroplasty. Although no significant differences were observed between methods, the use of mixed reality for surgical visualization and navigation reduces the cost and size of the system compared to C-NAV, which may improve usability and transportation in the operating room.

REFERENCES:

1. Abdic S. et al., Mixed-reality visualization in shoulder arthroplasty : is it better than traditional preoperative planning software? Clin Shoulder Elb. [In-Press] 2023:1-9.
2. Bercik MJ, Kruse K, Yalizis M, Gauci MO, Chaoui J, Walch G. A modification to the Walch classification of the glenoid in primary glenohumeral osteoarthritis using three-dimensional imaging. J Shoulder Elb Surg. 2016;25(10):1601-1606.
3. Sirveaux F, Favard L, Oudet D, Huquet D, Walch G, Molé D. Grammont inverted total shoulder arthroplasty in the treatment of glenohumeral osteoarthritis with massive rupture of the cuff. Results of a multicentre study of 80 shoulders. J Bone Jt Surg. 2004;86(3):388-395.

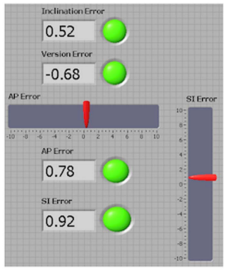

Figure 1: Graphic user interface of the C-NAV system providing real-time feedback on guide pin position and orientation. The green indicators turn on when the user is within 2mm or 2 degrees of the desired target. Error bars are also provided for AP and SI entry point error.

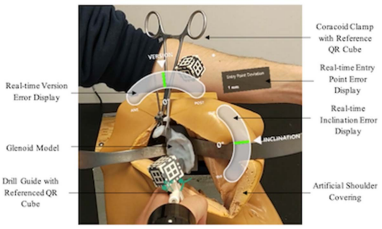

Figure 2: Surgeon's view of MR-NAV display during guide pin insertion.

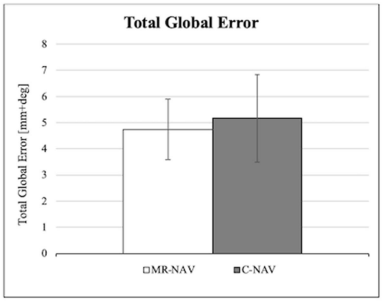

Figure 3: Total Global Error (TGE) of the guide pin for all insertion methods. Results are presented with ±1 standard deviation.