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An ultrasound score for knee osteoarthritis: a cross-sectional validation study

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SUMMARY

Objective: To develop standardized musculoskeletal ultrasound (MUS) procedures and scoring for detecting knee osteoarthritis (OA) and test the MUS score's ability to discern various degrees of knee OA, in comparison with plain radiography and the '*Knee injury and Osteoarthritis Outcome Score*' (KOOS) domains as comparators.
Method: A cross-sectional study of MUS examinations in 45 patients with knee OA. Validity, reliability, and reproducibility were evaluated.
Results: MUS examination for knee OA consists of five separate domains assessing (1) predominantly morphological changes in the medial compartment, (2) predominantly inflammation in the medial compartment, (3) predominantly morphological changes in the lateral compartment, (4) predominantly inflammation in the lateral compartment, and (5) effusion. MUS scores displayed substantial reliability and reproducibility, with interclass correlations coefficients ranging from 0.75 to 0.97 for the five domains. Construct validity was confirmed with statistically significant correlation coefficients (0.47–0.81, $P < 0.01$).
Conclusion: The MUS score suggested in this study was reliable and valid in detecting knee OA. In comparison with standing radiographs of the knees, the score detected all aspects of knee OA with relevant precision.

Introduction

A standing radiogram of the knee is still the primary imaging modality used to evaluate and confirm the diagnosis of knee OA and is considered as the gold standard for assessing joint damage in knee OA[1], as it demonstrates late osteoarthritic bony abnormalities and joint space narrowing[2]. Standing radiography is considered inexpensive and is widely available globally. However, standing radiograms of the knees are limited by their inability to directly visualize articular cartilage, synovial recesses, menisci, and other soft tissues involved in the pathophysiology of OA[3]. In contrast magnetic resonance imaging (MRI) may provide an accurate and reproducible evaluation of both bone, articular cartilage, and soft tissues[4–6]. Advantages of MRI include its non-invasiveness, multiplanar capability, and excellent soft tissue contrast. However, MRI is relatively expensive, time consuming, and not widely used for detecting knee OA.

Another modality used to visualize musculoskeletal disorders in research and clinical practice is high-frequency musculoskeletal ultrasound (MUS)[7]. MUS effectively depicts superficial periarticular structures (e.g., soft tissues, bony abnormalities) and to some extent, intra-articular structures (e.g., meniscus, articular cartilage[8–11]). MUS is considered reliable for identifying knee effusion[12] and Baker's cyst[13], and it has a higher sensitivity than physical examination for detecting these pathological findings[14]. MUS has considerable advantages over other imaging modalities by being non-invasive (like MRI), quick to perform even at bedside, at relatively low cost, and therefore feasible. The power/color Doppler mode in MUS has shown hyperemia indicating inflammation in

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knee OA[12,15], but ultrasound as a diagnostic tool in knee OA remains to be fully explored[2,16]. MUS's usefulness as an outcome measure has been questioned due to a perception of observer dependence, which may be overcome by a proper learning program[17]. Structured scoring of the images has been validated for some joints[18,19], although this technique remains to be developed for the knee.

The objective of this study was to develop standardized MUS procedures and scoring for detecting knee OA and test the MUS score's ability to discern various degrees of knee osteoarthritis (OA), in comparison with plain radiography and the '*Knee injury and Osteoarthritis Outcome Score*' (KOOS) domains as comparators.

Methods

Study design

We used a cross-sectional study design with ultrasound examination in a large range of specified positions in a standardized sequence. The pathological characteristics examined consisted predominantly of cartilage damage with concomitant bone abnormalities and inflammatory processes within the synovium.

Study framework

We followed the standard methodology for a quality of life instrument development[20], including four phases: (1) identification of a specific patient population, (2) item generation, (3) item reduction, and (4) determination of validity and reliability. Step 1 involved finding a proper population with knee OA of a clinical severity meriting investigation for the study. Step 2 involved developing an ultrasound procedure for evaluating the soft tissues around the joint, the menisci, synovial perfusion, bony abnormalities, and focal cartilage lesions in patients with knee pain. Experts within clinical use of MUS in knee OA were heard (i.e., content experts, considered end users). These two steps are considered basic methodology (i.e., reported in the Methods section). Whereas step 3, item reduction, involved testing the individual items of the MUS procedure through intra-observer reliability and exploratory factor analysis, step 4 involved testing the final MUS scoring system of knee OA for construct validity and reliability. Steps 3 and 4 are described in the Results section.

Population identification

Inclusion criteria were participants' $\geq$18 years of age, under suspicion of Knee OA referred from the Department of Orthopedic Surgery to the Department of Radiology, Frederiksberg Hospital to a standing knee radiogram. The investigator of this study was present at the Department of Radiology on Thursdays from December 2007 through the end of March 2008, recruiting participants consecutively, which gave 12 days of scanning. Exclusion criteria were: lack of motivation to participate; or inability to speak and read Danish fluently. Signed informed consent was obtained from all participants. The local Ethical Committee approved this study's being part of clinical practice at the Copenhagen University Hospital.

Outcome measures (constructs)

As a supplement to the standing knee radiogram, the participants were offered an ultrasound examination of their X-ray-examined knee or, if both knees were involved, their more painful knee. Participants also were asked to complete the 'KOOS questionnaire[21].

Radiographic examination

Bi-plane weight-bearing semi-flexed (15°) radiograms were taken of the target knee; one in the posteroanterior view, and one in the lateral–medial view. The radiograms were obtained using a Philips Optimus apparatus. All examinations were performed by experienced radiographers and evaluated by an experienced musculoskeletal radiologist using the Kellgren–Lawrence score (KL score)[22] as previously described in the work by this group[3].

Item generation

The item generation phase included first reviewing the literature, then conducting a focus group interview, involving experts within clinical use of MUS in OA (radiologists, rheumatologists and physiotherapists). Subsequently, the extended US examination was created from all the experts' input on what they considered relevant in monitoring the pathology of knee OA when examined with ultrasound. The expert panel had two co-chairs: an ultrasound expert with extensive experience in MUS and an experienced rheumatologist with a major interest in OA[18]. An ultrasound examination, including 14 positions on the knee with 61 items in total, was agreed upon (see Appendix 1 for a thorough specification of the ultrasound examination). Gray scale ultrasound (GSUS) and Color Doppler ultrasound (CDUS) examinations were performed in all positions with recording of still images, with the exception of positions 3, 6, 10, 11 and 12, where CDUS was not done. If synovitis defined by color Doppler activity was present, an image with maximal flow and minimal flow was taken from the same live clip. Examination of the anterior part of the knee joint was performed with the participant supine with extended and relaxed knee; the knee was flexed 90° during scanning of positions 10, 11, and 12. At the anterior part of the knee, the ultrasound examination included: the quadriceps tendon and patellar tendons, looking for signs of overuse (e.g., thickening, changes in architecture, intratendinous hyperemia); the supra-patellar, lateral, and medial recesses to look for effusion, hyperemia and/or thickening of the synovial membrane; and the medial and lateral joint lines to look for osteophytes and protrusion of the menisci. Examination of the posterior part of the knee was performed with the participant lying in prone position with extended and relaxed knee. At the posterior part of the knee, ultrasound was used for detecting a potential Baker's cyst and possible hyperemia, if present. The full ultrasound examination took about 5 min to perform, with aspiration of joint fluid; about 10 min. The ultrasound examination was exported in a DICOM file for analysis. The subsequent analysis of the ultrasound images for the MUS score took 10–15 min in all.

In Table I, the scoring of the 61 items in the 14 positions is shown. The ultrasound examination was performed with a General Electric, Logiq9™ (General Electric, Milwaukee, Wisconsin, USA), using the 14 MHz M12L linear transducer. The fixed B-mode settings for gray-scale were adjusted for musculoskeletal examination; gain, focus and depth were adjusted individually when needed. The Doppler sensitivity was optimized for low flow with fixed Doppler settings (pulse repetition frequency 0.9 kHz, wall filter 114 Hz and 7.5 MHz Doppler frequency). The Doppler settings ensured that all color pixels were generated by flow and not by random noise. Measurements of cartilage thickness were done at the lateral and medial condyle, where the underlying bone was perpendicular to the ultrasound transducer. In the fovea trochlearis the cartilage thickness was measured in the most profound part of the fovea. All the ultrasound examinations were done by investigator A (BFR), a younger physician trained in MUS.