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Validity of Musculoskeletal Ultrasound for Identification of Humeroradial Joint Chondral Lesions: A Preliminary Investigation

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Context: Epicondylalgia is a common condition involving pain-generating structures such as tendon, neural, and chondral tissue. The current noninvasive reference standard for identifying chondral lesions is magnetic resonance imaging. Musculoskeletal ultrasound (MUS) may be an inexpensive and effective alternative.

Objective: To determine the intrarater reliability and validity of MUS for identifying humeroradial joint (HRJ) chondral lesions.

Design: Cross-sectional study.

Setting: Clinical anatomy research laboratory.

Patients or Other Participants: Twenty-eight embalmed cadavers (14 women, 14 men; mean age = 79.5 ± 8.5 years).

Main Outcome Measure(s): An athletic trainer performed MUS evaluation of each anterior and distal-posterior capitellum and radial head to identify chondral lesions. The reference standard was identification of chondral lesions by gross macroscopic examination. Intrarater reliability for reproducing an image was calculated using the intraclass correlation coefficient (3,k) for measurements of the articular surface using 2 images. Intrarater reliability to evaluate a single image was calculated using the Cohen κ for agreement as to the presence of chondral lesions. Validity was calculated using the agreement of MUS images and gross macroscopic examination.

Results: Intrarater reliability was 0.88 (95% confidence interval = 0.77, 0.94) for reproducing an image and 0.93 (95% confidence interval = 0.80, 1.06) for evaluating a single image. Identifying chondral lesions on all HRJ surfaces with MUS demonstrated sensitivity = 0.93, specificity = 0.28, positive predictive value = 0.58, negative predictive value = 0.77, positive likelihood ratio = 1.28, and negative likelihood ratio = 0.27.

Conclusions: Musculoskeletal ultrasound is a reliable and sensitive tool for a clinician with relatively little experience and training to rule out HRJ chondral lesions. These results may assist with clinical assessment and decision making in patients with lateral epicondylalgia to rule out HRJ chondral lesions.

Key Words: elbow joint, articular cartilage, reliability, assessment

Key Points

- When used by a clinician with limited experience and training, musculoskeletal ultrasound imaging was reliable and sensitive for ruling out humeroradial joint chondral lesions.
- More study is needed, but musculoskeletal ultrasound imaging may be helpful in assessing and managing patients with lateral epicondylalgia.

The elbow is one of the joints most commonly affected by articular cartilage degeneration and loosening of chondral fragments.[1] Chondral lesions and articular cartilage degeneration primarily occur in the lateral compartment of the elbow within the humeroradial joint (HRJ).[2–4] Although HRJ chondral lesions can occur secondary to acute trauma, they may be present in the absence of trauma.[5]

Lateral elbow conditions occur in a variety of sports,[6] and up to 50% of overhead athletes experience elbow injuries.[7] In overhead athletes, valgus extension overload is observed during the late cocking phase of throwing.[8] This results in significant compression forces of up to 500 N on the HRJ, which can lead to chondral lesions.[8,9] In the general population, HRJ chondral lesions have been demonstrated in 51% to 81% of patients with chronic lateral elbow pain.[5,10] Articular cartilage lesions are easily misdiagnosed as tendinopathy of the wrist extensors because they have similar clinical presentations.[5,11] Symptoms include insidious onset of lateral elbow pain, pain with resisted wrist extension, and failure to respond to conservative treatment.[5] To our knowledge, no validated clinical examination exists for the differential diagnosis of HRJ chondral lesions from lateral epicondylopathy.

The current noninvasive reference standard for the diagnosis of chondral lesions is magnetic resonance imaging.[12] Musculoskeletal ultrasound (MUS) is a safe and inexpensive alternative imaging technique that is effective in showing articular cartilage abnormalities and loose bodies,[1,13] although most research to date has focused on the hip, knee, and hand.[12,14,15] At the elbow joint, several authors[16,17] have demonstrated validity for detecting loose bodies with MUS. However, we know of no authors who have evaluated the validity of MUS for identifying HRJ chondral lesions.

Traditionally, radiologists perform and interpret MUS examinations.[18] More recently, the use of MUS has expanded to sports medicine clinicians, physiotherapists, and athletic trainers.[18–21] As the use of MUS extends into clinics and athletic training facilities, the reliability of clinicians' examinations with MUS must be expanded because the technique is user dependent.[22] Furthermore, it is critical to establish whether the performance of such clinicians is equal to that of expert technicians. However, before interrater reliability can be evaluated, MUS must be validated for identifying HRJ chondral lesions to determine its usefulness.

Although our purpose was not to establish the reliability of clinicians' use of MUS, we know that for a tool to be valid, it must be reliable.[23] Therefore, the purposes of our study were to (1) investigate the intrarater reliability and validity of an athletic trainer to identify chondral lesions in the HRJ using MUS and (2) determine the prevalence of HRJ chondral lesions in elderly specimens. We hypothesized that an athletic trainer would be reliable at reproducing and evaluating MUS images and accurate in identifying chondral lesions at the HRJ using MUS.

METHODS

Research Design

We selected a cross-sectional design to examine the reliability and validity of a clinician using MUS to identify chondral lesions at the HRJ. The reference standard was gross macroscopic examination.

Participants

We assessed a convenience sample of 28 embalmed cadavers obtained through the institutional willed body program at the local university. We recorded the demographic information, measured the specimen's height using a tape measure, and measured available elbow range of motion for flexion, extension, pronation, and supination using a goniometer. All demographic and anthropometric measurement data are reported in Table 1. Exclusion criteria were above-elbow amputation or presence of a fracture at or near the HRJ.

Examiner

The lead author (C.M.L.), who had 2 years of hands-on MUS experience but no formal MUS training or practice in HRJ MUS evaluation, collected and analyzed the MUS images. The examiner's training consisted of approximately 20 hours of informal training sessions with a radiologist and subsequent clinical use during employment as a physician extender at an orthopaedic sports medicine clinic. The examiner was blinded during reliability testing and analysis of the MUS images to identify chondral lesions.

Procedures

Pilot Testing. The examiner performed a preliminary MUS evaluation on 1 embalmed cadaver to ensure proper visualization of the HRJ structures. Once visualization of articular cartilage was confirmed, the examiner performed pilot testing for practice (approximately 10 hours) and preliminary reliability analysis in which 10 sets of images were collected and analyzed.

Musculoskeletal Ultrasound Imaging. The examiner evaluated the capitellum and radial head of bilateral elbows in 28 cadavers ($n = 56$) with MUS for the presence of chondral lesions. The examiner captured 8 images each of the anterior surface and the distal-posterior surface of each HRJ, for a total of 16 images examined per elbow.

To assess the anterior HRJ, the examiner prepositioned each elbow in end-range extension and supination. She placed the MUS transducer (model LA523 with 7.5- to 12-MHz linear array; Esaote North America, Inc, Indianapolis, IN) along the long axis on the anterior surface to visualize the HRJ in the sagittal plane (Figure 1A). Two images of both the capitellum and radial head were captured to ensure complete visualization of the entire articular surface. The examiner then rotated the transducer 90° along the short axis to visualize the HRJ in the transverse plane (Figure 1B). Again, 2 images of both the capitellum and radial head were captured to visualize the entire articular surface.

To assess the distal-posterior HRJ, the examiner prepositioned each elbow in end-range flexion and supination. The examiner followed the same imaging procedure for the distal-posterior surface to capture 4 images each of the distal capitellum and the posterior radial head (Figure 1C and D).

The MUS imaging procedures took less than 7 minutes per elbow to complete. All 16 images were stored on the MUS hard drive (model MyLab25; Esaote North America, Inc). The examiner evaluated each image for chondral lesions approximately 1 week after capturing the images. Before examining the images for chondral lesions, she evaluated each image for quality and classified it as *good* or *poor*. A poor image had evidence of imaging artifacts, such as refraction, reverberation, or speed-of-sound artifact

Table 1. Demographic Information for the Cadavers

Variable	n	Mean ± SD	Minimum	Maximum
Age, y	27	79.5 ± 8.5	58.0	91.0
Height, cm	27	166.3 ± 8.2	147.3	185.4
Weight, kg	27	73.0 ± 11.9	49.9	93.0
Body mass index	27	26.4 ± 3.9	19.6	36.8
Elbow-flexion range of motion, °	53	104.4 ± 15.4	75.0	140.0
Elbow-extension range of motion, °[a]	53	–3.0 ± 3.4	–14.0	0.0
Forearm-supination range of motion, °	53	76.5 ± 9.5	50.0	90.0
Forearm-pronation range of motion, °	53	72.8 ± 16.6	25.0	91.0

[a] Negative value indicates extension lag.

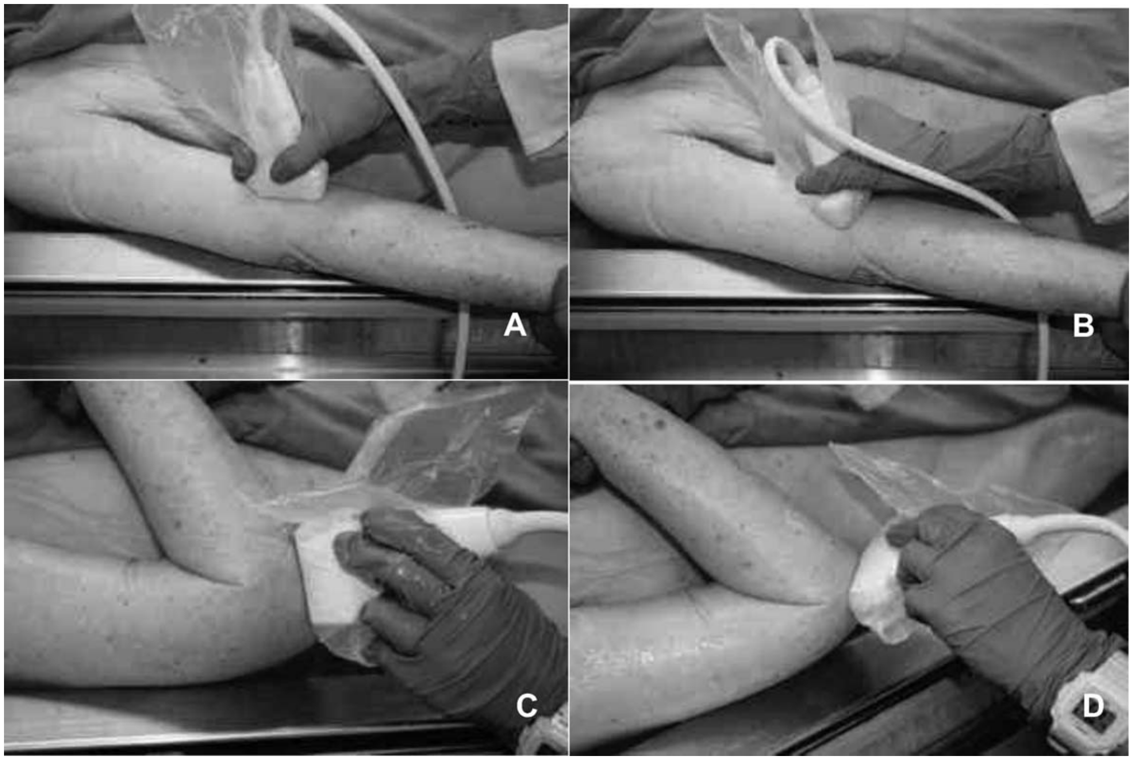

Figure 1. Musculoskeletal ultrasound imaging procedure with placement of the transducer for visualization of the following: A. Anterior capitellum along the long axis in the sagittal plane. B. Anterior capitellum along the short axis in the transverse plane. C. Posterior capitellum along the long axis in the sagittal plane. D. Posterior capitellum along the short axis in the transverse plane.

secondary to examiner imaging error.[24] All images classified as poor were excluded from analysis.

A good image was positive for a chondral lesion if at least 2 of the 3 following factors were noted in both the sagittal and transverse views: (1) loss of the sharpness of the edges of the hypoechoic band, (2) loss of the homogeneity of the distribution of the hypoechoic band, or (3) thinning of the cartilage to <1 mm (Figure 2).[25]

Reliability Testing Procedure. In 10 randomly selected elbows, the examiner performed MUS imaging on 2 days within 1 week's time to evaluate intrarater reliability for reproducing comparable images. The blinded examiner measured the width and length of the capitellum and radial head on both sets of the respective image. The average of 3 measures for each image was used for analysis. To evaluate intrarater reliability for identifying chondral lesions on MUS images, the blinded examiner evaluated the first set of images twice within a 2-week period to determine the presence or absence of a lesion.

Cadaveric Dissection. After completing the MUS imaging, the examiner dissected each elbow of all the soft tissues using standard dissection techniques. The examiner carefully disarticulated the HRJ and macroscopically evaluated the capitellum and radial head for chondral lesions. Each bony surface was divided into 2 equal coronal sections to evaluate the anterior and distal-posterior surfaces separately for chondral lesions. Chondral lesions were identified using a previously published grading scale (Table 2).[3] As suggested by Debouck and Rooze,[3] grades 0 and 1 were considered absent of chondral lesions for our analysis.

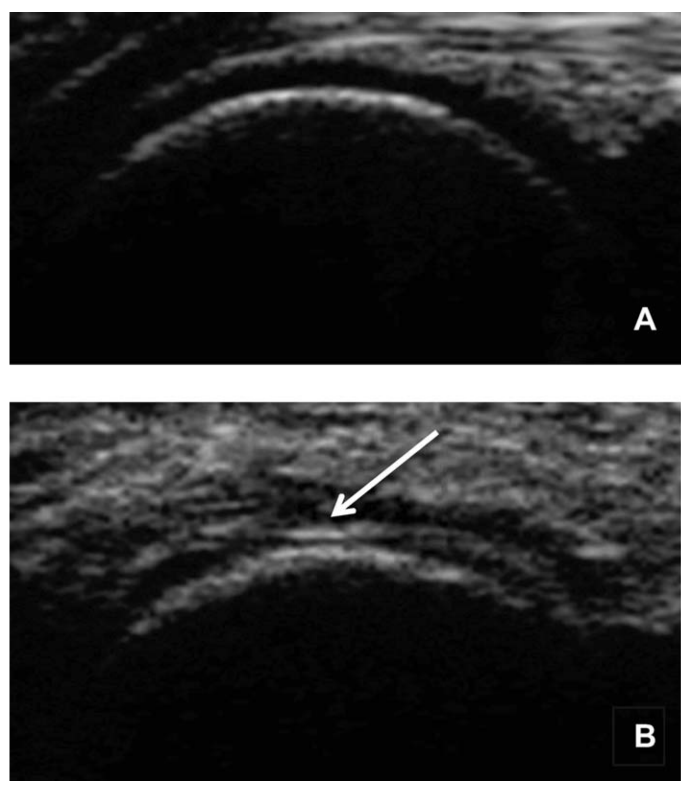

Figure 2. Musculoskeletal ultrasound images. A, Normal cartilage on anterior capitellum (hypoechoic band). B, Chondral lesion on anterior capitellum (arrow).

Table 2. Chondral Lesion Grading Scale[a]

Grade	Description
0	Absence of lesions
1	Minor lesions: roughening of the cartilage and beginning of the appearance of tears
2–4	Major lesions
2	Ulceration
3	Major ulceration with erosion of the deeper layers of cartilage
4	Eburnation

[a] From Debouck C, Rooze M. A topographical study of cartilaginous lesions to the elbow. *Surg Radiol Anat*. 1995;17(4):301–305. ©Springer-Verlag France 1995, permission granted by Springer-Verlag.

Statistical Analysis

Data were analyzed with IBM SPSS (version 20.0; IBM Corporation, Armonk, NY). Intrarater reliability for reproducing a MUS image was determined using the intraclass correlation coefficient (3,k). Intrarater reliability for analyzing MUS images for the presence of chondral lesions was determined using the Cohen κ. Validity testing was conducted for the anterior and distal-posterior capitellum and radial head to determine the sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, and negative likelihood ratio for the agreement of MUS image examination and the reference standard (direct macroscopic visualization) in identifying chondral lesions. Prevalence was calculated as the ratio of the number of elbows with a chondral lesion (via direct macroscopic visualization) to the total number of elbows included in the study.

RESULTS

Of the 56 elbows evaluated, 3 were excluded from evaluation (2 due to excessive body mass index [>36], resulting in an inability to visualize the HRJ with MUS, and 1 due to a distal humerus fracture). The remaining 53 elbows were examined by MUS, producing 848 images. Of the 848 MUS images, 37 (4.4%) were excluded from analysis because of poor quality.

Reliability and Validity

Intrarater reliability (intraclass correlation coefficient [3,k]) for reproducing the HRJ measurements of a MUS image for the width and length of the capitellum and radial head was 0.88 (95% confidence interval = 0.77, 0.94). The overall percentage of exact agreement of the MUS images for the presence or absence of a lesion was 97% (38 of 39 images) with $\kappa = 0.93$ ($P < .001$, 95% confidence interval = 0.80, 1.06). Sensitivity, specificity, false-positive rate, false-negative rate, positive predictive value, negative predictive value, positive likelihood ratio, and negative likelihood ratio for MUS images compared with gross macroscopic examination are presented in Table 3. Overall, the percentage of exact agreement between MUS and gross macroscopic examination for the presence or absence of a lesion was 60% (124 of 205 surfaces).

Prevalence

Gross macroscopic examination revealed that 52.2% (107 of 205) of the surfaces evaluated had chondral lesions. Frequencies of each stage of chondral lesions are presented in Figure 3. Photographic samples of each grade are presented in Figure 4. Prevalence of HRJ chondral lesions was 89% (47 of 53 elbows).

DISCUSSION

To our knowledge, we are the first to examine the reliability and accuracy of an athletic trainer to detect HRJ chondral lesions using MUS imaging. We found that a novice clinical sonographer had good reliability (intraclass correlation coefficient [3,k] = 0.88) for reproducing MUS images and excellent agreement (97%, $\kappa = 0.93$) when examining MUS images for chondral lesions. It is striking to find such high reliability values for a novice sonographer because MUS is known to be user dependent.[22] Additionally, each MUS examination took less than 7 minutes to complete. These findings suggest that even with limited experience and in the absence of formal training, a clinician can efficiently use MUS for the HRJ with excellent reliability. Although we acknowledge that the primary goal of this study was not to establish MUS as a widespread, clinically reliable tool, the reliability is a requisite component to substantiate its validity.

Our study supports previous evidence of a high prevalence of chondral lesions in the HRJ.[2–4] Nevertheless, because of discrepancies in methods, direct comparison of prevalence values could not be performed. Other authors have reported such high prevalence in patients with chronic tendinopathy of the wrist extensors, suggesting that the chondral lesions were the cause of symptoms of the tendinopathy, the initial diagnosis was incorrect or

Table 3. Validity Values for Identifying Humeroradial Joint Chondral Lesions With Musculoskeletal Ultrasound Versus Gross Macroscopic Examination

Site or Grade	Sensitivity	Specificity	False-Positive Rate	False-Negative Rate	Positive Predictive Value	Negative Predictive Value	Positive Likelihood Ratio	Negative Likelihood Ratio
All humeroradial joint surfaces	0.93	0.28	0.72	0.07	0.58	0.77	1.28	0.27
Radial head	0.94	0.05	0.95	0.06	0.61	0.33	0.99	0.07
Capitellum	0.91	0.44	0.56	0.09	0.55	0.86	1.62	0.21
Anterior	0.94	0.36	0.64	0.06	0.70	0.78	1.46	0.18
Posterior-distal	0.91	0.22	0.78	0.09	0.47	0.76	1.17	0.41
Grade 0,1,2[a]	0.91	0.28	0.72	0.09	0.27	0.87	1.26	0.32
Grade 0,1,3[a]	0.87	0.28	0.72	0.13	0.28	0.87	1.20	0.47
Grade 0,1,4[a]	1.00	0.28	0.72	0.00	0.30	1.00	1.38	0.00

[a] Grade 2–4 lesions compared with grades 0 and 1.

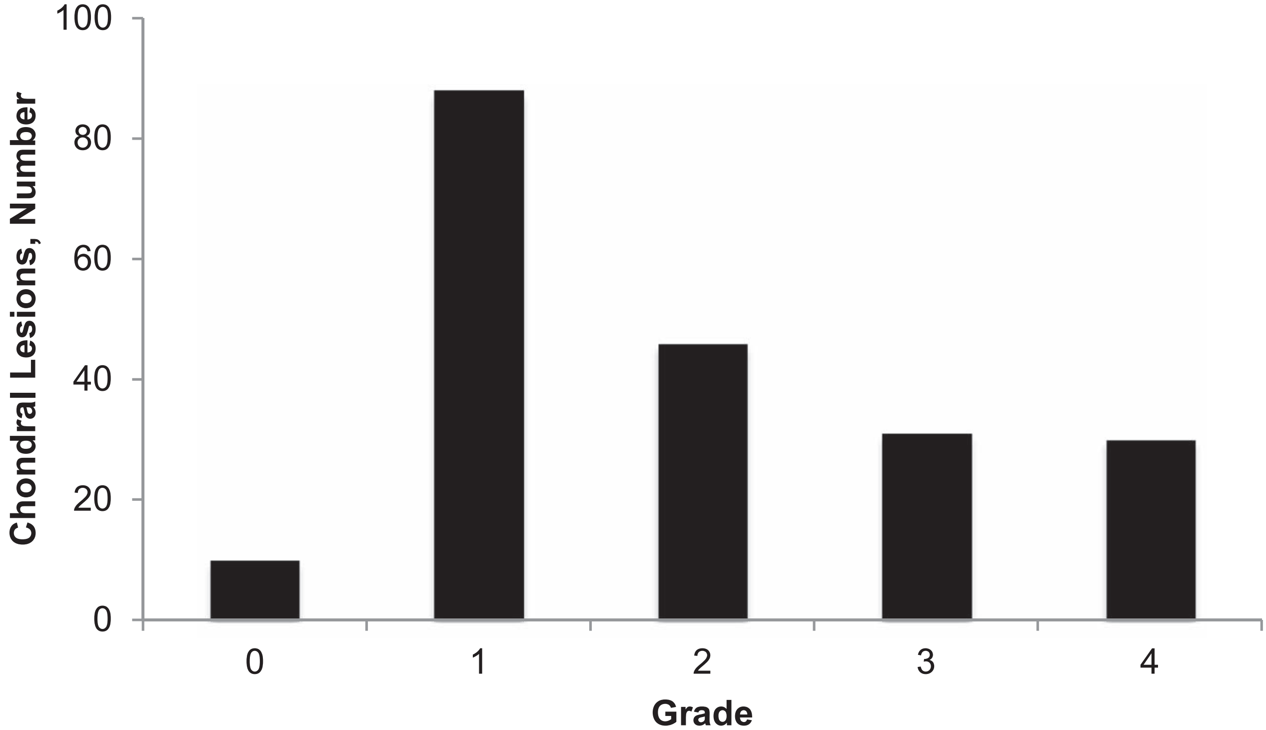

Figure 3. Frequency of different grades of chondral lesions.

incomplete, or the presence of tendinopathy altered the mechanical pattern, ultimately leading to articular wear.[5,10] An incorrect diagnosis of chronic tendinopathy and subsequent management may perpetuate complaints of chronic, unresolved symptoms. It is important to recognize the potential sequelae with regard to the timing of the accurate diagnosis, particularly if improper management is causing further insult to the articular surfaces. These conclusions raise a question as to why chondral lesions are underdiagnosed.

The underdiagnosis of HRJ chondral lesions may lie in the absence of validated clinical examination testing and accessible diagnostic imaging. Proper diagnosis is essential as it may alter the course of treatment and interventions. The current noninvasive reference standard for diagnosis of chondral lesions is magnetic resonance imaging.[12] Even though magnetic resonance imaging and computed tomographic arthrography exhibit comparable validity for evaluating chondral lesions in the elbow,[26] some authors[27] reported that neither technique was accurate enough to assess the thin cartilage in the elbow. These diagnostic imaging examinations are somewhat effective, but they present concerns for many patients, including financial burdens, exposure to radiation, and small spaces (which may be problematic if the patient is claustrophobic). In 1 study,[27] the best method for evaluating patients with chronic lateral elbow pain was direct visualization with elbow arthroscopy, despite its invasiveness.

Our results demonstrate that identifying HRJ chondral lesions with MUS was highly sensitive (0.93) but lacked specificity (0.28). The negative likelihood ratio was 0.27, which indicated a decrease in the likelihood of having a chondral lesion with a negative MUS examination. The low specificity, positive predictive value, and positive likelihood ratio indicate that this method may not be ideal for ruling in a chondral lesion with a positive examination due to the high false-positive rate. However, the high sensitivity and negative predictive value, combined with the low negative likelihood ratio, suggest that MUS could accurately rule out HRJ chondral lesions with a negative examination. This proposal is further supported by the low false-negative rates. These values vary when examining different surfaces and different grades of chondral lesions, as shown in Table 3. Of particular interest are the sensitivities and negative likelihood ratios for the radial head (0.94 and 0.07, respectively), the anterior surface of both the radial head and capitellum (0.94 and 0.18, respectively), and grade 4 lesions (1.00 and 0.00, respectively). Thus, a negative examination with MUS in these specific areas should provide a clinician with confidence in ruling out the presence of a chondral lesion.

Although the overall agreement (60%) for the presence or absence of a lesion was not particularly compelling, this value is comparable with previous findings of MUS validity for identifying chondral lesions in other joints.[15,28,29] In our study, this seemingly moderate percentage of agreement was due in part to the high sensitivity of the MUS to identify chondral lesions. This meant that MUS would more often identify grades 0 or 1 (considered normal[3]) as grades 2 or 3, thereby lowering the accuracy and the agreement between MUS and gross macroscopic assessment.

It was beneficial to capture 2 images in both the sagittal and transverse views for each chondral surface to ensure that the entire surface was examined and reduce the number of chondral lesions missed with MUS. Of all 168 lesions, only 8 (all stages 2 and 3) were missed by MUS, whereas no grade 4 lesions were missed.

Other researchers[30] have demonstrated that MUS displays similar specificity values as magnetic resonance imaging for detecting chronic soft tissue lesions associated with

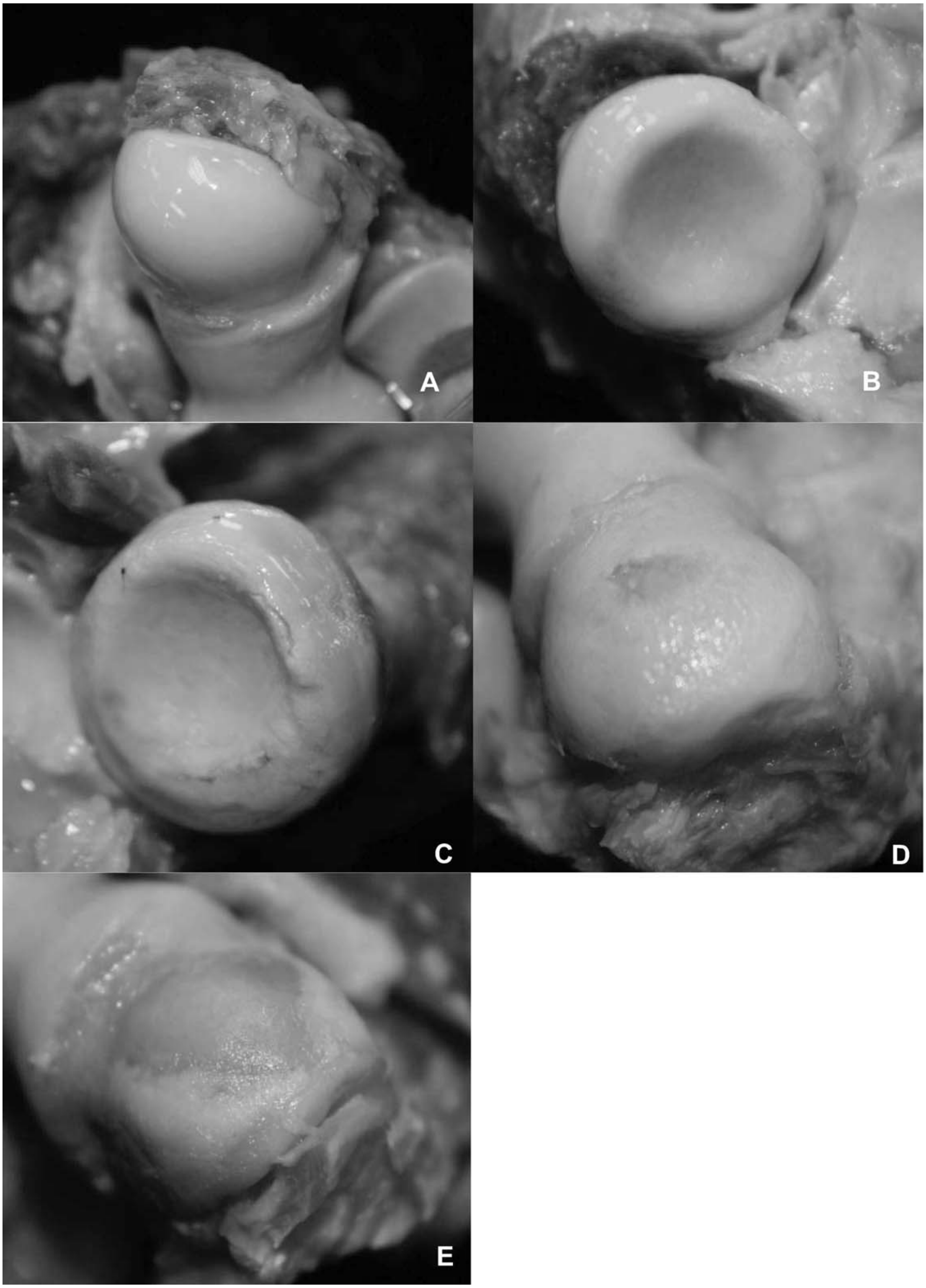

Figure 4. Gross macroscopic chondral lesion grades: A, Grade 0. B, Grade 1. C, Grade 2. D, Grade 3. E, Grade 4.

chronic tendinopathy of the wrist extensors and is more cost effective. Considering these findings along with our results, we suggest that MUS may be a practical and efficient method to assist in the clinical assessment of lateral elbow pain.

We showed that MUS is a sensitive tool to identify chondral lesions in cadaveric specimens. Although this study has provided crucial information for determining the clinical application and usefulness of this tool, future investigators should evaluate interrater reliability to compare the performance of different health care practitioners. Furthermore, in vivo studies would be valuable to determine the usefulness of MUS for identifying HRJ chondral lesions in patients with lateral elbow pain.

Despite good reliability and validity results, imaging errors accounted for a few lesions missed upon MUS image evaluation. We expect that additional training and experience would improve these results. Furthermore, limits in elbow range of motion in cadaveric specimens caused the clinician to miss 2 chondral lesions on MUS image evaluation. If elbow-flexion range of motion is limited, lesions on the distal capitellum may be missed; if elbow-extension range of motion is limited, lesions on the anterior capitellum may be missed. Future researchers can investigate the reliability and validity of identifying HRJ lesions by clinicians who have undergone additional MUS training and have more experience and in patients with full elbow range of motion.

Our study had several limitations. We examined embalmed elderly cadavers. Previous authors[31] demonstrated that the embalming process of human cadaveric specimens did not affect articular cartilage, thereby supporting our methods and the validity of our results.[31] The age of the cadavers, however, may have influenced the prevalence of chondral lesions, which can affect validity results. Nevertheless, chondral changes in the HRJ have been reported to occur throughout adulthood.[2] Additionally, the negative likelihood ratio is calculated independent of prevalence, further supporting the capacity of MUS to rule out chondral lesions with a negative examination.[23] Therefore, we suspect that similar results would be found in other age groups in vivo with varying prevalence values. Finally, we recognize the inherent limitation of studying the reliability of only 1 examiner. However, our purpose was to establish the validity of MUS to identify HRJ chondral lesions and provide justification for further clinical applicability and reliability studies.

CONCLUSIONS

Musculoskeletal ultrasound is a reliable and sensitive tool for a clinician with relatively little experience and training to rule out HRJ chondral lesions. These results may assist with clinical assessment and decision making in patients with lateral epicondylalgia.

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