Original Article With Video Illustration

Transhumeral Portal for Arthroscopic Glenohumeral Resurfacing Procedures: A Cadaveric Study of the Safety and Accuracy

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Purpose: To evaluate the safety and accuracy of a transhumeral portal to arthroscopically access and prepare the glenohumeral articular surface without subscapularis transection or glenohumeral dislocation. **Methods:** In 10 fresh-frozen cadaveric shoulders, we used a transhumeral portal and an anterior mini-open rotator interval exposure to arthroscopically prepare the humeral and glenoid articular surfaces. To evaluate our technique, we measured the distance from the portal to the branches of the axillary nerve and the biceps groove on the humeral extra-articular surface, the angle of trajectory of the portal through the humerus, and the accuracy of targeting the center-center of the humeral and glenoid surfaces. **Results:** The transhumeral portal allows perpendicular access to the humeral and glenoid articular surfaces without damage to the subscapularis, supraspinatus, or axillary nerve. The transhumeral portal courses an average of 20.7 $\pm$ 15.0 mm from the closest terminal branch of the anterior branch of the axillary nerve, enters the humerus 8.8 $\pm$ 2.7 mm lateral to the biceps groove, and traverses the humerus at an angle of 46.0° $\pm$ 4.3° relative to the humeral intramedullary axis. Arthroscopic guidance resulted in an average distance of 8.1 $\pm$ 5.6 mm from the humeral center and 3.9 $\pm$ 1.0 mm from the glenoid center. **Conclusions:** Creating an arthroscopic transhumeral portal allows perpendicular access to the humeral and glenoid articular surfaces without injury to the axillary nerve, subscapularis transection, or dislocation of the glenohumeral joint. However, this transhumeral portal did traverse within 5 mm of a terminal branch of the anterior branch of the axillary nerve in 20% of our specimens. **Clinical Relevance:** These findings describe an arthroscopic transhumeral portal that achieves perpendicular access to the glenohumeral joint surfaces without transection of the subscapularis or dislocation of the glenohumeral joint. This transhumeral portal may assist in articular cartilage repair and resurfacing of the glenohumeral joint.

Conventional surgical exposures for total shoulder arthroplasty and shoulder resurfacing require extensive open exposures. Conventional exposures typically involve ligating the anterior humeral circumflex vessels, transecting the subscapularis tendon, and dislocating the glenohumeral articulation. An arthroscopically assisted exposure using a transhumeral portal and a mini-open rotator interval approach can be used to access the glenohumeral joint for the purpose of resurfacing or repairing damaged articular surfaces. This arthroscopic-assisted transhumeral portal avoids transection of the subscapularis tendon and dislocation of the glenohumeral joint, potentially decreasing the risk of brachial plexus traction injuries, permanent subscapularis weakness, and decreased range of motion associated with open conventional exposures.[1,2] Other potential advantages include perpendicular access to both the glenoid and humeral articular surfaces without glenohumeral dislocation, resurfacing of both the humeral and glenoid surfaces without anatomic humeral head resection, and immediate postoperative strengthening and active range of motion.

The purpose of this study was to evaluate the safety and accuracy of the transhumeral portal to arthroscopically access and prepare the glenohumeral articular surface without subscapularis transection or glenohumeral dislocation. We hypothesized that the transhumeral portal would safely avoid the axillary nerve and allow

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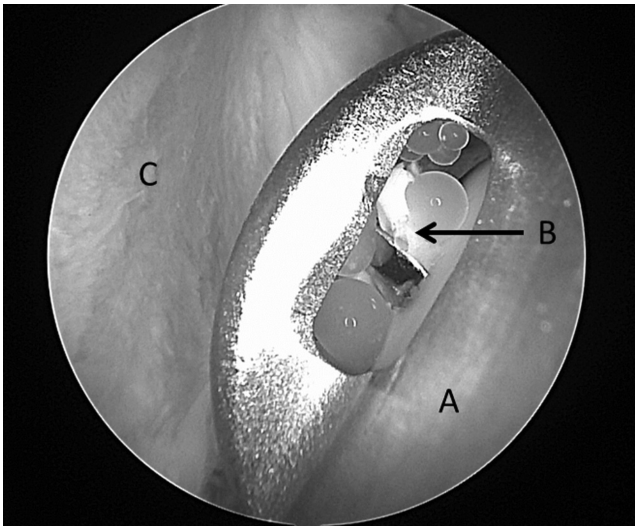

Fig 1. Arthroscopic view of the transhumeral guide target (A) positioned intra-articularly on the humeral head (B) with a guide pin penetrating the humeral surface, with the glenoid (C) in the background.

perpendicular access to the centers of both the humeral and glenoid articular surfaces.

Methods

Ten fresh-frozen cadaveric shoulders without anatomic abnormality were obtained from LifeLegacy (Tucson, AZ). Specimens were thawed at room temperature and positioned in a simulated beach-chair position and underwent the surgical method to create a transhumeral portal and access the glenohumeral joint surfaces. The transhumeral surgical method was developed by the senior author (S.C.C.), and the transhumeral instruments were produced by Arthrex (Naples, FL).

Standard anterior and posterior arthroscopic portals were created, and an anterior mini-open rotator interval approach to the glenohumeral joint was used. After creation of a 4-cm longitudinal skin incision just lateral to the coracoid tip, the deltopectoral interval was bluntly opened, with retraction of the cephalic vein laterally. Deep dissection was performed to open the rotator cuff interval and retract the subscapularis inferiorly to allow release of the anterior and inferior capsule as necessary. The surgical methods are shown in Video 1 (available at www.arthroscopyjournal.org).

The target of the arthroscopic transhumeral guide was inserted through the mini-open rotator interval exposure and centered on the humeral head (Fig 1) by arthroscopic visualization. With the shoulder in adduction and neutral rotation, the cannulated bullet of the transhumeral guide was bluntly inserted into the extra-articular surface of the humerus through a limited skin incision made 8.0 cm inferior to the anterolateral corner of the acromion. The anterior mini-open rotator exposure allowed the senior author to directly visualize the anterior branch of the axillary nerve and its terminal branches as the blunt-tipped cannulated bullet penetrated the deltoid and was positioned on the lateral humeral cortex, approximately 10 mm lateral to the biceps groove, a site previously described to be opposite the center of the humeral surface.[3]

With the target of the transhumeral guide centered on the humeral head, a guide pin was drilled along the central axis of the neck of the humerus, perpendicular to the humeral surface, and through the center of the humeral surface until it encountered the target (Fig 1). Then, the transhumeral portal was completed by drilling over the guide pin with a 5.5-mm cannulated reamer. A transhumeral sheath was inserted into the portal to protect the bone and surrounding soft tissues

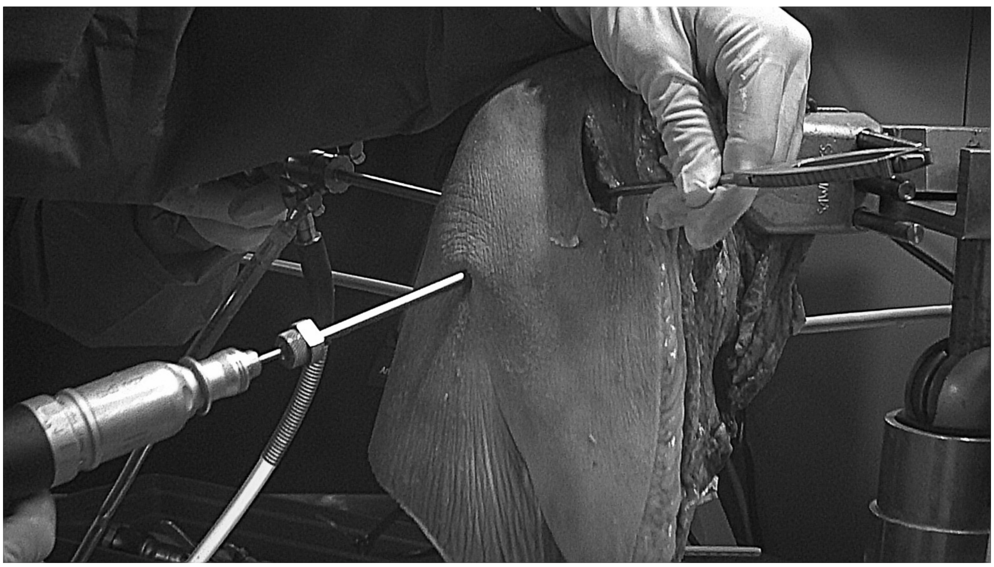

Fig 2. Working through a protective transhumeral sheath.

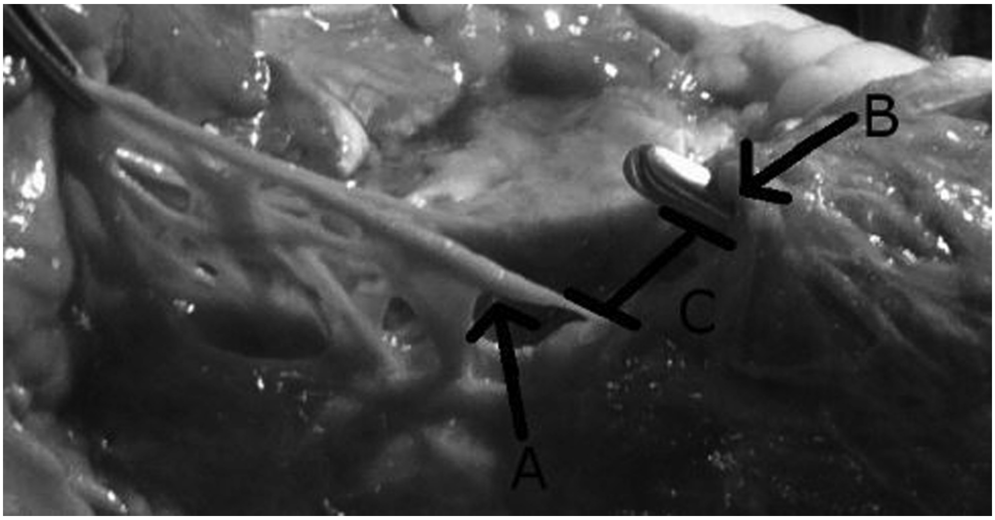

Fig 3. The course of the transhumeral portal through the deltoid (B) and the measured distance (C) to the terminal branches of the anterior branch of the axillary nerve (A) after gross dissection.

from the working modular transhumeral instruments (Fig 2). To prepare the humeral and glenoid surfaces, the working ends of both the modular humeral and glenoid reamers were introduced through the anterior mini-open rotator interval exposure while the reamer shafts were each inserted through the transhumeral portal within the protective transhumeral sheath to connect with the working end in the joint. A glenoid-centering guide was introduced through the anterior mini-open rotator interval exposure and used to drill a hole in the center of the glenoid surface to assist with preparation with the glenoid surface.

Subsequently, the shoulder was dissected and 2 separate individuals took 3 independent measurements for each variable. All distances were measured with a digital micrometer to 1 decimal point, and angles were measured with a goniometer to the nearest whole number. Two individuals took each measurement in triplicate, and if measurements between individuals differed by 2 cm or 2°, these were discussed and remeasured. If intraobserver variability was within 2 cm or 2°, the values were averaged to create a mean distance or angle.

With the protective transhumeral sheath in place, the deltoid was taken down from the acromion to expose its undersurface and measure the relative distance of the transhumeral sheath to the closest identifiable axillary nerve branch (Fig 3). In 8 of 10 specimens, this measurement was made to the closest terminal branch of the anterior branch of the axillary nerve, whereas in 2 of 10 specimens, the terminal branch was not identifiable and the measurement was made to the anterior branch of the axillary nerve. The subscapularis and supraspinatus tendons were inspected for damage. The humerus and glenoid were then stripped of all soft tissue, and we measured the distance from the opening of the transhumeral portal on the lateral cortex of the humerus to the lateral edge of the biceps groove, as well as to the level of the lateral humeral metaphyseal flare (Fig 4). We also measured the angle of trajectory of the transhumeral portal relative to the longitudinal axis of the humerus. To evaluate the accuracy of the technique, we measured the distance from the humeral intra-articular opening of the transhumeral tunnel and the centering hole in the glenoid to the measured center of both respective surfaces. The actual centers of the humeral and glenoid surfaces were determined by identifying the midpoint along the vertical and horizontal curves of the respective surfaces. After the center of the humeral surface was determined, the transhumeral guide was used to re-drill the transhumeral portal in reverse, perpendicular to the humeral surface, from the center of the humeral surface to the lateral

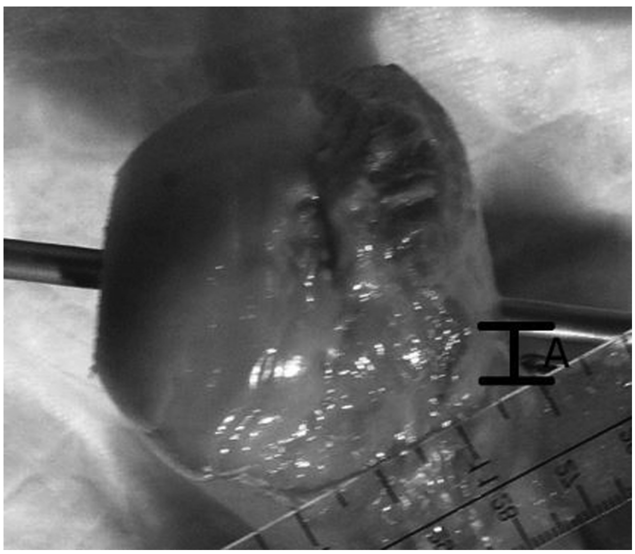

Fig 4. The measured distance (A) between the transhumeral portal entry point on the lateral proximal humerus and the humeral metaphyseal flare after gross dissection.

Table 1. Relation of Portal to Terminal Branches of Anterior Branch of Axillary Nerve

	Distance From Terminal Branches of Axillary Nerve, mm
Specimen 1	13.3
Specimen 2	19.0
Specimen 3	1.3
Specimen 4*	39.3
Specimen 5	4.7
Specimen 6	19.0
Specimen 7*	49.3
Specimen 8	10.7
Specimen 9	21.7
Specimen 10	28.7
Mean	20.7
SD	15.0

*The value is a measurement from the portal to the main anterior branch of the axillary nerve rather than to a terminal branch of the main anterior branch of the axillary nerve as observed in the remaining 8 specimens.

cortex. Using this "ideal" transhumeral portal, we measured the distance to the biceps groove and the lateral humeral metaphyseal flare. We also measured the new angle of trajectory for the ideal transhumeral portal relative to the humeral longitudinal axis.

Statistical Analysis

Descriptive statistics, means and standard deviations, were determined for the primary outcomes of the study—particularly, the distance of the course of the transhumeral portal to the branches of the axillary nerve.

Results

Relation of Portal to Surrounding Structures

Dissection showed intact subscapularis and supraspinatus tendons, with no damage to any proximate neurovascular structures, including the axillary nerve and its branches. In all trials the transhumeral portal coursed through the deltoid at a safe distance anterior to the division of the main anterior branch of the axillary nerve. The transhumeral portal traveled an average distance of 20.7 ± 15.0 mm from the closest branch of the axillary nerve (Table 1, Fig 3). In 8 of 10 specimens, this measurement was from the transhumeral sheath to the closest terminal branch of the anterior branch of the axillary nerve, whereas in the remaining 2 specimens, the terminal branches were not identifiable and the measured distance was taken to the main anterior branch of the axillary nerve. The anterior branch of the axillary nerve and its terminal branches were examined in each specimen and noted to be intact without any injury in all samples. In the 2 samples in which the portal was less than 5 mm from a terminal branch of the anterior branch of the axillary nerve, no nerve damage was visually apparent on gross dissection.

Relation of Portal to Humerus

The transhumeral portal entered the lateral cortex of the humerus 9.3 ± 7.1 mm lateral to the lateral edge of the biceps groove and 7.2 ± 2.3 mm superior to the point at which the humeral shaft began to flare into the metaphysis (Fig 4). We also observed that the relative longitudinal height of the lateral cortical opening of the transhumeral portal correlated with the inferior margin of the anatomic head of the humerus. The transhumeral portal traversed the proximal humerus at an angle of 43.8° ± 6.8° relative to the longitudinal axis of the humerus.

Humeral Accuracy

We plotted the average position of the measured center point of the humeral surface alongside the average position of the drilled transhumeral tunnel to determine the relative distance from center in both the x- and y-axes, with an average distance from center of 8.1 ± 5.6 mm. The transhumeral portal exited the humeral articular surface anteroinferiorly (n = 4), anterosuperiorly (n = 3), posteroinferiorly (n = 2), and posterosuperiorly (n = 1) relative to the center-center of the humeral surface (Fig 5).

Glenoid Accuracy

We plotted the average position of the measured center point of the glenoid surface alongside the average position of the drilled glenoid center to determine the relative distance from center in both the x- and y-axes, with an average distance from center of 3.9 ± 1.0 mm. The center

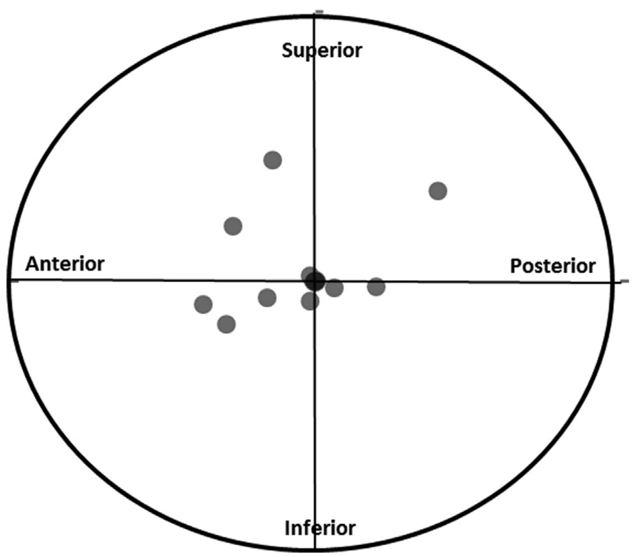

Fig 5. Plot of the points at which the transhumeral portal penetrated the humeral surface in all 10 specimens relative to the measured central point of the humeral surface.

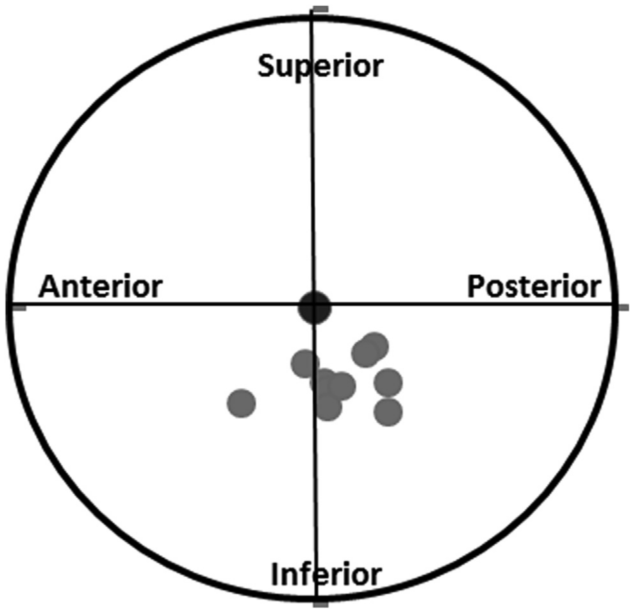

Fig 6. Plot of the points at which we drilled a centering hole in the glenoid surface in all 10 specimens relative to the measured central point of the glenoid surface.

of reaming on the glenoid most often deviated posteroinferiorly (n = 8) and anteroinferiorly (n = 2) (Fig 6). We were able to gain perpendicular access to the glenoid articular surface through the transhumeral portal in all specimens.

Ideal Position of Transhumeral Portal

By reverse drilling the ideal transhumeral portal perpendicular to the surface of the humeral head starting from the measured center-center of the humeral head, we measured the angle of trajectory of the transhumeral portal to be 46° ± 4.3° relative to the longitudinal axis of the humerus. This ideal transhumeral portal exited the lateral humeral cortex 8.8 ± 2.7 mm lateral to the lateral edge of the biceps groove and 7.5 ± 2.6 mm superior to the metaphyseal flare.

Discussion

The use of an arthroscopic-assisted transhumeral portal allows for perpendicular access to the glenohumeral surfaces without transection of the subscapularis tendon, glenohumeral dislocation, or injury to the axillary nerve. The transhumeral portal was created using arthroscopic assistance, a transhumeral guide, special transhumeral instruments, and an anterior mini-open rotator interval exposure. The transhumeral portal ideally enters the lateral cortex of the humerus 8.8 ± 2.7 mm lateral to the lateral edge of the biceps groove and 7.5 ± 2.6 mm superior to the metaphyseal flare and traverses the humerus at an angle of 46° ± 4.3° relative to the longitudinal axis of the humerus. In all trials the transhumeral portal coursed through the deltoid at a safe distance anterior to the division of the main anterior branch of the axillary nerve, but in 20% of specimens the portal did course within 5 mm of one of the multiple terminal branches of the anterior branch of the axillary nerve. The transhumeral portal traveled an average distance of 20.7 ± 15.0 mm from the closest branch of the axillary nerve. Arthroscopic visualization and the transhumeral instruments helped identify the center-center of the glenohumeral joint surfaces, with an average distance from center of 8.1 ± 5.6 mm for the humerus and 3.9 ± 1.0 mm for the glenoid.

The course of the described transhumeral portal traverses the deltoid and raises concern about injury to the anatomically proximate terminal branches of the axillary nerve. To target the retroverted orientation of the proximal humeral joint surface, the transhumeral portal traverses the deltoid anterior to the point where the anterior branch of the axillary nerve divides into its terminal branches. Using good surgical technique, incising just the skin in line with the anterolateral corner of the acromion, inserting guides with blunt trocars, and working through cannulated guides and a protective transhumeral sheath assisted in protecting the axillary nerve and its terminal branches from injury. In addition, gross tactile and visual localization of the axillary nerve is possible from the mini-open approach and can help direct the cannulas and sheaths safely past the nerve branches to the lateral humeral surface. The transhumeral portal in 2 specimens, or 20%, did come within 5 mm of one of the multiple terminal branches of the anterior branch of the axillary nerve. Although no gross damage to the nerve was observed, the proximity of the portal may risk injury to one of the terminal branches of the anterior branch of the axillary nerve and denervate a limited portion of the anterior deltoid.

Knowledge of surgical landmarks and anatomic references allow surgeons to more reliably and reproducibly perform surgical techniques. By use of arthroscopic guidance, the transhumeral approach along with an anterior mini-open rotator interval exposure allowed us to place a transhumeral portal along the central axis of the neck of the humerus at an angle of 43.8° ± 6.8° and enter the lateral cortex of the humerus 9.3 ± 7.1 mm lateral to the lateral edge of the biceps groove. The entry point of the portal on the lateral humeral cortex was comparable with results of a study that used magnetic resonance imaging in a cadaveric model to demonstrate a point 11.8 ± 3.5 mm lateral to the lateral edge of the biceps groove to be opposite the center of the humeral joint surface.[3] In addition, the trajectory of our experimental and ideal portals was comparable with and consistent with a 3-dimensional computed tomography study that measured the average inclination angle of the proximal humerus as 129.6° ± 2.9°.[4] The transition point on the lateral cortex of the humerus between the shaft and metaphysis, the metaphyseal flare, was selected as a reference point for judging the height of the bony entrance site for the transhumeral portal over the most inferior aspect of the anatomic head, which is often affected and distorted by inferior humeral osteophytes in cases with significant degenerative changes. The metaphyseal flare should be readily available for reference by intraoperative radiographs, fluoroscopy, or computer navigation. Further investigation is necessary to determine the consistency of the position of this landmark relative to the central axis of the neck of the proximal humerus.

Arthroscopic visualization and the special transhumeral portal guide allowed precise placement of the tunnel and have the capability to accurately target and address arthroscopically visible lesions such as focal cartilage injuries. However, arthroscopic visualization alone had limited accuracy regarding judging the center-center of the humeral and glenoid surfaces. More sophisticated targeting guides, intraoperative fluoroscopy, and computer navigation may assist the surgeon to better judge and target the center-center of the glenohumeral joint surfaces.

Limitations

This study was limited by the small number of specimens that likely underrepresented the full spectrum of anatomic variability, including the distance of the axillary nerve to the transhumeral portal. Regarding treating shoulders with extensive glenohumeral degenerative changes, our specimens also likely underrepresented the degree of anatomic variation often seen in arthritic shoulders, including—but not limited to—bony deformity and capsular contracture. These degenerative anatomic variations may create greater technical challenges for arthroscopic access and visualization, transhumeral portal positioning and creation, and glenohumeral surface preparation and replacement. We were unable to identify the smaller terminal branches of the anterior axillary nerve in 2 specimens, so the distances reported from the portal to the nearest branch in these 2 specimens were measured to the anterior branch of the axillary nerve. Drilling a transhumeral portal does create a stress riser in the bone and may pose a risk of fracture with a fall or injury. Previous case series have reported core decompression and drilling of tunnels of 5 mm to 1 cm in diameter for avascular necrosis of the humeral head without related complications,[5,6] providing some limited evidence of the ability to drill a 5.5-mm tunnel without complication.

Conclusions

Creating an arthroscopic transhumeral portal allows perpendicular access to the humeral and glenoid articular surfaces without injury to the axillary nerve, subscapularis transection, or dislocation of the glenohumeral joint. However, this transhumeral portal did traverse within 5 mm of a small terminal branch of the main anterior branch of the axillary nerve in 20% of our specimens.

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