Title: The Reliability of a New Scoring System for Knee Osteoarthritis MRI and the validity of BML assessment: BLOKS (Boston Leeds Osteoarthritis Knee Score)

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Abstract

Aim: MRI provides unparalleled visualization of all the anatomical structures involved in the osteoarthritis (OA) process. There is a need for reliable methods of quantifying abnormalities of these structures. The aim of this work was to assess the reliability of a novel MRI scoring system for evaluating OA of the knee and explore the validity of the bone marrow lesion (BML) scoring component of this new tool.

Methods: After review of the relevant literature, a collaborative group of rheumatologists and radiologists from centers in the UK and USA established preliminary anatomical divisions, items (necessarily broadly inclusive) and scaling for a novel semi-quantitative knee score. A series of iterative reliability exercises were performed to reduce the initial items, and the reliability of the resultant Boston-Leeds Osteoarthritis Knee Score (BLOKS) was examined. A further sample had both the BLOKS and WORMS (Whole Organ MRI Score) BML score performed to assess the construct validity (relation to knee pain) and longitudinal validity (prediction of cartilage loss) of each scoring method.

Results: The BLOKS scoring method assesses 9 intra-articular regions and contains 8 items, including features of bone marrow lesions, cartilage, osteophytes, synovitis, effusions and ligaments. The scaling for each feature ranges from 0-3. The inter-reader reliability for the final BLOKS items ranged from 0.51 for meniscal extrusion up to 0.79 for meniscal tear. The reliability for other key features was 0.72 for BML grade, 0.72 for cartilage morphology, and 0.62 for synovitis. Maximal BML size in BLOKS scale had a positive linear relation with VAS pain however the WORMS scale did not. Baseline BML was associated with cartilage loss on both BLOKS and WORMS scale. This association was stronger for BLOKS than WORMS.

Conclusion: We have designed a novel scoring system for MRI OA knee, BLOKS, that demonstrates good reliability. Preliminary inspection of the validity of one of the components of this new tool supports the validity of the BLOKS BML scoring method over an existing instrument. Further iterative development will include validation for use in both clinical trials and epidemiological studies.
Introduction

Osteoarthritis (OA) is the clinical and pathological outcome of a range of disorders that results in structural and functional failure of synovial joints (1). Whilst traditionally OA has been characterized by articular cartilage loss it is more accurately described as a multifactorial process characterized by changes in structure and function of the whole joint (2). Osteoarthritis of the knee is a major source of pain, disability, and health care utilization in the elderly (3). Despite its growing prevalence, it is a condition with few effective therapies that modify the course of the disease. Therapeutic development has in part been constrained by the lack of valid and responsive structural endpoints for clinical trials.

The advent of MRI measurement in OA brought with it optimism that this limitation in endpoint measurement would be addressed. MRI has the capability of visualizing all potentially relevant OA joint structures; therefore, it is not surprising that it has already proven to be an important tool in improving our understanding of knee OA by providing a tool for the study of healthy and diseased states, as well as in providing a means of assessing risk factors for pain in OA (4-6).

However, the utility of knee MRI in the study of OA has been limited by the facts that current technology does not provide rapid quantitative assessment of multiple tissues; and, that there are limited semi-quantitative scores that have been systematically developed with respect to item content, scaling, reliability and feasibility. Recent analyses of such scores applied to patient datasets have highlighted issues including: non-unidimensionality of items (where more than one construct may be included in a given item, for example measuring features such as cartilage morphology breadth, depth and signal intensity in one single score); problems with the scaling of items, especially in “early” OA cohorts where only the lower end of scales may be used; and consequent concerns about responsiveness (7;8).

In light of these limitations we undertook a program to iteratively develop a novel comprehensive semi-quantitative scoring method specific for knee OA and to assess the reliability of this scoring scheme, entitled the Boston Leeds Osteoarthritis Knee Score (BLOKS). As a first step in validating this new instrument we also explored the validity of assessment of bone marrow lesions (BMLs) using the BLOKS instrument. BMLs are an established feature of osteoarthritis and recently data has emerged that suggest lesions in the bone marrow are associated with the symptoms that emanate from knee osteoarthritis, and its structural progression (5;9). If the BLOKS method of BMLs assessment is valid and BMLs are associated with pain and structural progression then the strength of this association will reflect the validity of the measure.

Materials and Methods

Development of BLOKS

A collaborative program between 2 international centers was established in 2004, incorporating rheumatologists and radiologists who were experienced in OA MRI research and outcome measurement. An initial meeting addressed the items and scoring to be included in BLOKS, based on the OA MRI literature. We selected many of the items based on likely relevance to pain and structural damage or progression of OA (10). At the conclusion of this review the co-authors delineated a novel scoring scheme that was likely to be descriptive for each morphological feature including cartilage integrity, attrition, bone marrow lesions and cysts, osteophytes, ligaments, meniscus and synovitis, in addition to other morphological features that may warrant attention in OA.
Other items included in this preliminary BLOKS included meniscal displacement, collateral ligament contour, osteophyte signal, synovitis separate from effusion, subchondral plate signal and thickness, limb alignment and muscle quality. It was recognized that, in the absence of data concerning the importance of certain pathological features, the initial BLOKS should be broadly inclusive.

Assessment of Reliability

After an initial training and calibration session a series of three reliability exercises ensued to improve reader calibration and to assess the reliability of identifying and scoring individual features of the instrument (listed in Table 1). In each exercise, two expert readers (AJG, DG) read 10 subjects’ MRIs followed by an adjudication session. The particular focus of the scoring development exercise was to refine the features so they were more OA-centric, to remove redundant items (some of the more complex scales in the prior analyses indicated that frequently many scores were used infrequently if at all), and to develop a more reader-friendly measurement tool.

The analyses presented here are for inter-rater reliability (calculated using the weighted kappa (95%CI)) of the third scoring exercise after removing some of the items that were less reliable (kappa< 0.2) in the two prior exercises (e.g. subchondral plate thickness and shape, central osteophytes, limb alignment, muscle quality, osteophyte signal). The readers took an average of 42 minutes to score each knee using BLOKS.

Table 1. Features that are scored in BLOKS (a more complete description is attached as an appendix)

<table>
<thead>
<tr>
<th>BLOKS feature</th>
<th>Reliability (weighted kappa (95%CI))</th>
</tr>
</thead>
<tbody>
<tr>
<td>BML size</td>
<td>Score of 0-3 applied for BML volume in 9 different regions</td>
</tr>
<tr>
<td>BML % area</td>
<td>Score of 0-3 applied for % surface area adjacent to subchondral plate</td>
</tr>
<tr>
<td>% of lesion BML rather than cyst</td>
<td>Score of 0-3 for % of lesion that is bone marrow lesion as distinct from cyst</td>
</tr>
<tr>
<td>Cartilage 1</td>
<td>Score of 0-3 for size of loss and % of loss in region that is full thickness</td>
</tr>
<tr>
<td>Cartilage 2</td>
<td>Extent of any cartilage loss at specified points</td>
</tr>
<tr>
<td>Osteophyte</td>
<td>Score of 0-3 applied for osteophyte size in 12 locations</td>
</tr>
<tr>
<td>Synovitis</td>
<td>Score of 0-3 applied for synovial volume</td>
</tr>
<tr>
<td>Effusion</td>
<td>Score of 0-3 applied for size of effusion</td>
</tr>
<tr>
<td>Meniscal extrusion</td>
<td>Score of 0-3 applied for amount of extrusion in 4 locations</td>
</tr>
<tr>
<td>Meniscal signal</td>
<td>Scored as present or absent in 6 regions</td>
</tr>
<tr>
<td>Meniscus tear</td>
<td>Type of tear or degenerative process scored as present or absent in 6 regions.</td>
</tr>
<tr>
<td>Ligaments</td>
<td>Presence/ absence of tear</td>
</tr>
<tr>
<td>Periarticular features</td>
<td>Presence/ absence</td>
</tr>
</tbody>
</table>

Study Images for Reliability Exercise
The images for the reliability exercise were chosen at random from MRI scans undertaken within the Framingham Osteoarthritis Study (11). This is a group emanating from two different sources, the Framingham Offspring Study who are sons and daughters of the original Framingham Study cohort and their spouses and a new group recruited as a random sample of the community using random digit dialing. In 2002-2005, The Framingham Osteoarthritis Study recruited subjects without respect to a diagnosis of OA from the community. We obtained an MRI of one knee. All studies were performed with a 1.5T MRI system (Siemens, Mountain View, CA) using a phased array knee coil. A positioning device was used to ensure uniform placement of the knee among patients. T2-weighted fat-suppressed images in the sagittal and coronal planes were acquired, using the following pulse sequence parameters: time to recovery (TR) 3,610 msec, time to echo (TE) 40 msec, slice thickness 3.5 mm, and field of view 14 cm. T1-weighted spin echo images in the sagittal plane were acquired, using the following pulse sequence parameters: TR 475 msec, TE 24 msec, slice thickness 3.5 mm, and field of view 14 cm. 3D FLASH-water excitation sequence (resolution 0.3 x 0.3 mm x 1.5 mm) were acquired in coronal and axial planes with TR 16.8 msec, TE 7.6 msec, and field of view 16.4 cm.

Validity of BML Assessment

This question was assessed using data from The Boston Osteoarthritis of the Knee Study (BOKS). All subjects in this study had primary clinical knee osteoarthritis and met ACR criteria for this disorder (12). The source of recruited subjects and study design has been described in detail elsewhere (9). Of 324 subjects who entered the study, 193 men and 19 women received care from the Veterans Administration Health Care System and were recruited from the outpatient clinics there. Eight men and 104 women were recruited from the community. 86% completed a full comprehensive follow-up at a later time-point. The study included a baseline examination and follow-up examinations at 15 and 30 months.

At each visit, patients who did not have contraindications to MRIs had an MRI of the knee that was more symptomatic at baseline. At all examinations, patients had knee radiography and answered questionnaires about the severity of knee symptoms, including the Western Ontario McMaster Osteoarthritis (WOMAC) questionnaire. Patients were also weighed, with shoes off, on a balance-beam scale, and height was assessed. At the first follow-up visit, long-limb films were obtained with a 14 x 51 cassette, using methods described elsewhere (13). Mechanical alignment was measured as the angle formed by the intersection of the femoral and tibial mechanical axes. The femoral mechanical axis is the line from the femoral head through the centre of the knee and the tibial mechanical axis is drawn as a line from the centre of the ankle to the centre of the knee.

The institutional review boards of Boston University Medical Center and the Veterans Administration Boston Health Care System approved the baseline and follow-up examinations.

Magnetic Resonance Imaging for Validity Exercise

All studies in BOKS were performed with a Signa 1.5T MRI system (General Electric Corp., Milwaukee, Wisconsin) using a phased-array knee coil. A positioning device was used to ensure uniformity among patients with the patient reclining in the supine position with a fully extended knee immobilized in the knee coil and the foot perpendicular to the table. The imaging protocol included sagittal spin-echo proton density- and T2-weighted images (repetition time (TR), 2200 msec; time to echo (TE)
20/80 msec) with a slice thickness of 3 mm, a 1-mm interslice gap, 1 excitation, a field of view (FOV) of 11-12 cm, and a matrix of 256 X 192 pixels; and coronal and axial spin-echo fat-suppressed proton density- and T2-weighted images (TR 2200 msec; TE 20/80) with a slice thickness of 3 mm, a 1-mm interslice gap, 1 excitation, and with the same FOV and matrix.

Whole Organ MRI Scoring (WORMS) Scoring

This is a widely used semi-quantitative scoring method for OA features as seen on MRI (14). Tibiofemoral (TF) cartilage on MRI was scored paired and unblinded to sequence on 5 plates (central and posterior femur; anterior, central and posterior tibia), for the medial and lateral TF compartment, using the WORMS semiquantitative method on fat-suppressed T2-weighted FSE images. Both cartilage signal and morphology were scored using a 0-6 scale: 0=normal thickness and signal; 1=normal thickness but increased signal on T2-weighted images; 2=solitary focal defect of less than 1 cm in greatest width; 3=areas of partial-thickness defects (< 75% of the plate) with areas of preserved thickness; 4=diffuse partial-thickness loss of cartilage (≥75% of the plate); 5=areas of full-thickness loss (≥75% of the plate) with areas of partial thickness loss; 6=diffuse full-thickness loss (≥75% of the plate). Intraclass correlation coefficient (ICC) on agreement for cartilage readings ranged from 0.75-0.97 for intra and interobserver reliability.

In WORMS, grade 1 does not represent a change in shape but rather a change in signal in cartilage of otherwise normal shape. Grades 2 and 3 represent similar types of abnormality of the cartilage, focal defects without overall thinning. Therefore, to create a consistent and logical scale for evaluation of cartilage morphologic change and a fair comparison with radiographic changes in joint space narrowing, we collapsed the WORMS cartilage score to a 0-4 scale, where the original WORMS score of 0 and 1 were collapsed to 0, the original scores of 2 and 3 were collapsed to 1, and the original scores of 4, 5 and 6 were considered 2, 3 and 4, respectively, in the new scale. The score at all 5 plates in both the medial and lateral TF joint was summed to give a score with a possible range from 0-20. Cartilage loss was defined as a change in the summary score at subsequent follow-up. For measurement of cartilage loss films were read paired and unblinded to sequence using MRI sequence data from the sagittal and coronal planes.

BMLs in the subarticular marrow are defined as poorly marginated areas of increased signal intensity in the normally hypointense fatty marrow on the fat-suppressed spin-echo T2 weighted images, and graded in each region from 0 to 3 based on the extent of regional involvement; 0=none; 1 less than 25% of the region; 2= 25% to 50% of the region; 3= more than 50% of the region. The intra and inter-observer agreement (ICC) for reading BML’s ranged from 0.76- 0.82, read by the same musculoskeletal radiologists. In this scoring system, BMLs were graded in the anterior, central, and posterior regions of the medial and lateral femur and tibia, and the subspinous region on the tibia blinded to sequence (14).

BLOKS Scoring

BMLs were also assessed on 74 subjects selected randomly from the larger BOKS sample using the Boston Leeds Osteoarthritis Knee Score (BLOKS) semi-quantitative scoring system. Each BML generates a grade for (i) size, and (ii) the percentage of the lesion’s surface area that is adjacent to the subchondral plate (iii) the percentage of the lesion that is BML as distinct from cyst. The inter-rater reliability for reading BML’s is 0.72 (0.58-0.87) (weighted kappa).
Analysis: Assessment of Validity

**Construct Validity:** Construct validity is present to the extent that the measurement is consistent with other measurements of the same phenomenon. We explored the construct validity of different measures of BMLs (from WORMS and BLOKS) and their relation to pain severity. We explored the relation of the predictor variable (baseline BMLs) to the outcome variable (VAS pain). The BMLs were defined in 3 ways:

1. maximal BML in a knee (range 0-3): maximal of BML in all regions (9 regions for BLOKS scale, 15 regions for WORMS)
2. any BML in a knee (dichotomous): BML>=1 in any region *
3. large BML in a knee (dichotomous): BML>=2 in any region *

*definition (2) and (3) were used in the prior publication investigating BML and pain (9).

Analyses were adjusted to age, sex and BMI.

**Longitudinal validity:** We compared the longitudinal validity of different ways of measuring BMLs (BLOKS vs. WORMS) by comparing their respective associations with cartilage loss. If BML score has longitudinal validity (15) we would expect it to predict cartilage loss on MRI (16).

Among the 74 subjects who had BML reading in BLOKS scale, we used 53 subjects who had longitudinal BML reading in both BLOKS and WORMS scale, and had alignment measures. One knee was used for each subject.

Baseline BML was defined as the summary of BML on both BLOKS and WORMS scale in the medial TF compartment and lateral TF compartment, respectively.

Using a similar definition as that previously used (16), BML change was defined as maximal BML change on both BLOKS and WORMS scale. Cartilage loss was defined as the summary of cartilage loss on WORMS scale in the medial TF compartment and lateral TF compartment, respectively.

The model was used to assess the relation between cartilage loss and baseline BML, change of BML on both BLOKS and WORMS scale in medial compartment and lateral compartment, respectively. Then the relation between cartilage loss and baseline BML, change of BML on both BLOKS scale was assessed stratified by

(a) maximal BLOKS BML % surface area adjacent to the subchondral plate in the same compartment at baseline, 0-2 vs 3

(b) maximal BLOKS BML % of lesion as distinct from cyst in the same compartment at baseline, 0-2 vs 3

These analyses were adjusted for confounding of age, gender, BMI and in another multivariate step for malalignment defined on a long limb film (16).

**Results**

**A. Reliability Exercise**
Upon completion of the development of the third iteration of BLOKS we conducted an exercise to ascertain the interobserver reliability (DG and AJG) of the instrument on 10 subjects randomly chosen from the Framingham OA Cohort. Their mean age was 67 years (SD 9) with a mean BMI of 26.5 kg/m² (SD 4.7). Of the 10 knees that were assessed their Kellgren and Lawrence Grades were K&L=0 in one knee, K&L=1 in three knees, K&L=2 in two knees, K&L=3 in 3 knees, and K&L=4 in one knee. The reliability for the features described above are reported in Table 2.

Table 2. Interobserver reliability for reading of BLOKS features (weighted kappa)

<table>
<thead>
<tr>
<th>BLOKS feature</th>
<th>Reliability (weighted kappa (95%CI))</th>
</tr>
</thead>
<tbody>
<tr>
<td>BML size</td>
<td>0.72 (0.58-0.87)</td>
</tr>
<tr>
<td>BML % area</td>
<td>0.69 (0.55-0.82)</td>
</tr>
<tr>
<td>% of lesion BML</td>
<td>0.72 (0.58-0.87)</td>
</tr>
<tr>
<td>Cartilage 1</td>
<td>0.72 (0.59-0.85)</td>
</tr>
<tr>
<td>Cartilage 2</td>
<td>0.73 (0.60-0.85)</td>
</tr>
<tr>
<td>Osteophyte</td>
<td>0.65 (0.52-0.77)</td>
</tr>
<tr>
<td>Synovitis</td>
<td>0.62 (0.05-1.00)</td>
</tr>
<tr>
<td>Effusion</td>
<td>0.61 (0.05-0.85)</td>
</tr>
<tr>
<td>Meniscal extrusion</td>
<td>0.51 (0.24-0.76)</td>
</tr>
<tr>
<td>Meniscal signal</td>
<td>0.68 (0.44-0.93)</td>
</tr>
<tr>
<td>Meniscus tear</td>
<td>0.79 (0.40-1.00)</td>
</tr>
</tbody>
</table>

B. Validity of BML Assessment

Among 74 subjects who had BML reading in BLOKS scale, we used the 71 subjects who also had WORMS reading (see descriptive characteristics in Table 3). These 71 subjects were comparable to the larger study sample.

Table 3. Descriptive Characteristics of 71 subjects

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>67.9 ± 9.3</td>
</tr>
<tr>
<td>BMI</td>
<td>31.9 ± 6.1</td>
</tr>
<tr>
<td>Sex (women %)</td>
<td>28.2</td>
</tr>
<tr>
<td>Baseline KL (%)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>8.7</td>
</tr>
<tr>
<td>1</td>
<td>15.9</td>
</tr>
<tr>
<td>2</td>
<td>18.8</td>
</tr>
<tr>
<td>3</td>
<td>37.7</td>
</tr>
<tr>
<td>4</td>
<td>18.8</td>
</tr>
<tr>
<td>BML (BLOKS) (%)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>47.9</td>
</tr>
<tr>
<td>1</td>
<td>28.2</td>
</tr>
<tr>
<td>2</td>
<td>16.9</td>
</tr>
<tr>
<td>3</td>
<td>7.0</td>
</tr>
<tr>
<td>BML (WORMS) (%)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>22.5</td>
</tr>
<tr>
<td>1</td>
<td>31.0</td>
</tr>
<tr>
<td>2</td>
<td>39.4</td>
</tr>
<tr>
<td>3</td>
<td>7.0</td>
</tr>
<tr>
<td>VAS pain, 0-100</td>
<td>40.3 ± 25.9 (0-100)</td>
</tr>
<tr>
<td>WOMAC pain, 0-20</td>
<td>6.7 ± 3.4 (0-14)</td>
</tr>
</tbody>
</table>
We first examined the correlation between BML on BLOKS and WORMS scale. The range of baseline BML summary in medial TF compartment was 0-4 on BLOKS scale, 0-8 on WORMS scale, with Spearman correlation coefficient 0.63 (p<.0001).

The range of baseline BML summary in lateral TF compartment was 0-4 on BLOKS scale, 0-8 on WORMS scale, with Spearman correlation coefficient 0.79 (p<.0001).

The range of change of BML in medial TF compartment was from -2 to 2 on BLOKS scale, from -5 to 4 on WORMS scale, with Spearman correlation coefficient 0.11 (p=0.28). The range of change of BML in lateral TF compartment was from -3 to 2 on BLOKS scale, from -4 to 3 on WORMS scale, with Spearman correlation coefficient 0.47 (p<.0001).

The relation of baseline maximal BML and VAS pain is presented in Table 4. This demonstrates increasing pain severity with increasing BML grade using the BLOKS grades (p for linear trend=0.04). In contrast there was no significant association with VAS pain and the WORMS scale.

<table>
<thead>
<tr>
<th>BLOKS scale</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>35.2</td>
<td>(25.6, 44.7)</td>
<td>39.2</td>
<td>(27.2, 51.1)</td>
<td>49.5</td>
</tr>
</tbody>
</table>

| WORMS scale | 33.4 | (19.8, 47.0) | 44.1 | (32.6, 55.6) | 42.1 | (30.8, 53.4) | 32.5 | (8.6, 56.3) |

*adjusting age, sex, BMI

Using the methodology from the prior publication (9) there was a trend to increasing pain with large BMLs using the BLOKS scoring method and no significant relation was found between pain and the WORMS scale (Table 5).

<table>
<thead>
<tr>
<th>Any BML (yes vs. no)</th>
<th>Large BML (yes vs. no)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjusted mean VAS pain difference (95% CI)*</td>
<td>p-value</td>
</tr>
<tr>
<td>BLOKS scale (yes vs no)</td>
<td>9.5 (-3.0, 22.0)</td>
</tr>
<tr>
<td>WORMS scale (yes vs no)</td>
<td>8.7 (-6.3, 23.7)</td>
</tr>
</tbody>
</table>

Baseline BML and change of BML and their relation to cartilage loss on BLOKS and WORMS scale
In the medial TF compartment, higher baseline BML summary score was related to more severe cartilage loss on both BLOKS and WORMS scale (Table 6). This association was stronger for BLOKS than WORMS and consistent with our prior work was diminished after adjusting for alignment (16). Change of BML summary score was not related to change of cartilage loss. When stratified by baseline BML area and by baseline BML percentage of lesion there was a strong association between baseline BML summary score and cartilage loss observed in the stratum with stratified variable less than 3 (for percent of surface area adjacent to the plate), and a weaker association was observed in the stratum with stratified variable equal to 3. This suggests that lesions in the medial compartment with less contact with the subchondral plate have a greater effect on the rate of cartilage loss.

In the lateral TF compartment (Table 7) a similar association was observed in the unstratified analyses as that seen in the medial TF compartment. Unlike the results in medial TF compartment in the stratified analyses, strong association between baseline BML summary score and cartilage loss was observed in the stratum with stratified variable equal to 3. No association between baseline BML summary score and cartilage loss was observed in the stratum with stratified variable less than 3.
Table 6. Baseline BML and change of BML and their relation to cartilage loss on BLOKS and WORMS scale in the Medial TF compartment

<table>
<thead>
<tr>
<th></th>
<th>Adjusting age, sex, BMI</th>
<th></th>
<th>Adjusting age, sex, BMI, alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline BML</td>
<td>Change of BML</td>
<td>Baseline BML</td>
</tr>
<tr>
<td></td>
<td>beta</td>
<td>p-value</td>
<td>beta</td>
</tr>
<tr>
<td>WORMS scale</td>
<td>1.5</td>
<td>&lt;.0001</td>
<td>0.8</td>
</tr>
<tr>
<td>BLOKS scale</td>
<td>3.0</td>
<td>&lt;.0001</td>
<td>0.9</td>
</tr>
<tr>
<td>BLOKS scale,</td>
<td>7.1</td>
<td>&lt;.0001</td>
<td>0.9</td>
</tr>
<tr>
<td>Max baseline</td>
<td>1.7</td>
<td>0.11</td>
<td>1.3</td>
</tr>
<tr>
<td>BLOKS scale,</td>
<td>7.7</td>
<td>&lt;.0001</td>
<td>0.7</td>
</tr>
<tr>
<td>Max baseline</td>
<td>1.7</td>
<td>0.09</td>
<td>1.4</td>
</tr>
<tr>
<td>BLOKS scale,</td>
<td>1.3</td>
<td>0.04</td>
<td>-0.2</td>
</tr>
<tr>
<td>Max baseline</td>
<td>2.7</td>
<td>&lt;.0001</td>
<td>0.4</td>
</tr>
<tr>
<td>BLOKS scale,</td>
<td>-0.4</td>
<td>0.49</td>
<td>0.9</td>
</tr>
<tr>
<td>Max baseline</td>
<td>3.4</td>
<td>0.0008</td>
<td>-0.1</td>
</tr>
<tr>
<td>BLOKS scale,</td>
<td>-0.08</td>
<td>0.89</td>
<td>0.7</td>
</tr>
<tr>
<td>Max baseline</td>
<td>4.5</td>
<td>&lt;.0001</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Table 7. Baseline BML and change of BML and their relation to cartilage loss on BLOKS and WORMS scale in the Lateral TF compartment

<table>
<thead>
<tr>
<th></th>
<th>Adjusting age, sex, BMI</th>
<th></th>
<th>Adjusting age, sex, BMI, alignment</th>
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<tr>
<td></td>
<td>Baseline BML</td>
<td>Change of BML</td>
<td>Baseline BML</td>
</tr>
<tr>
<td></td>
<td>beta</td>
<td>p-value</td>
<td>beta</td>
</tr>
<tr>
<td>WORMS scale</td>
<td>1.3</td>
<td>(0.03,2.5)</td>
<td>0.04</td>
</tr>
<tr>
<td>BLOKS scale</td>
<td>2.7</td>
<td>(1.5,3.9)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>BLOKS scale,</td>
<td>-0.4</td>
<td>(-1.7,0.8)</td>
<td>0.49</td>
</tr>
<tr>
<td>Max baseline</td>
<td>3.4</td>
<td>(1.4,5.3)</td>
<td>0.0008</td>
</tr>
<tr>
<td>BLOKS scale,</td>
<td>-0.08</td>
<td>(-1.2,1.0)</td>
<td>0.89</td>
</tr>
<tr>
<td>Max baseline</td>
<td>4.5</td>
<td>(2.9,6.2)</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>
Discussion

This manuscript describes the development and reliability of a novel scoring scheme for OA studies utilizing MRI of the knee. It is acknowledged that, at this stage of development, this system may serve multiple purposes (e.g. for outcome and risk factor assessments in clinical trials and for epidemiologic studies) and will ultimately have to be separately assessed and validated for each purpose. Just as MR technology and our knowledge of the OA process are in a rapid state of development, we intend for this instrument to continually evolve. The BLOKS scoring instrument may well contain elements that will likely be core as well as exploratory features. Determination of their continued inclusion will be critically evaluated after further exercises.

The BLOKS method of assessing BMLs has validity through stronger association with pain severity than that found with WORMS. In addition the BLOKS method’s ability to predict cartilage loss appeared stronger and provided additional information suggesting that the proximity of the lesion to the subchondral plate, and the amount of the lesion occupied by cyst influenced the rate of cartilage loss. Thus in addition to demonstrating the reliability of this instrument we have also demonstrated improved validity of the BML score within BLOKS over an existing instrument. Further investigative work will be needed to establish the validity and responsiveness of the BLOKS instrument and to explore the reasons for proximity of the lesion to the subchondral plate and the amount of lesion that is BML vs. cyst influencing the rate of cartilage loss.

The structural determinants of mechanical dysfunction and pain in arthritis are presently not well understood, but probably involve a multitude of interactive pathways characterized by changes in structure and function of the whole joint (2). The current practice of monitoring only a few of these features (usually radiographically-assessed joint-space narrowing and osteophytes) provides only a restricted view of the disease process and lessens the utility of such assessments.

MR can demonstrate soft-tissue structures and provide some insight into the tissue characteristics. For example, MRI studies of knee OA have been illuminating, revealing wide-ranging soft-tissue damage, hyaline cartilage defects, meniscal disruption, subchondral marrow changes and variability in appearance of cysts and osteophytes. They have shown that meniscal extrusion contributes to joint space loss in mild to moderate knee OA (17), and have uncovered pathologies such as bone marrow lesions and synovitis (18;19). This unparalleled imaging capability aligns well with a disease that affects the whole synovial joint organ and a need to capture detail on multiple different tissues in order to comprehensively evaluate a joint’s structural integrity. Because OA is a disease of all the tissues in the joints, measurements of structure need to be seen broadly and capture a broad number of important anatomic features, such as osteophytes, effusions, meniscal tears, subchondral bone architectural changes, in addition to cartilage loss. Most of these structures cannot be seen on plain radiography, whereas they are clearly visualized on MRI.

Before large investments are made in post-processing analysis of epidemiological studies (such as NIH OAI - a study in which 5000 subjects are having repeated longitudinal knee MRI assessments) and disease modifying OA drug clinical trials, researchers need to have available well-designed and validated tools. There are
currently a number of semi-quantitative methods used to measure changes in joint morphology (14;20-22) though (as this field is just developing) there is little research published regarding the traditional metric features of these tools. Recent data analysis exercises have raised concerns about the scaling and sensitivity to change of one semi-quantitative score that prompted the development of BLOKS (7;8).

We currently have additional studies underway on large datasets to ascertain the internal construct and content validity and the responsiveness of BLOKS. We are developing training tools and an instructional manual and atlas, and training tools to enhance further widespread use. A comprehensive atlas is needed so that the method can be applied by others. The increasing complexity of this instrument in an effort to separate constructs is a potential limitation of this development.

In conclusion, we have designed a novel expert-based scoring system for MRI OA knee, BLOKS, that demonstrates reasonable reliability and validity for BML assessment. Further iterative development will include validation for use in both clinical trials and epidemiological studies.

Acknowledgments

We would like to acknowledge the support of Astra Zeneca who sponsored the travel and meetings, and in particular Rose Maciewicz, John Waterton, Meilien Ho and Tony Nash for their ongoing support of this process. We would like to thank the participants and staff of the Framingham OA Study and the BOKS Study.

The Corresponding Author has the right to grant on behalf of all authors and does grant on behalf of all authors, an exclusive licence (or non-exclusive for government employees) on a worldwide basis to the BMJ Publishing Group Ltd and its Licensees to permit this article to be published in Annals of the Rheumatic Diseases editions and any other BMJPGL products to exploit all subsidiary rights, as set out in our licence http://ard.bmjjournals.com/ifora/licence.pdf
Appendix: Description of BLOKS

The BLOKS instrument was developed and tested on images obtained on a 1.5 T scanner with a dedicated peripheral knee coil. Other scanners with different field strengths will need to be evaluated.

Delineation of regional divisions

Osteoarthritis can affect one or multiple compartments in the knee. In BLOKS the knee is divided into 9 articular regions for scoring BMLS and articular cartilage:

1. The **patella** is divided into 2 regions, the medial and lateral patella on the axial view (see Figure 1), where medial delineates medial to the crista. If the lesion is centralized or at the crista then it is allocated to the medial region.

   ![Figure 1. Anatomical delineation of patella in axial plane.](image1)

2. The **femur** is divided into 4 regions—medial and lateral trochlea, and medial and lateral weight-bearing femur (the weight bearing femur includes the central and posterior femur).

   a. Method of dividing the regions (see Figure 2):

   i. **Trochlea** is defined as the femoral articular surface of the PF joint
   
   ii. For the division between the trochlea and weight-bearing regions, on the sagittal image a line is drawn parallel to the anterior aspect of the proximal tibia (at the margin of the tibial plateau) until it intersects the femoral surface (The rationale for choosing this division, as opposed to choosing the anterior aspect of the meniscus, was the concern that meniscal subluxation and degeneration would introduce variability into this delineation if used)
   
   iii. Anterior tibial margin is defined irrespective of the presence of osteophytes
   
   iv. The superior border of the femur is the epiphyseal line. The posterior border of the trochlea region is the anterior 50% of this region (as measured along the length of the epiphyseal line) (see figure 2)

   ![Figure 2. Anatomical delineation of femur into trochlea and weight-bearing regions on sagittal projection.](image2)

3. The **tibia** is divided into medial and lateral regions (the medial region includes the entire medial tibial plateau covered by articular cartilage, and the lateral the entire lateral tibial plateau covered by articular cartilage), and the subspinous (SS-region between the tibial spines) region is delineated for scoring related to the cruciate ligaments and BMLs and cysts.
Figure 3. Anatomical delineation of tibia on a coronal projection into medial, subspinous (SS) and lateral regions.

Special considerations for scoring in any region:
If there are features that span more than one region then the full size of the measured feature is attributed to the region that is most involved. Also, if a feature occurs within the subspinous region, but can be attributable to either the medial or lateral region, the lesion is assigned to the medial or lateral regions respectively.

Description of scoring for individual features

Each feature is scored separately. We have chosen a number of commonly recognized features based on their likely relevance to pain and structural damage or progression of OA. The scoring for BMLs and articular cartilage described is by regions as outlined above.

For each joint morphologic feature, we have listed the number (if there are multiple abnormalities), its location and grade. If there are multiple abnormalities within one region for a BML then each is scored separately. For cartilage which is scored by region the score is assigned for the region. This is in an effort to reduce the potential for mixing constructs. We have also described the optimal pulse sequences to delineate each feature.

1. **Bone Marrow Lesions (BMLs) and cysts** - includes areas of presumed bone marrow lesion (BML) (areas of irregular signal within the trabecular bone that are hypointense on T1-weighted images and hyperintense on T2-weighted fat-suppressed images) and associated bone marrow cysts (as opposed to a simple cyst without associated edema-like features). Previous studies have suggested that BMLs are an important factor in predisposing to cartilage loss (23) and also are associated with pain (9). It remains unclear as to whether the BMLs proximity to the subchondral plate is important for cartilage loss and or their specific regional location predicts cartilage loss immediately adjacent to the lesion. Although current scoring systems do not permit answering these questions, BLOKS specifically scores for each of these items.

   BMLs will be scored based on the standardized regions outlined previously. Multiple BMLs can occur within each region. Each BML will generate a separate grade for size, % surface area adjacent to subchondral plate and % of lesions that is BML as distinct from cyst (see Table 1).
   a. Each BML within a region is scored separately where they can be clearly demarcated, and if not scored as a single lesion.
   b. Each BML (including lesion and cyst) should be graded for size in comparison to the total volume of the region occupied by BML (see Figure 4).
   c. Percentage (%) surface area of the BML that is adjacent to subchondral plate (scored on image where lesion is largest and has area adjacent to subchondral plate) (see Figure 4). Although there is technically no articular cartilage in the region of the subspinous tibia, score for the subchondral plate as if there were cartilage in this area.
Table 1. Scoring system for bone marrow lesions

<table>
<thead>
<tr>
<th>Size of BML (including volume of any associated cysts) by volume</th>
<th>% surface area adjacent to subchondral plate</th>
<th>% of lesion that is bone marrow lesion (v. cyst)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0: none</td>
<td>0: none</td>
<td>0: none</td>
</tr>
<tr>
<td>1: &lt; 10% of whole bone* volume</td>
<td>1: &lt; 10% of BML’s subchondral surface area</td>
<td>1: &lt; 10%</td>
</tr>
<tr>
<td>2: 10 – 25% of whole bone* volume</td>
<td>2: 10 – 25% of BML’s subchondral surface area</td>
<td>2: 10 – 85%</td>
</tr>
<tr>
<td>3: &gt; 25% of whole bone* volume</td>
<td>3: &gt; 25% of BML’s subchondral surface area</td>
<td>3: &gt; 85%</td>
</tr>
</tbody>
</table>

*whole bone volume is defined as the region of the specified bone (e.g. medial trochlear femur, lateral tibia, or medial patella) bounded by the cortex and the epiphyseal plates

Figure 4. Line drawing examples of BML scoring system for size of BML and % surface area adjacent to subchondral plate.

d. Percentage of the volume of each BML that is BML (as distinct from cyst) is graded as; grade 0= none, grade 1 <10%, grade 2= 10-85% and grade 3 >85%.

e. If a cyst is present without associated bone marrow lesion, then cysts will be scored as a 0 for size % of lesions that is BML. The scoring system should be identical to the first 2 columns of bone marrow lesions (Table 1).

f. Do not score signal within osteophytes, however if the lesion extends beyond the osteophyte then it should be scored.

Pulse sequence

Suggested pulse sequences to evaluate BMLs are T2-weighted fat-saturated images in the axial, coronal, and sagittal planes.

2. Cartilage

Although many joint structures are affected, OA manifests prominently in the articular cartilage. Two methods for scoring cartilage were developed. The rationale for the development of the first system was to provide separate scores for the size (area affected) and extent of full thickness loss in each of the regional areas of the knee (Cartilage Score 1). This system is more complex as it requires the reader to integrate many focal abnormalities to arrive at one scale. To improve the reproducible selection of anatomic sites for reading purposes we also created a scoring system that facilitates scoring of the thickness at selected sites (Cartilage Score 2). These are sites where articular cartilage loss is most frequently observed.

Cartilage Score 1

☆ Grade each articular cartilage region (except the subspinous region) for size of loss (see figure 5) and % of loss in this region that is full thickness (Table 2 and figure 5).

Table 2. Delineation of grading for Cartilage Score 1

<table>
<thead>
<tr>
<th>Size of any cartilage loss (including partial and full thickness loss) as a % of surface area as related to the size of each individual region</th>
<th>% full thickness cartilage loss of the region</th>
</tr>
</thead>
<tbody>
<tr>
<td>0: none</td>
<td>0: none</td>
</tr>
<tr>
<td>1: &lt; 10% of region of cartilage surface area</td>
<td>1: &lt; 10% of region of cartilage</td>
</tr>
</tbody>
</table>
Annals March 12th 2007

<table>
<thead>
<tr>
<th>surface area</th>
<th>2: 10 – 75% of region of cartilage surface area</th>
</tr>
</thead>
<tbody>
<tr>
<td>3: &gt; 75% of region of cartilage surface area</td>
<td>3: &gt; 75% of region of cartilage surface area</td>
</tr>
</tbody>
</table>

**Figure 5.** Grade for size of any cartilage loss as a % of surface area as related to the size of each individual region

- Description of morphology at individual sites is not to be used to create cumulative scores of the knee as histopathology is unclear and this scale is not necessarily linear.

**Pulse Sequences:**

Optimal pulse sequences to evaluate cartilage is still undergoing extensive review and are detailed in a recent manuscript by Eckstein et al (24). This includes some of the following sequences:

- T1-weighted spoiled gradient recalled acquisition at steady state (i.e. spoiled gradient echo (SPGR) or fast low-angle shot (FLASH)) sequences with fat suppression
  - Advantage is high spatial resolution
  - Disadvantage: long acquisition time
  - Cartilage signal is bright / Synovial fluid signal is intermediate
- Selective water excitation (WE)
- Fat-suppressed, T2- or intermediate-weighted fast spin echo (FSE) driven equilibrium Fourier transform (DEFT) imaging
  - Cartilage signal is intermediate / Synovial fluid signal is bright

**Cartilage score 2**

This particular score is for site-specific cartilage loss and we would recommend this as an alternative grading scheme that contains less detail but is more easily administered (Table 3). This particular grade focuses on cartilage from 11 specific sites as described below.

For this score, only the listed locations will be evaluated including:

- 3 sites on the **medial and lateral patella** [on the axial image where the patella has the greatest width – the midpoint of the bisection], and the crista (see Figure 6).

**Figure 6.** 3 sites on the medial and lateral patella and the crista for grading

- 4 sites on the **medial and lateral weight-bearing tibia and femur** [for the medial regions, find the slice with the largest medial tibial spine on the coronal image– the site that bisects the horizontal line connecting the medial tibial spine and the edge of the tibial plateau → similar definition for lateral regions, in addition to site halfway between midpoint and edge of tibial plateau] (see Figure 7).

**Figure 7.** Slice with the largest medial tibial spine on the coronal image— the point that bisects the line connecting the medial tibial spine and the edge of the tibial
plateau → similar definition for lateral regions, in addition to point halfway between midpoint and edge of tibial plateau.

<table>
<thead>
<tr>
<th>Table 3. Delineation of grading for Cartilage Score 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of any cartilage loss at specified points</td>
</tr>
<tr>
<td>0: none</td>
</tr>
<tr>
<td>1: partial loss</td>
</tr>
<tr>
<td>2: complete loss</td>
</tr>
</tbody>
</table>

3. Osteophytes

Osteophytes are osteo-cartilaginous protrusions growing at the margins of osteoarthritic joints from a process that involves endochondral ossification. Previous radiographic studies have highlighted this feature as a hallmark of disease (25). For BLOKS each osteophyte is graded according to size (Table 5) and scored in the 12 regions outlined below:

a. Score osteophyte size for each region – 12 locations as listed in the table below with appropriate slice orientation

<table>
<thead>
<tr>
<th>Table 24. Sites for osteophyte scoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osteophyte Location</td>
</tr>
<tr>
<td>---------------------------------------</td>
</tr>
<tr>
<td>Anterior femur (trochlea)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Posterior Femur</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Weight Bearing Femur</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Patella</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Tibia</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

(Osteophytes along the trochlea, central weight bearing and posterior margins of the femoral condyles and weight bearing tibial plateaus, and along the medial, lateral, superior and inferior margins of the patella) (see Figure 8).

Figure 8. Location in sagittal plane to score osteophytes

<table>
<thead>
<tr>
<th>Table 5. Delineation of grading for osteophytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of Osteophyte</td>
</tr>
<tr>
<td>0: none</td>
</tr>
<tr>
<td>1: mild</td>
</tr>
</tbody>
</table>
b. Size of osteophyte should reflect protuberance (how far the osteophyte extends from the joint) rather than total volume of osteophyte (see Figure 9).

Figure 9. Grading for osteophyte size

C. An osteophyte must be visible on 2 consecutive slices (assuming the slice thickness is ≤3mm) to be scored.

d. Score the largest osteophyte within a given region

Pulse sequence

Optimal pulse sequences to evaluate osteophytes are standard non-fat-suppressed short TE-weighted (preferably T1 over proton density) images in the axial, coronal, and sagittal planes.

4. Synovitis

Synovitis is frequently present in osteoarthritis and may predict other structural changes in osteoarthritis and correlate with pain and other clinical outcomes (22). Quantitative MRI markers of synovitis include the volume of synovial tissue and fluid and the rate of synovial enhancement following intravenous injection of contrast material. Because it is less costly to obtain non-gadolinium enhanced MRIs and synovitis can still be visualized on these sequences, we have outlined a scoring scheme that will accommodate readings performed using these sequences. Synovial thickening around the infra-patellar fat pad using noncontrast MRI has been shown on biopsy to represent mild chronic synovitis (19). This abnormality is best described as hyperintense T2 signal located within the fat that in addition to synovitis could also be attributed to other etiologies such as arthroscopy or Hoffa’s disease. Therefore, as part of BLOKS, we have developed scoring for synovitis in 5 regions in the knee.

a. Infrapatellar score (on sagittal image) (one score for the whole knee) based on the region highlighted in Figure 10. Score is based on size: 0= normal; 1= mild, 2= moderate, 3= severe.

Figure 10. Region for scoring infrapatellar synovitis grade on sagittal image

i. Scale: Score is based on size
0: normal
1: mild
2: moderate
3: severe

b.ii. Other sites for synovitis
ii. Each site generates additional data based upon the presence/absence of synovitis at that site.
iii. List of sites:

4. Hoffa’s fat pad (infrapatellar) – present/absent (Viewed on sagittal sequences)
1. Medial Posterior-condylar – present/absent (Viewed on sagittal sequences)
2. Lateral Posterior-condylar – present/absent (Viewed on sagittal sequences)
3. Medial recess (deep to medial collateral ligament) – present/absent (Viewed on coronal sequences)
4. Lateral recess (deep to lateral complex) – present/absent (Viewed on coronal sequences)

Pulse sequences
Suggested pulse sequences to evaluate regions for synovitis are T2-weighted fat-saturated images in the axial, coronal, and sagittal planes.

5. Effusion
Effusions occur frequently in OA. Recent studies suggest that large synovial effusions may be associated with pain and stiffness in patients with OA (22). Effusions occur within the synovial space. Scores (Table 6) should be obtained from axial views (see Figure 11- for images portraying the text in table). Cysts and ganglion fluid should not be included in this score as they are considered separately.

<table>
<thead>
<tr>
<th>Size of effusion (based on Hill paper (22))</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>0: physiologic amount</td>
<td>Suprapatellar bursa only</td>
</tr>
<tr>
<td>1: small – fluid continuous in the retropatellar space</td>
<td></td>
</tr>
<tr>
<td>2: medium – with slight convexity of the suprapatellar bursa</td>
<td></td>
</tr>
<tr>
<td>3: large – evidence of capsular distention</td>
<td></td>
</tr>
</tbody>
</table>

Figure 11. Grading system for effusion size.

Pulse Sequence:
Optimal sequences for evaluating effusion scores are Proton Density or T2-weighted axial images where effusion signal is hyperintense.

6. Meniscus
The meniscus has many functions in the knee, including load-bearing, shock absorption, stability enhancement and lubrication (26;27). Previous studies have highlighted the importance of an intact and functioning meniscus in subjects with symptomatic knee osteoarthritis (28). A recent study has shown that both changes in position (also termed subluxation or extrusion) and meniscal morphologic change manifest as tears were shown to predispose to cartilage loss. We wanted a scoring system that delineated both of these items and provided detail on what the abnormality was and where in the meniscus this occurred.

\[\text{Extrusion:}\]

\[\text{a. Four areas where extrusion is scored (Table 7):}\]
Medial Meniscus: Medial extrusion relative to medial tibial margin (coronal image)

Medial Meniscus: Anterior extrusion (sagittal image) – where extrusion is maximum

Lateral Meniscus: Lateral extrusion relative to lateral tibial margin (coronal image)

Lateral Meniscus: Anterior extrusion (sagittal image) where extrusion is maximum

Note: we wanted to capture anterior extrusion to see if this is independently predictive of cartilage loss/pain/etc compared with medial or lateral extrusion. For each measurement the reference will be the edge of the tibial plateau (excluding osteophyte).

Table 7. Delineation of grading for extrusion

<table>
<thead>
<tr>
<th>Amount of extrusion (mm) -</th>
</tr>
</thead>
<tbody>
<tr>
<td>0: &lt;2mm</td>
</tr>
<tr>
<td>1: 2-2.9mm</td>
</tr>
<tr>
<td>2: 3-4.9mm</td>
</tr>
<tr>
<td>3: &gt;5mm</td>
</tr>
</tbody>
</table>

**Morphology**: (scored on medial and lateral meniscus for the anterior, body and posterior horn).

**Regions scored**:

1. Medial Meniscus: anterior, body, and posterior horn
2. Lateral Meniscus: anterior, body, and posterior horn

The anterior and posterior horn regions are scored using the sagittal sequences and body is scored using the coronal sequences.

**Morphologic features scored**:

1. Signal Y/N (not extending through meniscal surface i.e. not a tear): Y/N
2. Signal is defined as above as compared with "tears" which are defined as high signal extending to an articular surface
3. Vertical tear (includes radial and longitudinal tears) – must extend to both the femoral and tibial surfaces: Y/N
4. Horizontal tear: Y/N
5. Complex tear: (as defined by high signal that extends to 2 surfaces and > 3 points) Y/N
6. Root tear (posterior horn): Y/N
7. Macerated: Loss of overall normal morphological appearance of the meniscus and with an associated increased diffuse signal in the meniscal tissue Y/N
8. Meniscal cyst: Y/N

**Pulse sequence**

Optimal sequences to evaluate menisci are T1 or proton density fat-saturated images in both coronal and sagittal planes.

7. **Ligaments**
Anterior cruciate ligament tears will be recorded as either absent or present. Partial tears are infrequent and reportedly prone to poor reliability on interpretation.

a. Anterior Cruciate Ligament (ACL):
   i. Score: normal (0) / complete tear (1)
   ii. Associated with BML/cyst at site of insertion or origin?: Y/N
   iii. ACL Repair: Y/N

b. Posterior Cruciate Ligament (PCL):
   iv. Score: normal (0) / complete tear (1)
   v. Associated with BML/cyst at site of insertion or origin?: Y/N

c. Patellar tendon
   vi. Score: 0: no signal abnormality/ 1: signal abnormality present

Pulse Sequence
Optimal sequences to evaluate the aforementioned ligaments are coronal and sagittal, Intermediate-weighted, fat-suppressed, Turbo Spin Echo (TSE) images.

8. Periarticular features
   a. Pes anserine bursitis – absent / present
      This is a bursa that lies anterior and inferior to the medial tibial plateau and is a potential source of pain around the knee.

b. Iliotibial band signal – absent / present
   The iliotibial band is a strong, dense, broad layer of fascia that is part of the fascia lata. The iliotibial band encases the tensor fasciae lata which helps to steady the trunk on the thigh. ¾ of the gluteus maximus inserts into the iliotibial tract and the distal end inserts at the lateral tibial plateau.

c. Popliteal cyst-absent/ present
   If a popliteal cyst is present, it will occur just posterior to the region where the majority of the knee effusion lies.
   Pulse sequence: Optimal sequences for evaluating effusion scores are Proton Density or T2-weighted axial images where effusion signal is hyperintense.

d. Infrapatellar bursa signal – absent / present
   This is a bursa that lies posterior to the patella and is a potential source of pain around the knee.

e. Prepatellar bursa signal – absent / present
   This is a bursa that lies anterior to the patella and is a potential source of pain around the knee.

f. Ganglion cysts
   If located:
   1. Associated with the tibio-fibular joint
   2. Associated with meniscus
   3. Associated with PCL and ACL
   4. Associated with the semimembranosis
   5. Associated with the semitendinosus
   6. Other
Reference List


Ref Type: Abstract


Figures for BLOKS Manuscript
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Figure 2. Anatomical delineation of femur into trochlea and weight-bearing regions on sagittal projection.
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Figure 4. Line drawing examples of BML scoring system for size of BML and % surface area adjacent to subchondral plate for the tibial plateau.
Figure 5. Grade for size of any cartilage loss as a % of surface area as related to the size of each individual region.
Figure 6. 3 points on the medial and lateral patella and the crista for grading.
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Figure 8. Location in sagittal plane to score osteophytes
Figure 9. Grading for osteophyte size
Figure 10. Region for scoring infrapatellar synovitis grade on sagittal image
Figure 11. Grading system for effusion size.