A Novel Technique for Detecting Instability of the Distal Radioulnar Joint in Complete Triangular Fibrocartilage Complex Lesions

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Abstract

We performed this study to investigate whether discrepancy of bilateral dorsovolar shift of the distal radioulnar joint (DRUJ) is decisive for the diagnosis of DRUJ instability. Although several cadaver studies have quantified the amount of physiological dorsovolar shift, so far, there is no reliable method of quantification of DRUJ mobility in daily practice. The aim was to describe a novel sonographic method of quantifying DRUJ instability and evaluate its reliability and validity. In this study, 40 healthy volunteers and 17 patients with complete rupture of the triangular fibrocartilage complex (TFCC) underwent sonographic quantification of the grade of instability of their DRUJ bilaterally. Dorsovolar ulnar head translation relative to the distal radius was quantified by means of ultrasonography performed in a transversal plane through the ulnar head and Lister tubercle. Measurements were done while actively pressing the volar surface of the hand onto a brick 30 degrees pronated, and after lifting the hand. A quotient Q of the radioulnar distance (distance between the dorsal radius surface and the ulnar head) between the unloaded and loaded wrist was calculated for differentiation of a normal and unstable DRUJ. The Q ratio of the 17 patients with unilateral TFCC lesion was significantly different between the pathologic side and the contralateral wrist (1.19 vs. 0.54, $p < 0.001$). There was no significant difference in the Q ratio in the 40 healthy volunteers between the right and left side or dominant and nondominant wrist. A Q ratio > 0.8 was found to be a reasonable cut-off for pathologic laxity of the DRUJ with a sensitivity of 88% and a specificity of 81%. A quotient Q > 0.8 determines instability of the DRUJ reliably. This was a level II diagnostic study.

Keywords

- physiological laxity
- instability
- unstable distal radioulnar joint
- triangular fibrocartilage complex lesions
- ultrasound

The distal radioulnar joint (DRUJ) is important for wrist function, not only for forearm rotations but also for load and force transmission.¹ A variety of studies have been published focusing on stability of the DRUJ: its capsule,² the triangular fibrocartilage complex (TFCC),^{3,4} the palmar and dorsal ligaments,^{5–9} the ulnocarpal ligaments,⁸ the interosseous membrane,^{10–12} the extensor carpi ulnaris,¹³ subsheath, the pronator quadratus,^{11,14,15} and the bony joint configuration⁸ have been identified as contributors to DRUJ

stability. However, the majority of these studies conclude that particularly the TFCC plays a key role in stabilizing the joint. Forced torque motions as well as weight-bearing activities of the hand lead to a physiological dorsovolar displacement in the DRUJ.¹⁶ This physiological translation has been investigated in several clinical and cadaver studies.^{16–20} The total dorsovolar translation with the forearm in neutral rotation was documented to be 8 to 9 mm in normal cadaveric joints subjected to externally applied forces. It has been suggested

that the actual amount of translation may be considerably less in *in vivo* measurements. Computed tomography (CT) has been suggested as the imaging modality of choice for evaluating DRUJ because it may be performed in varying positions of rotation to provide information on its dynamic state.^{11,16,19} Real dynamic situations with force against a resistance are not feasible in a magnetic resonance imaging (MRI) setting. Several studies on techniques to determine the amount of translation on CT have been published,^{21–23} with a moderate or high interobserver reliability.²⁴ In a CT study from 1991, Pirela-Cruz et al measured a dorsal translation of 2.8 mm and a volar translation of 5.4 mm.¹⁹

The dorsovolar shift in patients is used in daily practice for the clinical diagnosis of a traumatic or degenerative TFCC lesion. The presence of an increased translation in comparison to the contralateral healthy side may be due to a TFCC lesion and indicates a DRUJ instability. In patients with a tense contralateral DRUJ, the injured side can easily be recognized as unstable, but in several other patients with general laxity and therefore increased translation of the DRUJ on the control reference side, it might be clinically more challenging to assess undue translation. “Instability” in the DRUJ is still established as clinically subjective; reliable tests to quantify the dorsovolar shift are missing. Some studies present tests with CT, but these examinations are time-consuming, not repeatable, expensive, and not available at all times. Further, radiation exposure is a disadvantage of CT.

The aim of this level II diagnostic study was to find a noninvasive and simple method to reliably determine physiological dorsovolar translation in healthy volunteers for definition of normal mobility of the DRUJ by means of ultrasonography, and find a measure that can distinguish a normal from an unstable DRUJ.

Materials and Methods

Two groups were formed. Group 1 ($n = 40$, mean age of 32.25 years) included 18 healthy men and 22 women without any history of wrist pain, previous hand or wrist trauma, previous surgery, or any history of acute or chronic rheumatic diseases. Of these 40 subjects, 4 were left-handed and 36 were right-handed. The second group (Group 2, $n = 17$) included patients with a complete TFCC lesion on one wrist that was proved in a preoperative MRI scan and confirmed by intraoperative findings. A lesion was defined as complete when the TFCC was fully detached from the fovea or radial sigmoid notch. The diagnosis was done intraoperatively through arthrotomy. The indication for operative reconstruction was chronic pain and symptomatic instability in patients with manual jobs. Complete ulnar detachment ($n = 13$) was the most common finding. Complete radial detachment was seen in only two patients and complex central lesions with complete palmar and dorsal ruptures were also seen in two patients. All patients were treated with reconstruction of the TFCC complex using the palmaris longus or an extensor tendon graft and an ulnar shortening, if a preoperative ulnar plus variance was present.²⁵ Group 2 included eight females and nine males with a mean age of 36.53 years (range, 15 to

63 years, standard deviation [SD] 12.96), all of them right-handed. The exclusion criteria included presence of any incomplete lesion, such as central lesions without rupture of both dorsal and volar radioulnar ligaments, and/or ruptures of only the superficial limb or only the deep part. Patients with wrist pain but no documented TFCC lesion in MRI or intraoperatively were also excluded from this study. The main reason for TFCC rupture was fall on the extended wrist and wrist sprain ($n = 11$). One of the patients showed an osteoligamentous avulsion at the radial insertion; five patients had a concomitant fracture (two Galeazzi fractures, two distal radius fractures, and one ulnar styloid fracture); and in one patient, the lesion resulted from a direct trauma to the wrist. All fractures had been primarily treated by surgery actively elsewhere.

All ultrasound examinations were performed with a high-resolution linear array transducer with 17–5 MHz frequency range (iU22 Ultrasonography System, Philips Medical Systems, Best, The Netherlands) by the same two independent observers, one an experienced musculoskeletal radiologist and the other an experienced hand surgeon.

Measurement Technique

Subjects sat on a chair beside a mobile measurement table in a comfortable position opposite the examiner. Both hands were subsequently positioned in a standardized manner (→ **Fig. 1**): the shoulder was abducted at 60 degrees and the elbow was placed on a pillow and flexed to 90 degrees. The hand was positioned in pronation of 30 degrees on a square brick such that the forearm was in a horizontal position. The brick was placed below the metacarpus and the stretched fingers so that the pisiform bone was just above it.

The transducer was placed dorsally above the DRUJ, perpendicular to the longitudinal axis of the ulna. The dorsal surface of the distal radius and the center of the ulnar head were displayed on the screen and the distance between them was measured. To determine the same measurement level in each volunteer, the highest aspect of the ulnar head was taken.

Measurements were performed on a picture archiving and communication system workstation (Cedara, Mississauga, Ontario, Canada). The first measurement was done without applying any force (→ **Fig. 2**). This was ensured by lifting the hand from the brick so that the ulnar head shifted to the most dorsal position. The distance between the dorsal surface of the ulnar head and the dorsal surface of the distal radius (X_1 , → **Fig. 2**) was measured in a dorsovolar direction. The osseous plane at the ulnar side of Lister tubercle (floor of the fourth extensor compartment) served as a reference plane for measurements to exclude irregularities caused by the Lister tubercle. The second measurement (X_2) was done while the volunteer pressed the hand flat onto the brick with maximal force so that the ulnar head shifted to the most palmar position. X_2 defines the distance between dorsal surfaces of the distal radius and the ulnar head. When the ulnar head passes the volar to the line or plane of the dorsal surface of the radius, X_2 becomes a negative value. With the described maneuver (volar pressing), the dorsal radioulnar ligament

Figure 1 Position of the individual during the measurement procedure. The hand was positioned pronated 90 degrees on a square brick and the elbow put on an oval pillow such that the whole forearm was positioned horizontally. The shoulder was abducted at 30 degrees and the elbow was placed on a pillow with the elbow flexed to 90 degrees. The palm of the hand is laid completely onto the brick with the os pisiform positioned near the edge of the brick.

is stressed particularly and tested, while the volar ligament is under limited load only during the hand lift and might not experience the whole amount of translation that is possible. A total of eight sonographic images (two of each wrist, two examiners) were obtained for each volunteer. Each high-resolution sonographic image was captured at the level of the maximum diameter of the ulnar head.

To determine the amount of ulnar head dislocation based on the pressure force applied by the volunteer, we used a weighing scale instead of the square brick. Measurements were done on 5 volunteers, on both sides (10 wrists). Five sonographic pictures of each volunteer was captured. The first one was done unloaded followed by 2.5, 5.0, 7.5, and 10 kg of pressure. The distance between the dorsal ulnar head surface and the dorsal radial surface was measured in each condition as described above.

Calculation

Prestudy tests and clinical observations of healthy volunteers allow us to assume that the ulnar head usually does not drop under the dorsal radius surface in a stable, uninjured DRUJ while performing the maneuver described above, except in patients with marked preexisting laxity in both wrists. In patients with a complete TFCC lesion the ulnar head usually drops that level, while the contralateral healthy side is tighter and does not reach the level of the dorsal radius surface. Therefore, a quotient Q was designed to express the relationship between the ulnar head and the dorsal radial surface. X_1 describes the radioulnar distance in the unloaded (hand

Figure 2 (A and B) Sonography of a healthy wrist. X_1 represents the distance between the dorsal surface of the ulnar head (UH) and the dorsal surface of the distal radius (DR). (A) For a reliable measurement the Lister tubercle (LT) must be displayed completely. (B) While pressing the hand flat onto the brick, the UH dislocates to the volar side and X_2 can be measured. (C and D) The same situation is seen in a wrist diagnosed with complete triangular fibrocartilage complex rupture. In the loaded position the UH drops below the level of the dorsal surface of the radius. EDC, extensor digitorum communis tendons; EPL, extensor pollicis longus.

lifted up) position. X_2 describes the radioulnar distance during maximal pressure force; its value becomes negative when the head drops the volar to the dorsal radius surface. Q expresses the quotient of the complete dorsovolar translation and the radioulnar distance in the unloaded position.

$$Q = \frac{X_1 - X_2}{X_1}$$

With this quotient, if the ulnar head stays above the dorsal radial surface during pressure, Q stays below 1. If the ulnar head drops below the dorsal radial surface, Q becomes greater than 1.

Results

Influence of Pressure Force

The relationship between the amount of radioulnar translation ($X_1 - X_2$) and the pressure force is shown in ▶Fig. 3. There was no significance in dislocation either between 5 and 7.5 kg or between 5 and 10 kg ($p > 0.1$). The maximum was

Figure 3 Relationship between pressure force and the radioulnar distance. The distance in the unloaded setting (0 kg) was taken as 100%.

reached after 5 kg; a higher pressure force did not further increase the amount of translation (→Fig. 3).

Normal Controls (Group 1)

The quotients of the dominant side (0.63 ± 0.27) and the nondominant side (0.65 ± 0.28) were not significantly different ($p = 0.44$). Therefore, for further analysis, each wrist was used individually to enhance the sample size of the control group from 40 to 80 wrists. The overall interobserver agreement of sonographic measurements, as measured by Pearson correlation, was high for the amount of translation ($r = 0.8307$, $p < 0.0001$).

The average total dorsovolar translation of all 80 wrists was 2.5 mm (SD = 1.03). Differences between both wrists were small (mean 0.65 mm; min 0, max 1.65). Only seven patients (17.5%) showed a difference of > 1.0 mm between both wrists.

Unstable DRUJ (Group 2)

In eight patients, the TFCC lesion concerned the dominant wrist and in nine patients, the nondominant wrist. All TFCC ruptures were diagnosed with preoperative wrist MRI and later confirmed intraoperatively.

Q was determined for the pathological side with a TFCC lesion (Q_{PATH}). Q_{CONT} includes the contralateral healthy side ($n = 17$) and was significantly different from Q_{PATH} ($p < 0.001$) (→Fig. 4). There was also a significant difference ($p < 0.001$) when Q_{PATH} was compared with all healthy wrists ($n = 97$). The mean of Q_{PATH} was 1.19 ± 0.45 in contrast to Q_{CONT} of 0.62 ± 0.27 ($p < 0.0001$).

Additionally, there was no significant difference in the amount of radioulnar distance (X_1) in the unloaded wrist between the healthy and the pathological sides ($p = 0.12$).

The average dorsovolar translation of the pathological wrists was 5.1 mm (min 2.4, max 7.1). Differences between both wrists were larger than in the healthy group (mean 2.80 mm, min 0.75, max 5.18). The difference between the healthy and the pathological wrists was < 1.0 mm in only one patient (2.5%).

Cut-Off

To achieve a clinically reasonable cut-off and an optimal relation of specificity and sensitivity, the distribution of the

Figure 4 Distribution of the calculated Q for the pathological group Q_{PATH} ($n = 17$) and the control group $Q_{CONTROL}$ ($n = 97$).

Qs of both the pathological and the healthy DRUJs was drawn and the cut-off of 0.8 was determined to achieve a specificity and sensitivity of the interindividual control (pathological side vs. healthy side of Group 2 of both 88%). With that cut-off, the comparison of all healthy wrists (Group 1 and the healthy side of Group 2, $n = 97$) and all wrists with TFCC lesions ($n = 17$) showed a sensitivity of 88% and a specificity of 81%.

Discussion

Traumatic and degenerative TFCC lesions are common clinical entities in daily practice, and the clinical assessment of the dorsovolar translation in comparison to the contralateral healthy side is the most common method for detecting instability. The presence of increased translation in comparison to the contralateral healthy side is consistent with instability and may be symptomatic, which is an indication for ligament reconstruction. In patients with generalized ligamentous laxity, it is more challenging to determine if this degree of laxity is pathological. Several methods have been described to quantify the amount of dorsovolar translation based on CT, such as the radioulnar line method,²² the congruity and epicenter methods,²³ and the radioulnar ratio method.²¹ The aim of this study was to assess the use of ultrasound as a noninvasive, cost-effective, simple, and rapid method to assess the degree of physiological dorsovolar translation in healthy volunteers as well as in patients with trying fibrocartilage tears.

The advantages of sonography, such as rapid availability and low costs, are well known and sonography of the musculoskeletal system is widely performed by radiologists, hand surgeons, and rheumatologists. The settings of the measurement technique are simple and the score can easily be calculated. As sonography is highly dependent on the examiner, the measurement of the ulnar head translation may vary

especially when patients press their hands on the brick, which can introduce an error. In addition, the distal dorsal radius surface is usually not completely flat and varies from individual to individual, especially after a fracture of the distal radius or forearm. The position of the Lister tubercle also may vary. It is therefore important to keep the ultrasound probe at the same level both during measurements at rest and with volar pressure. The base of the Lister tubercle should be identified with ultrasound but only the radial aspect of the tubercle should be used as a reference point to measure the degree of ulnar head translation (→Fig. 2). The amount of radioulnar translation is dependent on the amount of force exerted. A strong person may exert more force which can result in greater degrees of displacement of the ulna. Wrist pain due to an injury also might inhibit the patient from pressing. But this was not seen in our series. We investigated this in a group of 5 healthy volunteers (10 wrists) by using a weighing scale and a force of 5 to 10 kg. While pressing the flat hand with 5 kg of force on the brick, the dorsal part of the TFCC is tightened, which prevents any further volar translation of the ulnar head. The results of the total dorsovolar in vivo translation are comparable with the data reported in the literature.¹⁹ Compared with cadaveric studies, the amount of translation is considerably less because of changes in the tissue characteristics and the absence of dynamic good stability through muscular contraction. Although it was shown that even if the exerted pressure was greater than 5 kg there was no further increase in the palmar translation of the ulna, but the pressure distribution over the palm itself (thenar vs. hypothenar) may have an influence on the degree of translation. Therefore, the patient should be instructed to apply the force mainly through the hypothenar eminence. With the described maneuver (volar pressing) the dorsal radioulnar ligament is stressed particularly and tested whereas the volar radial ulnar ligament is under limited load which may cause minimal ulnar head translation and can therefore not be assessed by this test. A quotient $Q \geq 0.8$ was most likely pathological if the contralateral side was normal ($Q < 0.8$). An absolute difference of >1 mm was also highly suspicious for DRUJ instability.

The limitations of this study include small sample size and examination of only one type of destabilizing wrist pathology. Furthermore, instability in supination was not tested. Some degree of dorsal subluxation exists in the general population unrelated to foveal tears, which cannot be detected due to the small sample size.

In conclusion, the quotient that is described in the study is a clinically useful and rapid tool for assessing instability of the distal radioulnar joint. It may have value as a predictive factor in assessing the efficacy of the DRUJ reconstruction but further studies are required to establish this.

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