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An anatomic evaluation of arthroscopic access to the radial head

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Abstract

Purpose: The purpose of this study is to determine the area of the radial head accessible for visualization and screw placement from the standard anteromedial and anterolateral portals used in elbow arthroscopy.

Methods: Five cadaveric elbows were arthroscopically evaluated using standard anteromedial and anterolateral portals. Markers (pins) were placed into the accessible portions of the radial head at maximal pronation and supination. Specimens were then evaluated by CT and the arc of the radial head accessible from each portal was determined.

Results: A continuous $220.04 \pm 37.58^\circ$ arc of the radial head was accessible from the combination of the anterolateral and anteromedial portals. From the anteromedial portal the arc obtained measured $147.96^\circ \pm 21.81$, and from the anterolateral portal the arc obtained measured $156.02^\circ \pm 33.32$. Using the radial styloid as a marker for 0° , the mean total arc ranged from $92.3^\circ \pm 34.06$ dorsal to $127.74^\circ \pm 23.65$ volar relative to the radial styloid.

Conclusions: Standard anteromedial and anterolateral portals used for elbow arthroscopy allow access to an average 220-degree area of the radial head.

Clinical Relevance: This study defines the area of the radial head that can be contacted using commonly used, safe, simple portals.

Introduction:

Radial head fractures are common injuries, accounting for approximately 4% of all fractures in adults^{1–3}. In 1954 Mason described three distinct groups of radial head fractures, including nondisplaced (type I), simple displaced (type II), and comminuted fractures (type III)⁴. Later modification added a fourth type, radial head fractures associated with a dislocation⁵.

While roughly 90% of all radial head fractures can be managed nonoperatively, patients with significant displacement, block to motion, or high demand may benefit from surgical

intervention⁶. Historically, the management of radial head fractures discussed excision versus non-operative treatment⁷. Early fixation techniques included the use of conventional screws, but were limited by screw head impingement at the proximal radio-ulnar joint⁸. Screw placement was limited to this safe zone, measuring 110–113°, where impingement between the screw head and the ulna would not occur^{8,9}.

The introduction of the Herbert screw for management of Mason II and III fracture patterns allowed for extending fixation outside of the safe zone, given the low profile and lack of protruding screw head. More recently, research has been directed towards exploring the utility of arthroscopy in fixation of radial head fractures, as this allows for improved visualization of the joint space, minimal invasiveness, and decreased need for fluoroscopy¹⁰.

Portal placement in elbow arthroscopy allows for a variety of portals to be placed within various locations safe from neurovascular structures, referred to as safe zones. Commonly used portals to the elbow include the proximal anteromedial, proximal anterolateral, proximal posterolateral, and soft spot portals^{11, 12}. Several cadaveric studies have outlined the anatomical relationships of nerves and vasculature in the elbow to determine the safety of the arthroscopic approach through these portals, particularly with necessary intraoperative movement of the joint^{13–17}. Advances in surgical technique and anatomical understanding have thus allowed for safer, more standardized use of elbow arthroscopy, and its use in radial fracture management is continually evolving^{12, 18–20}.

As elbow arthroscopy becomes more common, it is important that surgeons have a clear understanding of which arthroscopic portals are appropriate for a given injury. The purpose of this study is to determine the area of the radial head accessible for visualization and screw placement from the standard anteromedial and anterolateral portals used in elbow arthroscopy. We hypothesized that these standard portals would allow significant visualization and access to the radius to be used in fracture fixation.

Methods:

Specimens:

Five fresh-frozen cadaveric upper extremities were obtained (MedCure, Cumberland, RI). Inclusion criteria included cadaveric upper extremities from the proximal humeral diaphysis distally. Exclusion criteria included pediatric specimens (age below 18 years), gross or arthroscopic evidence of prior surgery or trauma, or any identifiable congenital malformation or condition, as assessed by the first and last authors. All specimens obtained met criteria for inclusion. Specimens were thawed at room temperature for 24 hours prior to use.

Arthroscopic Technique:

Each arm was positioned to mimic a supine surgical position (Figure 1). The proximal humeral shaft was stripped of soft tissue and placed into a clamp, and distally the fingers were placed into atraumatic

finger traps allowing the elbow to be positioned with the forearm vertical and the humeral shaft parallel to the floor. The radial head, capitellum, lateral and medial epicondyle, and olecranon were then marked. The elbow joint was injected with between 20–30cc of normal saline in order to distend the capsule.

All arthroscopy in this study was carried out directly by the senior author (MD). To begin the arthroscopy a proximal anteromedial superficial portal incision was made 1 cm proximal and 1 cm anterior to the medial epicondyle. The subcutaneous tissues and capsule were then parted with a small hemostat, and a standard trochar for a 3.5mm arthroscope was placed through the portal. Once access to the joint and good visibility was established the arthroscope was removed and an anterolateral portal was developed by placing a blunt trochar through the anteromedial portal and tenting the lateral skin. Superficial skin laterally was incised with a scalpel, and the trochar was used to divide the capsule and soft tissue.

After establishing the portal locations, a brief diagnostic arthroscopy was performed and any loose bodies or obstructing synovium were removed. With the arthroscope in the anterolateral portal, our pin placement device was inserted in the anteromedial portal (Figure 2). This device was developed specifically to allow placement of 5–10mm metallic pins to be inserted through cortical bone. With the cadaver hand held in maximal pronation, the device was placed in the anterior and radial-most aspect of the radial head that was accessible, with effort made to target the pins trajectory towards the center of the radial head. The forearm was then brought into maximal supination, and a pin was placed in the ulnar-most aspect of the radial head.

After placement of the first two pins from the anteromedial portal, the arthroscope was transferred to the anteromedial portal and our pin placement device placed in the anterolateral portal. The process was repeated with a pin placed posteriorly with the hand in pronation and an anterior pin placed with the hand in maximal supination. Throughout the arthroscopy one assistant diagramed the location of each pin on a representative drawing of the radial head.

At the termination of arthroscopy each specimen was dissected. The distance from the radial nerve to the anterolateral portal was measured. After these measurements were taken each specimen was stripped of all soft tissue, leaving an intact radius with markers still in place.

Radiographic Evaluation:

Specimens then underwent Computed tomography (CT) scan. Computed tomography was chosen over anatomic dissection because this allowed for measurement of pin angulation, and because by using CT data the pins could be buried into the radial head so as to prevent impingement against the ulna during specimen pronation/supination.

The CT scan data for each specimen was loaded into DICOM viewer software that allowed three-dimensional manipulation and accurate measurements to be calculated of the various angles between the placed pins (OsiriX, ©Pixmeo, Geneva, Switzerland) (Figure 3). Each scan was individually evaluated, and all measurements were agreed upon by two authors of the study (JDH, TDB).

In order to develop a standard zero-degree point to reference, the radial styloid was used. To do this, a marker was placed at the distal most point of the radial styloid on an axial image. This point was superimposed onto a representative axial image of the radial head that included all four metal pins. When all four pins were visible on multiple slices the most proximal image was used. All further measurements referenced the radial styloid as a zero-degree point.

Two series of measurements were taken. The first measurement was an evaluation of the total arc of the radial head that could be contacted from each portal, as determined by the arc of the radial head between pins placed from the same portal in maximal supination and maximal pronation. To measure this, the proximal-most axial slice of the radius containing all pins was used. A marker was placed at the point where each pin contacted the radial cortex. Pins were digitally labeled according to their placement, for example “Lateral portal, Pronation”. Angles were then measured from the maximal supination pin position, to the radiographic center of the radial head, to the maximal pronation pin position for each portal.

In order to determine whether pins were appropriately placed at or near perpendicular to the surface of the radial head a second series of measurements were taken. A line was drawn from each pins cortical contact point to the radiographic center of the radial head. The angle between this line and the pins trajectory was measured. For all measurements standard descriptive statistics were utilized.

Results:

Demographic information for each is documented in Table 1. Range of motion testing of the specimens demonstrated a mean of 85° of pronation (range 80–90°, SD 3.54) and mean supination of 84° (range 70–90°, SD 8.22) prior to instrumentation. The mean total arc of motion was 169°, SD 8.94.

The measured arc that could be contacted from the anteromedial portal averaged 147.96° (SD 21.81), or 41.1%. The arc that could be contacted by means of the anterolateral portal averaged 156.02° (SD 33.32), or 43.3%. In all specimens the arc of contact from the anteromedial portal overlapped with the arc obtained from the anterolateral portal, with a mean overlap of 83.94°, therefore using only these two portals, the average total area of the radial head contacted was 220.04° (SD 37.58), or 61.12%. These results are demonstrated in Figure 4.

Relative to the radial styloid, the total arc of contact averaged 92.3 ± 34.1° dorsal and 127.7 ± 23.7° volar to the styloid.

Of the 40 pins, the average angle of pin trajectory relative to the center of the radial head was 22.17°, with a standard deviation of 19.13°. Thirty-eight of 40 pins were within 45° of targeting the center of the radial head (95%).

The dissection of specimens revealed that no anterolateral portal came within 10mm of the radial nerve. Portals averaged 25mm away from the nerve when measured at the same tissue level

Discussion

The results from this study show that both the anteromedial and anterolateral portals can be used to access predefined zones on the radial head. The anterolateral portal allows access to approximately 156° of the radial head while anteromedial portal would give access to a 147° arc. There was some partial overlap of the two arcs. Using these two portals, a 220° arc of the radial head can be accessed. While 140° of the ulnar side of the radial head is not accessible from either of these portals, further investigation may reveal that other portals contact this dark side of the radial head.

Knowing the area of the radial head each portal accesses provides critical information for preoperative planning, and can be used to predict whether an open procedure is required for a given fracture pattern. More specifically, the arcs of the radial head available for placement of pins in this study can be extrapolated to be the same arc available for screw placement from the same portals, as a rigid device was used in the placement of these pins similar to a wire-driver or screw driver for use in fracture fixation. The use of the radial styloid as a neutral point allows for a universally applicable “zero degree” point that any surgeon can reference. This information can assist in counseling patients about their expected operation and postoperative course, as well.

The mode of fixation of radial head fractures is often debated in the literature. Open reduction and internal fixation has been the gold standard for fixation of this fracture, however, arthroscopic stabilization of radial head fractures provides direct visualization of fracture reduction and congruence of the joint surface¹⁹. Arthroscopic fixation of elbow fractures in the pediatric population has produced successful outcomes while also preserving the epiphyseal blood supply and decreasing periosteal stripping in comparison to open reduction²¹. The idea of decreased soft tissue damage and direct visualization of fracture reduction has gained interest in the orthopedic community in regards to radial head fixation.

Arthroscopic stabilization of radial head fractures has been applied to Mason Type II fractures with good to excellent results^{18, 19}. Arthroscopic fixation has been shown to decrease analgesic requirement, decrease hospital stay, decrease use of x-ray, and a decrease the need for a second surgery compared to open reduction and internal fixation of radial head fractures²². While this surgery is highly technical and has a steep learning curve, arthroscopic fixation of radial head fractures should be considered an option for surgeons with adequate experience.

Elbow arthroscopy has been labeled as a relatively safe procedure with complications rates reported as low as 2%¹⁹. However, a major concern is nerve transection during portal placement. The radial nerve has been shown to be at risk during placement of the anterolateral portal, with the nerve being substantial closer during full arm flexion. With full supination at 90° of flexion the radial nerve was reported to be furthest away from the portal. The anteromedial portal was found to be closet to median nerve and brachial artery in full extension¹⁵. In our study we choose the anterolateral and anteromedial portals because they have been documented as relatively safe during arthroscopic fixation of radial head fractures¹⁸. Rolla et al. reported on displaced Mason II fractures of the radial head, and

reported no short complications and return to pre-morbid conditions at 6 months¹⁸. Our study supports the safety of the anteromedial and anterolateral portals as there were no injuries to any neurovascular structures visualized on dissection of the cadavers.

Limitations

Our study design has its limitations. First, we used only two portals in our study; other portals that we did not test may capture some or all of the arc of the radial head that was not accessible by these portals. The posterior portals were not examined in this particular study as our main objective was to determine the arc of the radial head that was accessible through the anteromedial and anterolateral portals. Furthermore, when creating the anteromedial and anterolateral portals there may be some variability from surgeon to surgeon which may affect the potential arc that is accessible.

This is a cadaveric study, and changes to subject range of motion and tissue compliance may have occurred. The location of nerves and blood vessels are assumed not to have been altered by the freezing and thawing process, however this cannot be said with certainty. The region of the radial head contacted from each portal consistently overlapped in all of our subjects. Standard deviation was 21.81° for pins placed from the anteromedial portal and 33.32° from the anterolateral. Increasing the number of subjects may further refine these results. Additionally, the distance between the radial styloid and the radial head allows for some variance in results due to natural anatomical variation.

Conclusion

Standard anteromedial and anterolateral portals used for elbow arthroscopy allow access to an average 220-degree area of the radial head. A dark side of the radial head measuring 140° remains inaccessible. Further evaluation of other portals may further extend the area of the radial head that can be accessed for arthroscopic fixation, and further research may help identify safe portals or stab incisions through which this area can be reached.

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Figure 1:
Surgical positioning. A: Cadaveric specimens were positioned to mimic the operating room setup seen here. B and C: Representative arthroscopic images from the anteromedial (B) and anterolateral (C) portals with a shaver indicating the radial head in each.

Figure 2:
Pin placement device designed for arthroscopic marker placement. Shown are three pins (top), the outer cannula (middle) and the trochar used to advance pins (bottom).

Figure 3:

A: Representative CT images of pin placement in the radial head. B: Measurements of the arc between pin origin sites. C: Evaluation of the accuracy of pin placement relative to the center of the radial head.

Figure 4:

Diagram of the radial head demonstrating the average arc of the radial head available from the AM portal, AL portal, and the total area. Solid blue lines border the mean arc, while dashed lines border standard deviation. The radial styloid is used as an anatomic reference for 0° . SI: Superior/Inferior axis; PD: Proximal/Distal axis; ML: Medial/Lateral axis.

Table 1:

Demographics of the five cadaveric tissues evaluated

Specimen Demographics			
Laterality	Age	Gender	Ethnicity
Right	74	F	Caucasian
Left	68	F	Caucasian
Left	78	F	Caucasian
Left	62	F	Caucasian
Left	76	M	Hispanic