Ultrasound Assessment of the Postero-lateral Elbow Ulnohumeral Gap in Normal Subjects with and without Posterolateral Drawer Testing

Running Title: Postero-lateral elbow ulnohumeral ultrasound

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This study was approved by the University of British Columbia – Providence HealthCare Research Ethics Board (H16-01707).

A video demonstrating our unique imaging technique has been included in this Submission.

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ABSTRACT

Background: Posterolateral rotator instability (PLRI) is the most common pattern of recurrent elbow instability and current imaging to aid PLRI diagnosis is limited. Thus, we sought to define use of ultrasound (US) to determine normal lateral ulnohumeral joint measurements, with and without posterolateral drawer testing to provide an insight into how US may aid diagnosis.

Methods: Sixty elbows were evaluated in thirty healthy volunteers. The lateral ulnohumeral gap (LUHG) was measured with US in the resting position whilst the posterolateral drawer stress test maneuver was applied. Joint laxity was calculated as the difference between maximum stress and average rest measurements. Two independent readers assessed each elbow with comparison performed between stress and rest positions.

Results: Differences in LUHG were evident between stress and rest conditions (Reader 1: p<0.0001 and Reader 2: p=0.0002). At rest median LUHG values were 2.31 mm and 2.05 mm for readers 1 and 2 respectively, whilst at stress 2.88 mm and 2.9mm for readers 1 and 2. Median joint laxity was 0.8 mm for reader 1 and 1.1 mm for reader 2. Pearson correlation was whilst under stress r = 0.457 (absolute ICC = 0.608) at rest r = 0.308 (absolute ICC = 0.417). Median joint laxity demonstrated a Pearson correlation of r = 0.161 and absolute ICC = 0.252.

Conclusions: This study demonstrates a dynamic US assessment for PLRI, which aimed to assess the usefulness and feasibility of a laxity measurement following the application of a posterolateral drawer stress maneuver in a healthy population. Whilst establishing concordance between readers in measuring a LUHG under stress, the utility of a laxity measurement alone is not clear as correlation of measurements is not excellent, hence an upper limit of normal (ULN) for the
ulnohumeral gap under stress maybe more useful. Further evaluation of this technique is required in patients with PLRI.

**Keywords:** posterolateral rotator instability, PRLI, ulnohumeral gap, ultrasound, posterolateral drawer testing, diagnosis.

**Level of Evidence:** Anatomy Study; Imaging

Posterolateral rotator instability (PRLI) is the most common cause of recurrent elbow instability and is increasingly recognized as a source of elbow pain and dysfunction\(^1\)\(^-\)\(^3\). PLRI typically occurs following a forced forearm supination rotating the forearm away from the distal humerus. Typical presentation involves a history of recurrent subluxation, catching and apprehension. A history of dislocation may be present. PLRI should be considered in patients with a history of elbow trauma without dislocation, surgery for tennis elbow or prior surgery involving the radial head\(^3\),\(^9\),\(^10\),\(^12\),\(^16\),\(^19\).

Despite increasing awareness of PLRI, the diagnosis can be difficult based on physical examination. As noted in surgical studies, the posterolateral rotatory drawer and lateral pivot-shift tests aid diagnosis and are highly specific but sensitivity is operator dependent\(^4\),\(^9\),\(^14\),\(^18\). The role of imaging is also currently limited. Performing stress radiographic views are advocated but not easily feasible. Moreover, although MRI in conjunction with physical examination has been shown
to be useful, it is a static modality. Ultrasound (US) however affords the ability for dynamic testing of the elbow, similar to clinical examination US is somewhat operator dependent, as such a more experienced practitioner is likely to have an increased diagnostic sensitivity and specificity for this technique. 

The potential use of US was demonstrated using posterolateral rotatory stress tests to detect increased posterolateral ulnohumeral laxity evidenced by posterolateral ulnohumeral widening in a cadaveric study. Hence, we hypothesize that US can be utilized as a dynamic non-invasive method to demonstrate PLRI in asymptomatic patients, describing a reproducible dynamic imaging technique to define US measurements of the lateral ulnohumeral gap (LUHG). A potential aim is to demonstrate the utility of ultrasound of this methodology in symptomatic patients in the future.

**METHODS**

**Patient population and study design**

Thirty volunteers were consented for participation in the study. Inclusion criteria were age over eighteen. Volunteers were excluded if they had elbow pain or prior lateral elbow pain for greater than three months, past elbow trauma, past elbow surgery, overuse injury or injection therapy, history of osteoarthritis or rheumatoid arthritis, or abnormal elbow range of motion. This study was approved by the institutional research ethics board.

**Ultrasound assessment and LUHG measurement**

US assessment and measurements were performed by fellowship-trained musculoskeletal radiologists on a Philips Epiq ultrasound machine. A high-frequency linear US probe (L12-5) was
orientated transverse to the long axis of the humerus and the probe then moved distally along the lateral column to visualize the lateral ulnohumeral joint. The landmarks used to define the ulnohumeral joint were the bony acoustic landmarks of the trochlea and the crista supinatoris of the ulna; seen as two hyperechoic peaks with acoustic shadowing located on either side of the ulnohumeral joint. The LUHG was measured at rest with the elbow in a resting position in slight (10-15°) flexion and neutral rotation; this was repeated three times removing the probe after each rest measurement. The LUHG was re-measured while the elbow was stressed using the posterolateral drawer stress maneuver and repeated three times. (Figure 1 -3).

To test inter-observer variability, each elbow was assessed for a second time at a later time point by a different fellowship trained radiologist. The interval was three months and no participant incurred injury to suggest a change in the underlying clinical status (i.e. no elbow injury to invalidate their participation in the study). Laxity was calculated as the difference between maximum stress and average rest measurements.

**Statistical Analysis**

Comparison of LUHG at rest and stress was completed by a paired t-test. The correlation and agreement between mean values for reader 1 and reader 2 for joint laxity as well as stress and rest measurements were assessed by Pearson correlation and interclass correlation coefficient respectively as indicated. Reliability was assessed on absolute agreement of observers. All measurements were calculated using IBM SPSS Statistics for Macintosh (Version 21.0; IBM, Armonk, NY, USA).

**RESULTS**

**Study population**
Study participant demographics are shown in Table I. Participants had a median age of 33 years (range: 25 – 38) with 17/30 (56.7%) being male. No patients were excluded from this study as none met the specific exclusion criteria described earlier.

**Ulnohumeral Measurements**

Measurements of the LUHG at stress compared to rest were significantly different for both readers. Assessment of left and right elbows across all patients by Reader 1 (N = 30) reported a median rest gap of 2.3 mm (range 1.9 - 2.9), at stress 2.8 mm (range 2.4 – 3.5) p < 0.0001 for reader 1. For reader 2, the median rest gap was 2.1 mm (range 1.6 - 2.3) and stress 2.9 mm (range 2.7 – 3.3), p = 0.0002. Comparison of LUHG measurements between reader 1 and reader 2 demonstrated at stress, Pearson correlation r = 0.457, with an absolute intraclass correlation coefficient (ICC) = 0.608. At rest Pearson correlation r = 0.308 and absolute ICC = 0.417, as summarized in Table II.

**Joint laxity**

Elbow joint laxity was defined as the difference between measurements performed at maximum stress and average rest. For reader 1, median laxity was 0.8 mm (range: 0.4 – 1.1) and for reader 2 median laxity was 1.1 mm (range: 0.7 – 1.4). Agreement as measured by Pearson correlation was r = 0.161 and the absolute ICC = 0.252. All LUHG measurements and resulting laxity values are shown in Supplemental Table I.

**DISCUSSION**

PLRI is a common cause of elbow instability associated with persistent pain and the role of imaging in aiding diagnosis has been limited. The elbow remains the second most dislocated
joint in the body and PLRI is the most common pattern of associated instability\(^{16}\), which is discussed in detail by O’Driscoll et al.\(^{1,5}\) Whilst this is not the focus of this article it is important to note that the pattern of injury discussed in this article is focused on the lateral ulnar collateral ligament (LUCL) triggering progressive tearing of the soft tissues, capsule and stabilizing ligaments of the elbow in a lateral to medial and anterior to posterior path otherwise known as the arc of Horii\(^{1,5}\). It is important for the reader to be cognizant of other mechanisms of elbow injuries including beginning in the medial compartment although this is not the focus of this article. Clearly early detection of such an injury is of paramount importance to prevent significant morbidity. The most common setting to find this constellation of clinical features is trauma but it has been described in previous elbow surgery as well as with tennis elbow (lateral epicondylitis)\(^{13}\).

Multiple clinical tests exist to assess PLRI including the lateral pivot shift test, lateral pivot shift apprehension test, posterolateral rotatory drawer test, table top relocation test, active floor push up sign and chair sign\(^{15,16,17}\). Through combined external rotation of the forearm, axial and valgus loading, these tests place the elbow in a highly unstable position in order to reproduce the patient’s symptoms or displace the radial head. The resulting ‘stress’ on the joint can be uncomfortable. Whilst our test requires manipulation of the elbow to evaluate the ulnohumeral gap we believe patients can tolerate the examination. Thus far at the time of writing there is no literature report of imaging approaches allowing dynamic evaluation of patients with PLRI. Our novel study aims to define the US technique and its role in evaluating the LUHG whilst also assessing the usefulness of normative values in joint laxity.

This investigation demonstrates that US is a feasible imaging modality for demonstrating ulnohumeral widening in normal healthy live subjects with presumed low laxity when the posterolateral drawer stress maneuver is applied as a significant difference was found between
stress and rest conditions for both readers (p < 0.0001 for reader 1 and P = 0.0002 for reader 2). Interestingly, measurements obtained at rest and stress were similar to dimensions reported in a recent cadaveric study³, wherein a mean LUHG of 3mm at rest and 4mm at stress was reported resulting in a mean laxity of 1mm. In our study the average LUHG at rest was 2.3 mm for reader 1 and 2.1 mm for reader 2, whilst under stress 2.88 and 2.9 mm for reader 1 and 2 respectively. The Internal or Ulnar collateral ligament (UCL) was not assessed. Moderate Pearson correlation was shown whilst under stress r = 0.457 (absolute ICC = 0.608) with poor to moderate correlation at rest r = 0.308 (absolute ICC = 0.417). Median joint laxity however demonstrated poor agreement as per Pearson correlation with r = 0.161 and absolute ICC = 0.252.

Consistency and reliability in our measuring technique is more evident between readers in stress testing. This could perhaps be explained by the novel nature of this technique, which requires an element of dexterity. Both musculoskeletal fellowship trained radiologists were taught this technique by experienced musculoskeletal and elbow orthopedic attendings with a combined experience of thirty years. We were able to perform this examination and appropriate stress testing without assistance with relative ease, ultimately becoming comfortable with this technique within five practice attempts each. However, variation in normal anatomy between participants, for example the anatomy of crista supinatoris or patient positioning at rest may have contributed to the over or under estimation of LUHG at rest. This may account for the dis-concordant observer correlations inhibiting accurate laxity measurements as reflected by our lack of adequate reader agreement. We do believe however that non-radiologists can easily learn such an imaging technique performing it in a reasonable time delay to help facilitate a quick, non-invasive, reliable, adjunct to clinical examination as well as CT or MRI, which can aid diagnosis in the clinical setting.
The laxity measurement should also be further considered. Due to the variability in individual rest measurements it was necessary to utilize an average rest value in addition to maximum stress to calculate the maximum laxity. Reader agreement was poor with an absolute agreement of 0.161 and consistency of 0.252, neither of which reached statistical significance. Furthermore, laxity values were minute, 0.4 – 1.14 mm (reader 1) and 0.7 – 1.4 mm (reader 2). The usefulness of such data appears academic, particularly in a normal population. Our results suggest it is therefore perhaps more sensible to define an upper limit of normal (ULN) value for the LUHG and further studies should aim to evaluate a threshold diagnostic of PLRI.

Finally, the utility of this process in patients with significant discomfort following an acute injury is challenging. Such an examination must be performed with due diligence so as to not aggravate any injury and therefore US is not likely to have much benefit in aiding management in this setting. In-fact patients often have imaging and an examination under anesthetic (EUA) to help corroborate and confirm a diagnosis. Hence, we advise a dynamic ultrasound in these settings after a period of rest to maximize the effectiveness of the ultrasound process. A further study exploring this technique is currently recruiting participants.

It is important to note limitations in our study. We acknowledge that three rest measurements were taken in succession, followed by three stressed measurements. The sequence of testing was in this order as we were cognizant that performing rest measurements after stress maneuvers could alter the native rest measurement and falsely stretch the joint further creating spurious laxity data, thereby precipitating discrepancies in the rest measurements. As the study strives to evaluate technique, feasibility and report normative values, the applicability of the results to pathological settings (e.g. PLRI) is limited at present. However, the proposed imaging technique has been taught to incumbent musculoskeletal fellows who are currently recruiting patients with a clinical
diagnosis of PLRI for further ultrasound evaluation utilizing the technique described in this study
to define its utility in measuring the ULN of the LUHG.

A lack of experience in this novel technique and the smaller numbers of participants from a narrow
age group is a further limitation of the study.

Our study sought to define the role of US in evaluating the LUHG to define normative values in
joint laxity. The results suggest a beneficial adjunct to clinical examination as well as static
imaging. We also conclude that laxity per se may not be a useful measure in helping diagnose
PLRI and that defining an ULN of the LUHG could have more clinical utility. Furthermore, the
ability to learn this imaging technique is apparent, coupled with the relative ease, affordability,
study rapidity and the non-invasive nature of ultrasound, our findings describe a viable technique
for assessing PLRI. The next step for further evaluating posterolateral instability would require a
clinical ultrasound-MRI comparison and perhaps further research in this area should be focused
upon this correlate.

CONCLUSION

The current study provides new knowledge around the potential utility of US for diagnosis of PLRI
by outlining the LUHG measurements in both rest and stress as well as widening after applying
the posterolateral drawer stress maneuver in asymptomatic individuals.

REFERENCES


FIGURE AND TABLE LEGENDS

Figure 1: ultrasound probe positioning and clinical examination of the lateral ulnohumeral space

Figure 2a: representative US probe positioning with sonographic and MRI correlate for identifying the ulnohumeral gap. Move the probe craniocaudally using the bony acoustic landmarks as a guide (purple bars and yellow lines).

Figure 2b: Target site is highlighted (yellow bar and text)

Figure 3a: positioning and action of the examiner to elicit the posterolateral drawer test whilst scanning to assess the lateral ulnohumeral gap

Figure 3b: comparative sonographic images of the lateral ulnohumeral gap. Those of the left elbow provide an example of a patient with positive PLRI.

Video 1: demonstrating the ultrasound technique for assessing posterolateral drawer test and measurement of the elbow ulnohumeral gap.

Table I: Patient demographics

Table II: Reader correlation and agreement

Supplemental Table I: Gap measurements at rest and stress

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Table II: Reader correlation and agreement

Supplemental Table I: Gap measurements at rest and stress
Table 1: Patient demographics

<table>
<thead>
<tr>
<th>Demographic</th>
<th>N = 30</th>
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<tbody>
<tr>
<td>Age (Years)</td>
<td>33 (25-38)</td>
</tr>
<tr>
<td>Sex (Male)</td>
<td>17 (56.7%)</td>
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<td>Excluded</td>
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Table II: Reader correlation and agreement

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Pearson Correlation (Reader 1 vs Reader 2)</th>
<th>Absolute Correlation Coefficient (Reader 1 vs Reader 2)</th>
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<tr>
<td>Rest</td>
<td>0.308</td>
<td>0.417</td>
</tr>
<tr>
<td>Stress</td>
<td>0.457</td>
<td>0.608</td>
</tr>
<tr>
<td>Laxity</td>
<td>0.161</td>
<td>0.252</td>
</tr>
</tbody>
</table>
Tip of the lateral humeral epicondyle characterized by a pointed contour (this is proximal to the target site).

Distal lateral humeral epicondyle characterized by a more broad-based contour (this is proximal to the target site).
Place the probe on the lateral ulnohumeral space, holding it between thumb and index finger. The rest of the fingers (3rd-5th digits) of the same hand are placed on the volar aspect of the elbow joint just distal to the antecubital fossa (blue arrows). The other hand is placed on the distal humerus (purple arrow).

Transverse sonographic image of the lateral ulnohumeral joint in the “stress” position is demonstrated.

**Drawer Test:** A posterior and lateral/external rotation/valgus force is applied to the lateral ulnohumeral joint space via the 3rd-5th digits of one hand (curved blue arrow). The other hand stabilizes the humerus (purple arrow).
Transverse sonographic images of the lateral ulnohumeral joint in the “rest” and “stress” positions position is demonstrated.

The comparative left elbow of the patient was positive for PLRI, demonstrating the ultrasound technique, with a widened ulnohumeral gap (yellow lines).
Figure 1: Representative images of techniques for evaluating the ulnohumeral gap and performing stress maneuver.

A. Palpation of the ulnohumeral joint space

B. Positioning of the ultrasound probe transverse to the long axis of the humerus.

C. Ultrasound probe migrated distally to identify the bony acoustic landmarks of the trochlea and crista supinatoris of the ulna (ulnohumeral joint).

D. Positioning for performing the posterior draw test.
Figure 2: Representative images of US evaluation of the ulnohumeral gap at stress and rest. Cross hairs (white) denote measurement boundaries.
Position the ultrasound probe (blue bar) along this cleft/fossa, transverse to the longitudinal axis of the humerus.

With the patient in a seated position, place his forearm dangling on his side or front while in pronation. Palpate the lateral deltoid enteral space using the visible cleft or fossa in the skin as guide (blue arrow).