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CASE REPORT

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Enhancing Dynamic Anterior Stabilization of the Shoulder with Mixed Reality Navigation

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ABSTRACT

This study examines the application of Mixed Reality (MR) in arthroscopic dynamic anterior stabilization (DAS) of the shoulder, focusing on transferring the long head of the biceps (LHB) through a subscapularis split to the anterior glenoid rim. This creates a sling effect for stabilization. While various approaches exist to secure the LHB, including the posterior suture button method noted for its rigidity, biological integration, and minimal invasiveness, concerns regarding the proximity to the suprascapular nerve (SSN) persist. This paper explores the use of MR for guiding the DAS procedure.

Methods

A mixed-reality navigation system employing holographic lenses was used to project a 3D image of the scapula and SSN. The DAS, involving a posterior suture button, was conducted on eight fresh shoulder cadavers using a custom-developed drill guide that corresponds with the 3D image. The 3D hologram and virtual guide were accurately aligned with the cadaver's anatomy, maintaining a safe distance from the SSN. The distance from the actual SSN to the drill exit was measured post-procedure. An acceptable distance from the nerve was predefined as ≥15mm.

Results

The system setup time averaged 5.07±0.13 minutes (SD), with a p-value of 0.73, indicating minimal impact on overall procedure time. The 3D holographic anatomical model and drill guide could be co-visualized with the patient's actual anatomy and arthroscopic camera. The average distance between the SSN and posterior drill hole was 25.12mm±6.35 (SD), with a significant p-value of 0.0028.

Conclusion

The application of the MR system in DAS procedures allowed for more precise guide placement, ensuring safer drill exits in relation to the SSN. The setup time was minimal, not significantly extending the procedure duration.

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Introduction

Dynamic Anterior Stabilization (DAS) of the shoulder is a surgical approach to address anteroinferior instabilities, involving the fixation of the long head of the biceps tendon (LHBT) to the anterior glenoid rim via a subscapularis tendon split. This procedure, often combined with Bankart reconstruction, provides a triple soft tissue block for enhanced stabilization. It is primarily indicated for cases in the "grey zone" of glenoid bone loss, which are inadequate for Bankart procedures due to minimal loss2, yet insufficient for a Bristow-Latarjet procedure in cases of significant bone loss. The exact threshold of bone loss that contraindicates DAS is a subject of ongoing debate, with some authors suggesting a limit above 20% [1].

Various LHBT fixation techniques have been developed, including Onlay methods using anchors and Inlay techniques with buttons and interference screws. The Inlay technique, particularly employing buttons, has demonstrated robust fixation and improved biological integration3,6. However, this approach raises concerns about the risk of injury to the suprascapular nerve (SSN) due to the posterior positioning of the glenoid drill exit [2,3]

Similar concerns regarding the SSN's safety arise in Bristow and Latarjet surgical procedures, especially during drilling and screw placement, even though the rate of neurological injury to the SSN is about 1% [4-6]

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The advent of new technologies, including robotics9, virtual reality (VR)10, augmented reality (AR)8, and mixed reality (MR)11, has substantially improved surgical outcomes, providing enhanced education, safety, and accuracy [7-10].

MR technology allows for the simultaneous visualization of the real world and 3D holographic models, enhancing anatomical understanding and material handling, thus increasing surgical precision and safety. MR also supports functions such as pre-surgical planning, intraoperative guidance, and educational training [11].

To date, the application of MR in arthroscopic shoulder surgery, specifically in DAS procedures, has not been extensively documented, with most applications reported in shoulder arthroplasty. This study aims to explore the utilization of MR in shoulder DAS, focusing on identifying the optimal drill exit point to prevent neurological injury to the SSN.

Methods

In this study, the authors captured 3D images of a standard scapula, the suprascapular nerve, and a custom-designed perforation guide (Razek São Carlos – Brazil) incorporating a virtual line for the guide (Figure 1 and 2).

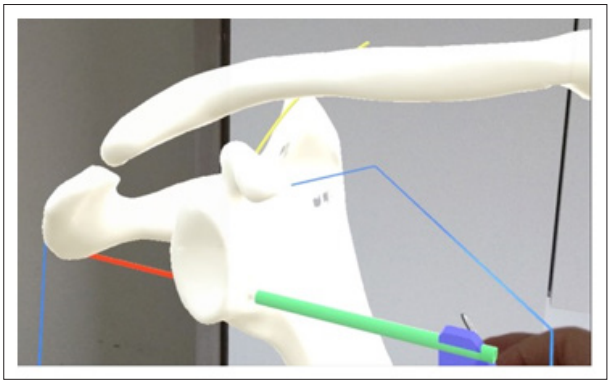

Figure 1: Scapular 3D Hologram and the Guide Positioned Properly.

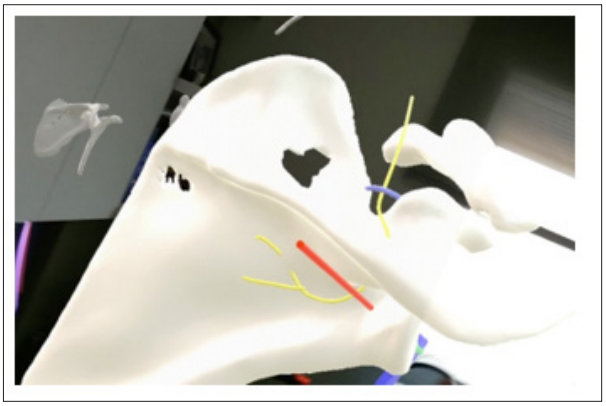

Figure 2: Scapular 3D Hologram, the Exist Drill Point and its Relation to the Suprascapular Nerve (SSN).

The Mixed Reality (MR) navigation was facilitated using the HoloLens 2 MR Headset system (Microsoft Corporation, Redmond, Washington, USA) (Figure 3).

Figure 3: The Drilling in the Cadaver was made by using the guide by Razek, São Carlos, Brazil, and the Hololens 2 Mr Headset System - Microsoft Corporation, Redmond, Washington, USA.

This system projected a holographic 3D image of the scapula, guide, virtual line, and the suprascapular nerve (SSN) onto the cadaver shoulders, aligning the hologram with the cadaver anatomy. A virtual ruler set a standard distance of 25mm from the nerve (Figure 4), using the acromion, coracoid, and scapular spine as anatomical references.

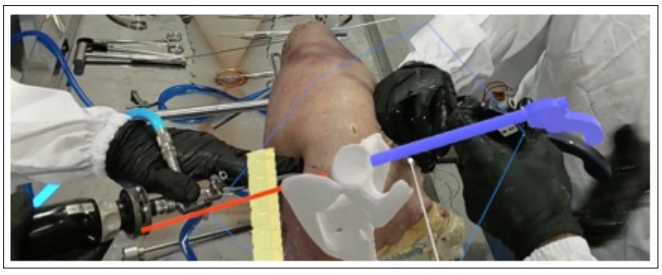

Figure 4: The projected 3D-image of the scapula, guide, virtual line and suprascapular nerve (SSN) by the holographic lens in the cadaver.

The 3D virtual guide was placed at a safe distance from the SSN, deemed acceptable if ≥15mm. The Dynamic Anterior Stabilization (DAS) procedure, guided by MR and employing a posterior suture button, was conducted on eight fresh shoulder cadavers using the custom drill guide. Posterior shoulder dissections were performed to expose the SSN and the button, with distances measured using a standard ruler (Figure 5).

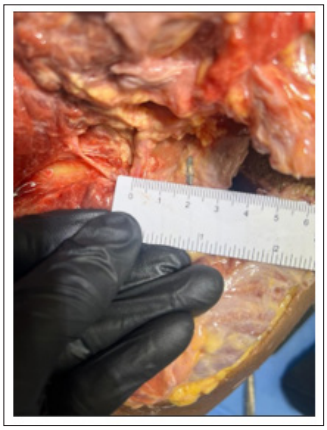

Figure 5: Posterior glenoid with the button and the distance between suprascapular nerve (SSN) and the device.

Setup time was recorded in minutes. Statistical analysis was conducted using STATA13.1 software (Texas, USA).

Results

The 3D holographic anatomical model and drill-guide model were successfully co-visualized with the actual anatomy and the arthroscopic camera field. The mean distance between the SSN and the posterior drill hole was 25.12mm±6.35 (ranging from 16 to 33mm), with a statistically significant p-value of 0.0028. The system's setup time averaged 5.07±0.13 minutes, with a p-value of 0.73, indicating a minimal impact on the overall procedure time. The MR headset was utilized solely during the drilling phase.

Discussion

Scapular perforation procedures such as Bristow, Latarjet, and DAS, which have posterior exit points, pose risks to the SSN. The posterior aspect of the scapula is typically challenging to evaluate in these procedures. Modern technology, including guides, navigation systems, robotics, and holography, has enhanced the precision of orthopedic surgeries. Unlike navigation and robotics that rely on joint surface readings, holography allows surgeons to estimate other anatomical parameters, beneficial in minimally invasive surgeries like arthroscopy. This study examined the potential to increase the precision of arthroscopic shoulder stabilization procedures using MR, a innovative technology that integrates bone anatomy and estimated nerve locations. The study found that the setup time was negligible, not extending the procedure by more than 5 minutes, thereby not adversely impacting surgery progression or patient safety. In cases requiring a CT scan for pathology evaluation, 3D-CT-based models do not add additional costs or radiation exposure, though this may not apply to all pathologies.

While the results demonstrated safety within the study's standardization, variations may occur due to discrepancies between holographic and actual images. Future enhancements, potentially involving Artificial Intelligence and automated processes, could refine alignment and improve procedure accuracy. The authors suggest extending this study to other procedures like Bristow and Latarjet to explore similar accuracy improvements.

Conclusion

The implementation of MR in DAS surgeries showed high accuracy and precision concerning the exit point's relation to the SSN. Furthermore, the brief setup time, approximately 5 minutes, confirms MR as a valuable tool in enhancing safety during arthroscopic button DAS procedures.

Level of Evidence: Level IV

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