Diagnostic Performance of Ultrasonography for Evaluation of Osteoarthritis of Ankle Joint

Comparison With Radiography, Cone-Beam CT, and Symptoms

Mika T. Nevalainen, MD, PhD ©, Milla-Maaria Pitkänen, BM, Simo Saarakkala, PhD ©

Objectives—To determine the diagnostic performance of ultrasonography (US) for evaluation of the ankle joint osteoarthritic (OA) changes. Cone-beam computed tomography (CT) was used as the gold standard and US performance was compared with conventional radiography (CR). As a secondary aim, associations between the imaging findings and ankle symptoms were assessed.

Methods—US was performed to 51 patients with ankle OA. Every patient had prior ankle CR and underwent cone-beam CT during the same day as US examination. On US, effusion/synovitis, osteophytes, talar cartilage damage, and tenosynovitis were evaluated. Comparison to respective imaging findings on CR and cone-beam CT was then performed. Single radiologist blinded to other modalities assessed all the imaging studies. Symptoms questionnaire, the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), was available for 48 patients.

Results—US detected effusion/synovitis of the talocrural joint with 45% sensitivity and 90% specificity. For the detection of anterior talocrural osteophytes, US sensitivity was 78% and specificity 79%. For the medial talocrural osteophytes, they were 39 and 83%, and for the lateral talocrural osteophytes 54 and 100%, respectively. Considering cartilage damage of the talus, US yielded a low sensitivity of 18% and high specificity of 97%. Overall, the performance of US was only moderate and comparable to CR. The imaging findings showed only weak associations with ankle symptoms.

Conclusions—The ability of US to detect ankle OA is only moderate. Interestingly, performance of CR also remained moderate. The associations between imaging findings and WOMAC score seem to be weak in ankle OA.

Key Words—ankle; cone-beam CT; osteoarthritis; radiography; symptoms; ultrasonography

Osteoarthritis (OA) is a progressive, degenerative, and chronic disorder affecting over 300 million people globally.1 Although OA most commonly affects the knee and hip joints, the ankle joint can also be involved. However, the ankle joint OA is a relatively uncommon clinical entity. Unlike bigger joints, up to 90% of ankle OA cases are considered secondary to trauma; patients affected are usually younger and generally healthier than patients affected by OA of bigger joints. Accordingly, altered joint mechanics, including malalignment,
instability, and incongruity are seen as predisposing factors for the development of ankle OA.2 Traditionally, ankle OA is diagnosed based on clinical features and conventional radiography (CR)3,4 although cross sectional imaging, ie, computed tomography (CT) or magnetic resonance imaging (MRI), are nowadays considered as the gold standard imaging methods.2 Exercise, weight loss, analgesics, and intra-articular corticosteroids or viscosupplements are the primary treatment methods for ankle OA. The surgical options include ankle joint distraction, osteotomy, arthrodesis, and eventually arthroplasty.3

During the 2010s, ultrasonography (US) has also gained significant role in the evaluation of OA, especially for knee, hand, and foot joints.5,6 Concerning the ankle joint, US can be used to evaluate the superficial soft tissues of the ankle including tendons, ligaments, bursae and nerves.7,8 In addition, bony cortical irregularities (ie, osteophytes), loose fragments, and cartilage damages within the ankle joint can also be evaluated with US to some extent.9,10 However, to date, there are no studies investigating the capability of US to assess the osteoarthritic changes of the ankle joint. As the US is safe, inexpensive, and most importantly widely available imaging modality, it could offer additive power to the imaging of the ankle OA. Therefore, the primary aim of this study was to determine the diagnostic performance of US for evaluation the ankle joint OA changes. Cone-beam CT was used as the gold standard and US performance was compared with CR. As a secondary aim, associations between the imaging findings and ankle symptoms were assessed.

Materials and Methods

Patients
Initially, 132 ankle CR images with OA were acquired from our hospital’s PACS system. Patients with recent ankle fracture (less than 6 months ago), rheumatoid arthritis, or history of previous ankle surgery were excluded. Out of these initial candidates, we were able to recruit only 51 patients suffering from clinical ankle OA to this study during September 2018 and February 2019. The mean patient age was 67.5 years (range 45–85 years), and 47% were males. The Kellgren–Lawrence (KL) grade distribution of the ankles was: one KL 0, three KL 1, thirty-three KL 2, seven KL 3, and four KL 4 ankles. The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) questionnaire was used to assess the ankle symptoms of the patients, and 48 out of the 51 patients filled the questionnaire. The study was carried out in accordance with the Declaration of Helsinki and approved by the Ethical Committee of the Northern Ostrobothnia Hospital District (#216/2018). Written informed consent was obtained from every patient.

Imaging Technique and Analysis

Ultrasonography
The GE LOGIC S7 ultrasound device (GE Healthcare, Milwaukee, WI, USA) with 15 MHz linear transducer (type ML6–1S) was used to perform the US imaging. For each patient, the B-mode imaging settings were similar, and the focus point was placed at the level of interest. A musculoskeletal fellow radiologist with 5 years of experience—blinded to the clinical and other imaging findings—performed the US assessment of each ankle. Routine US technique was used to evaluate the ankle joint,7,9 and the grading system for osteophytes and cartilage damage was adapted from knee US.11 Initially, a patient lying supine and ankle being in a neutral position, the presence of effusion/synovitis was evaluated; anteriorly, the threshold of 4 mm of fluid or synovial bulging was used. Osteophytes were examined on the talocrural joint anteriorly and medially; the following grading was used: grade 0 = no osteophytes, grade 1 = minimal osteophyte, grade 2 = definite osteophyte, grade 3 = large osteophyte. Subsequently, ankle was plantar flexed as much as possible to assess the cartilage of the talus; cartilage was evaluated as grade 0 = normal cartilage (a homogenous, black zone with distinct interfaces), grade 1 = increased echogenicity of the cartilage and/or loss of the normal sharpness of interfaces, grade 2 = obvious local cartilage damage (less than 50%), grade 3 = local cartilage damage (more than 50% but less than 100%), and grade 4 = full thickness cartilage damage. Next, the ankle was bent to supination to evaluate the anterior talofibular ligament (ATFL; thickness of 2 mm was held as a normal threshold12,13), and the ATFL was graded as either normal or abnormal (including the absence or the ligament). Finally, the medial tendons (tibialis posterior, flexor digitorum longus and flexor hallucis longus) and the lateral tendons (peroneus longus & brevis) were examined for tenosynovitis (absent/present).8,9
Conventional Radiography and Cone-Beam CT

All patients had a previous weight-bearing antero-posterior (AP) or mortise and lateral radiography performed on average and median of 25 weeks (range 7–49 weeks, standard deviation 11 weeks) prior to US imaging. For the mortise projection, the foot was rotated internally around 10°; the lateral projection was taken 90° to the mortise view. The same blinded radiologist evaluated the radiographs and CT images for osteophytes, joint space narrowing and KL grades. Osteophytes were assessed on the anterior tibia, and on the medial and lateral aspects of the talocrural joint as follows: grade 0 = no osteophyte, grade 1 = minimal osteophyte, grade 2 = a definite osteophyte. The talocrural joint space was evaluated either normal or narrowed, and subsequently KL grade was given for the ankle joint. On the same day as the US, the non-weight-bearing cone-beam CT was performed with the ankle in a neutral position. A grading similar to CR concerning osteophytes and joint space narrowing was applied, while the effusion/synovitis was defined as 4 mm bulging of the joint capsule on the cone-beam CT.

Statistical Analysis

Owing to the rather small sample size and skewed distributions of US findings, particular variables were dichotomized: On US grading, osteophytes were classified as nonsignificant (grades 0 and 1) or significant (grades 2 and 3) and cartilage damage as nonsignificant (grades 0 and 1) or significant (grades 2, 3, and 4); the osteophytes detected on CR or cone-beam CT were grouped as nonsignificant (grades 0 and 1) or significant (grade 2). Total sum score of the US findings was formed by summing all the dichotomous US variables including osteophytes, cartilage damage, effusion/synovitis, tenosynovitis, and ATFL damage; the maximum score was eight points. Data of US and CR findings are presented as numbers of true positives/positive findings in cone beam CT; TN/N2, number of true negatives/negative findings in cone beam CT; N3, total number of readings concordant with cone beam CT findings in 51 ankles; 95% CI, 95% confidence interval.

Table 1. The Diagnostic Efficacy of Ultrasonography to Identify Osteoarthritic Changes of the Ankle When Using Cone Beam CT Findings as a Gold Standard

|                               | TP/N1 | Sensitivity, % (95% CI) | TN/N2 | Specificity, % (95% CI) | N3 | Accuracy, % (95% CI) | Positive Predictive Value, % (95% CI) | Negative Predictive Value, % (95% CI) |
|-------------------------------|-------|-------------------------|-------|-------------------------|----|----------------------|---------------------------------------|---------------------------------------|
| Osteophytes                   |       |                         |       |                         |    |                      |                                       |                                       |
| Anterior talocrural joint     | 21/27 | 78 (58–91)              | 19/24 | 79 (58–93)              | 40 | 78 (65–89)           | 81 (65–90)                           | 76 (60–87)                            |
| Medial talocrural joint       | 11/28 | 39 (22–59)              | 19/23 | 83 (61–95)              | 30 | 59 (44–72)           | 73 (50–88)                           | 53 (44–61)                            |
| Lateral talocrural joint      | 20/37 | 54 (37–71)              | 0/14  | 100 (77–100)            | 34 | 67 (52–79)           | 100 (N/A)                            | 45 (37–54)                            |
| Cartilage damage of talus     | 4/22  | 18 (5–40)               | 28/29 | 97 (82–100)             | 32 | 63 (48–76)           | 80 (52–97)                           | 61 (56–66)                            |
| Effusion/synovitis            | 6/11  | 45 (27–77)              | 36/40 | 90 (76–97)              | 41 | 80 (67–90)           | 56 (29–79)                           | 86 (78–91)                            |

TP/N1, number of true positives/positive findings in cone beam CT; TN/N2, number of true negatives/negative findings in cone beam CT; N3, total number of readings concordant with cone beam CT findings in 51 ankles; 95% CI, 95% confidence interval.

Figure 1. A 61-year-old female subject with Kellgren-Lawrence (KL) grade 2 ankle osteoarthritis (OA) showing a mild effusion/synovitis (white arrow) measuring 5 mm in longitudinal ultrasonographic view (A), and in sagittal plane of cone-beam computed tomography (B). On ultrasound image, a scalebar in centimeters is shown.

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Table 2. The Diagnostic Efficacy of Radiography to Identify Osteoarthritic Changes of the Ankle When Using the Cone Beam CT Findings as a Gold Standard

|                      | TP/N1 | Sensitivity, % (95% CI) | TN/N2 | Specificity, % (95% CI) | N3 | Accuracy, % (95% CI) | Positive Predictive Value, % (95% CI) | Negative Predictive Value, % (95% CI) |
|----------------------|-------|-------------------------|-------|-------------------------|----|----------------------|--------------------------------------|--------------------------------------|
| Osteophytes          |       |                         |       |                         |    |                      |                                      |                                      |
| Anterior talocrural joint | 16/27 | 59 (39–78)              | 22/24 | 92 (73–99)              | 38 | 75 (60–86)           | 89 (67–97)                          | 67 (56–76)                          |
| Medial talocrural joint | 20/28 | 71 (51–87)              | 16/23 | 70 (42–87)              | 36 | 71 (56–83)           | 74 (60–85)                          | 67 (51–79)                          |
| Lateral talocrural joint | 18/37 | 49 (32–66)              | 12/14 | 86 (57–98)              | 30 | 59 (44–72)           | 90 (71–97)                          | 39 (30–48)                          |
| Cartilage damage of talus | 12/22 | 55 (32–76)              | 25/29 | 86 (68–96)              | 37 | 73 (58–84)           | 75 (53–89)                          | 71 (61–80)                          |

TP/N1, number of true positives/positive in cone beam CT; TN/N2, number of true negatives/negative in cone beam CT; N3, total number of readings concordant with cone beam CT findings in 51 ankles; 95% CI, 95% confidence interval.

Figure 2. A 81-year-old male subject with Kellgren–Lawrence (KL) grade 2 ankle osteoarthritis (OA) showing anterior large osteophyte (white arrow) in longitudinal ultrasonographic view (A), in lateral conventional radiography (B), and in sagittal plane of cone beam computed tomography (C). On ultrasonography, grade 2 cartilage damage (white arrowheads) is also depicted (A); the corresponding cone beam computed tomography image is not shown here. On ultrasound image, a scalebar in centimeters is shown.
positive and negative findings according to cone-beam CT findings. Moreover, for each finding sensitivity, specificity, accuracy, as well as positive and negative predictive values with their 95% confidence intervals were calculated. To calculate confidence intervals for sensitivity, specificity, and accuracy, Clopper-Pearson technique was used, and for predictive values the standard logit confidence intervals were applied. McNemar’s test was utilized to compare sensitivities between US and CR within positive cone-beam CT findings. To analyze the associations of the imaging findings and WOMAC total score, Mann–Whitney and Kruskal-Wallis tests were applied. Finally, association between the US sum score and KL grades was studied using Spearman correlation coefficient. Statistically significant P-value was set to $P < .05$, and SPSS 25.0 statistical software was employed.

Results

The Diagnostic Performance of US and CR Compared to Cone-Beam CT

The osteoarthritic changes were highly prevalent in this study cohort. On US, effusion/synovitis of the talocrural joint was detected with a sensitivity of 45% and a specificity of 90%. For the US detection of anterior talocrural osteophytes, the sensitivity was 78% and the specificity was 79%. For the medial talocrural osteophytes, the corresponding values were 39 and 83%, and for the lateral talocrural osteophytes 54 and 100%, respectively. Considering the cartilage damage of the talus, US yielded a low sensitivity of 18% and high specificity of 97%. Table 1 shows the performance of the US to detect OA changes of the ankle, and Figure 1 shows an example of effusion/synovitis detected on US and cone-beam CT.

On CR, anterior talocrural osteophytes were found with a sensitivity of 59% and a specificity of 92%. For the medial talocrural osteophytes, the corresponding values were 71 and 70%, and for the lateral talocrural osteophytes 49 and 86%, respectively. Cartilage damage, ie, joint space narrowing was detected with a 55% sensitivity and a 86% specificity. In Table 2, the performance of CR to detect ankle OA is shown.

When US and CR findings were compared using the cone-beam CT findings as the gold standard, the overall diagnostic performances of both US and CR were only moderate. Considering anterior talocrural osteophytes (Figure 2), US seemed to outperform CR, but no statistical significance was found ($P = .057$). On the detection of medial talocrural

Figure 3. A 65-year-old female subject with Kellgren–Lawrence (KL) grade 2 ankle osteoarthritis (OA) presenting medial (white arrow) and lateral talocrural osteophytes (white arrowhead). In longitudinal ultrasonographic view, medial (A) and lateral osteophytes are detected (B). In anteroposterior (or mortise) conventional radiography, osteophytes are also readily seen (C). In the coronal plane of cone beam computed tomography, definite osteophytes are present, too. Of note, some of these changes may represent sequelae of previous ligamentous injuries (D). On ultrasound image, a scalebar in centimeters is shown.
osteophytes and cartilage damage of the talus, CR was superior to US ($P = .012$ and $.007$, respectively). On the detection of the lateral talocrural osteophytes, both US and CR performed poorly. In Figure 3, examples of osteophytes in US, CR, and cone beam CT are shown. Table 3 summarizes the diagnostic performance of US and CR, when using cone-beam CT as the gold standard. Finally, the total US sum score and KL grades assessed on cone beam CT showed moderate but statistically significant correlation ($r = 0.503$, $P < .001$).

**Associations Between Imaging Findings and Symptoms**

Overall, rather poor associations between symptoms (assessed with the total WOMAC score) and imaging findings were observed in this study. On US, anterior talocrural osteophytes ($P = .030$), medial tenosynovitis ($P = .020$), lateral tenosynovitis ($P = .013$), and US sum score ($P = .027$) showed a statistically significant association with the WOMAC sum score. Concerning the CR and cone-beam CT findings, all the associations were statistically insignificant. Table 4 depicts all the tested associations.

**Discussion**

In this study, we primarily evaluated the diagnostic performance of US for detection of OA changes of the ankle joint. Owing to the rather complex osseous anatomy of the ankle, the diagnostic performance of the US was only moderate when cone-beam CT was used as the reference imaging modality (gold standard). Interestingly, the first line imaging technique of the osteoarthritic joint, CR, showed also rather poor diagnostic performance. For the imaging of the osteoarthritic knee joint, the US has been shown to outperform CR in the detection of the osteophytes\(^{11,15,16}\); however, in this study the US did not outrank CR. Nevertheless, this is a relevant finding, as prior literature includes only one review article mentioning detection of the ankle joint osteophytes with the US.\(^9\) Although Kok et al\(^{10}\) managed to assess anterior talar osteochondral lesions on US, we cannot recommend US to image cartilage

| US Finding vs Radiography Finding | Total | US+/R+ N (%) | US+/R− N (%) | US−/R+ N (%) | US−/R− N (%) | $P$  |
|----------------------------------|-------|--------------|--------------|--------------|--------------|------|
| **Osteophytes**                  |       |              |              |              |              |      |
| Anterior talocrural joint        | 27    | 15 (55.6)    | 6 (22.2)     | 1 (3.7)      | 5 (18.5)     | .057 |
| Medial talocrural joint          | 28    | 10 (35.7)    | 1 (3.6)      | 10 (35.7)    | 7 (25.0)     | .012 |
| Lateral talocrural joint         | 37    | 11 (29.7)    | 9 (24.3)     | 7 (18.9)     | 10 (27.0)    | .000 |
| Cartilage damage of talus        | 22    | 3 (13.6)     | 1 (4.5)      | 9 (40.9)     | 9 (40.9)     | .007 |

US+, positive in ultrasound; US−, negative in ultrasound; R+, positive in radiography; R−, negative in radiography. McNemar’s test was used for the statistical analyses.

**Table 4.** The Tested Associations Between Imaging Findings and The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) Total Score

| Imaging Finding                  | Negative/ Positive Cases | $P$ Value |
|----------------------------------|--------------------------|-----------|
| **Ultrasonography**              |                          |           |
| Anterior talocrural osteophytes  | 24/24                    | .030      |
| Medial talocrural osteophytes    | 33/15                    | .824      |
| Lateral talocrural osteophytes   | 29/19                    | .158      |
| Cartilage damage of talus        | 43/5                     | .062      |
| Effusion/synovitis               | 40/8                     | .406      |
| Anterior talofibular ligament damage | 18/30               | .890      |
| Medial tenosynovitis             | 42/6                     | .013      |
| Lateral tenosynovitis            | 45/3                     | .020      |
| Total sum score                  | N/A                      | .027*     |
| **Conventional radiography**     |                          |           |
| Anterior talocrural osteophytes  | 30/18                    | .197      |
| Medial talocrural osteophytes    | 22/26                    | .488      |
| Lateral talocrural osteophytes   | 30/18                    | .055      |
| Cartilage damage of talus        | 32/16                    | .896      |
| **Cone beam computed tomography**|                          |           |
| Anterior talocrural osteophytes  | 22/26                    | .150      |
| Medial talocrural osteophytes    | 21/27                    | .240      |
| Lateral talocrural osteophytes   | 13/35                    | .178      |
| Cartilage damage of talus        | 26/22                    | .812      |
| Effusion/synovitis               | 38/10                    | .102      |
| Kellgren–Lawrence grade          | N/A                      | .026      |

Mann-Whitney and Kruskal–Wallis tests were used for the statistical analyses. *After Bonferroni correction the association was statistically insignificant.
damage of the talus owing to the very low sensitivity (18%) as compared to cone-beam CT. Taken together, all these findings emphasize the complex anatomy of the ankle joint, which hinders the ultrasonographic and radiographic assessment of this joint.

In addition to the assessment of superficial bony contours, the US offers visualization of the soft tissues which are also affected by the OA. Although detecting joint fluid is a hallmark of the US, the sensitivity for the effusion/synovitis of the ankle joint was only moderate (45%) in our study. This can be explained by the fact that the ankle effusion can also bulge posteriorly, and thus be undetectable with the anterior US scanning technique. Accordingly, this explanation is supported by the high specificity (90%) of the US for effusion/synovitis we found here.

The associations between US findings and symptoms (according to the WOMAC total score) were weak in this study. Although several US parameters, including anterior talocrural osteophytes, medial tenosynovitis, lateral tenosynovitis, and US sum score, presented a statistically significant associations, the low number of study subjects \( (n = 48) \) and the skewed distribution of the US positive/negative cases (Table 4) undermines the reliability and clinical significance of our findings. However, intuitively it is plausible that inflammatory findings such as tenosynovitis are related to symptoms. This is also corroborated by two studies who also found association between peroneal tenosynovitis and ankle pain duration or symptoms in rheumatoid arthritis,\(^{17,18}\) but further studies are needed to confirm this. Interestingly, we found no association between radiographic imaging (CR and cone-beam CT) and symptoms in ankle OA. This contradicts the results by Holzer et al, who studied 150 ankle CR images and found association between higher KL grades and ankle symptoms and pain.\(^3\) However, it should be remembered the association between imaging findings and clinical symptoms in OA in general is still considered elusive.\(^{19}\)

Several limitations exist within this study. First, the fairly low number of patients inherently diminishes the power of this study as does the rather long interval between the CR and US/cone beam CT imaging. Second, the KL grade distribution of the ankles was heavily skewed on KL grade 2 (65% of the cases), so our findings reflect mostly mild-to-moderate OA as the portion of the KL grade 0 to 1 was 3% and KL grade 3 to 4 was 22%. Third, the complex anatomy of the ankle joint posed issues on US imaging; accordingly, the visualization of the talus medially and laterally for osteophytes was challenging, and the acoustic window to the cartilage of the talus only modest. Fourth, although cone-beam CT offers good characterization of the bony cortex and joint space width, it is not the best modality to assess joint effusion/synovitis and is unsuitable for reliable evaluation of tenosynovitis. Therefore, MRI might have served as the better gold standard, but it was unavailable for our patients in this study. As US can view articular cartilage directly, but CR and cone-beam CT can only show joint space narrowing, the comparison of cartilage damage was direct (US) versus indirect (CT). Moreover, the CR was performed with weight-bearing and the cone-beam CT non-weight-bearing limiting the comparison between these modalities.

In conclusion, the diagnostic performance of both US and CR to detect ankle OA changes is only moderate. The benefit of the US over CR is the evaluation of the effusion/synovitis and tendon pathology. Finally, the overall association between imaging findings and WOMAC score seems to be poor in ankle OA.

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