Diagnosis of Knee Osteochondral Lesions With Ultrasound

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Abstract

Evaluation of articular cartilage and subchondral bone is essential in diagnostics of joint diseases and injuries. Inter- and intra-observer reproducibilities of arthroscopic grading are only poor to moderate. Thus, for quantitative and objective evaluation of cartilage and subchondral bone, ultrasound arthroscopy (UA) has been introduced to clarify this dilemma. The clinical feasibility of high frequency ultrasound (US) during six knee arthroscopies was conducted and the surgical technique is presented. US imaging was conducted with a flexible 9 MHz ultrasound catheter inserted into the joint trough conventional portals. US and arthroscopy videos were synchronously recorded and US parameters for cartilage and subchondral bone characteristics were measured. Arthroscopy and US imaging were combined in cartilage grading. UA produced quantitative data on lesion size, cartilage quality and revealed subchondral bone changes. Visualization of an OCD lesion not detected by conventional arthroscopy and US guided retrograde drilling were possible with UA. To conclude, UA proved to be clinically feasible and aided diagnostics when assessing knee osteochondral lesions.

Introduction

Evaluation of articular cartilage and subchondral bone is essential in diagnostics of joint diseases and injuries. Currently, diagnostics is based on clinical history, examination, radiographic imaging and magnetic resonance imaging (MRI). Diagnosis of cartilage lesions should be immediate, sensitive and reproducible to optimize treatment and prevent trauma-initiated osteoarthritis. Unfortunately, chondral lesions can sometimes be overlooked by MRI due to suboptimal resolution, sensitivity and accuracy (1). Nonetheless, non-traumatic joint diseases, like osteochondritis dissecans (OCD), are reported to cause major knee related morbidity, especially among adolescents and young adults.
Numerous surgical techniques have been described for repair of ochondral lesions (2). An accurate evaluation, grading and delineation of chondral lesion relative to subchondral bone are essential when selecting the appropriate cartilage repair technique.

Arthroscopic assessment of chondral injuries and stability of OCD is challenging (3), and the inter- and intra-observer reproducibilities of grading of cartilage lesions have been reported to be poor, especially in the differentiation of intact International Cartilage Research Society (ICRS) 0 from softened ICRS 1 cartilage and ICRS 2 from ICRS 3 lesion. (4). An apparent need for more objective and quantitative arthroscopic methods has been identified (5).

Several cartilage measurement instruments, like external US, arthroscopic indentation techniques and optical coherence tomography, have been introduced. Quantitative US is reported to detect an increase in articular cartilage surface roughness, degradation of superficial collagen, changes in subchondral bone mineralization and cartilage healing after surgical repair and this technique is recently been applied in human knee arthroscopies (6,7). Ultrasound arthroscopy (UA) is a quantitative imaging technique that enables simultaneous visualization of cartilage and subchondral bone. The US device, applied in our previous and present publications is approved by the Food and Drug Administration (FDA) for human cardiographic imaging.

**Surgical technique**

A standard knee arthroscopy set up is used. The patient is placed supine with the hip flexed at about 50° and knee flexed at about 100°. A thigh torniquet is recommended, but not mandatory. We prefer a straight operating table with a side post and a foot rest. Both spinal and general anesthesia can be used. In addition an ultrasound imaging device with a separate monitor, placed near the arthroscopy monitor, is needed making it possible to follow both monitors. Conventional portals (anteromedial and anterolateral) are prepared in the usual way. The arthroscope is inserted through the anterolateral portal and diagnostic arthroscopy is performed. Additional portal
placement (superolateral or -medial, posterolateral or -medial) can be used when needed for the UA. Encountered osteochondral pathology is classified according to the International Cartilage Repair Society (ICRS) guidelines (1,8). A sterile US imaging catheter is prepared injecting sterile saline with a needle into the tip of the 2.8 mm flexible 9 MHz US catheter (diam. 2.8mm, Boston Scientific Co, CA, USA). The US device is activated and inserted into the knee joint manually through the arthroscopy portal and guided, if needed, within the joint by an arthroscopic half-pipe instrument or a hook (Fig. 3). The narrow and flexible catheter can be guided to reach every region in the knee joint. Due to the brittle construction of the US catheter, forceful manipulation or pushing towards a resistance need to be avoided. Similarly excessive bending of the catheter can cause disturbances in the US imaging. US- and arthroscopy can be synchronously recorded. The US probe is adjusted manually to achieve perpendicular US incidence at lesion surface in order to optimize visualization and to maximize US reflection. In addition to high resolution real time imaging, US reflection coefficient (R), integrated reflection coefficient (IRC) and US roughness index (URI) are recorded for the cartilage and subchondral bone in normal and pathologic sites of the knee (Figs. 1,2,3 and 4). Treatment modalities for each defect are chosen by combining data from visual inspection, mechanical probing and US characteristics.

UA enables quantitative measurement of cartilage lesion depth relative to cartilage thickness offering more information for the ICRS grading (Figs. 1, 2, 3 and 4). Normal (ICRS 0) and nearly normal (ICRS 1) cartilage showed similar reflection values (R and IRC), providing no additional information for the ICRS grading. However, US roughness index was elevated in ICRS 1 cartilage. (Fig. 1). A decrease in US reflection (R) was noted between abnormal (ICRS 2) and severely abnormal (ICRS 3) cartilage (Fig. 2). On the other hand US roughness index (URI) was increased in abnormal cartilage (ICRS 2-3) compared to normal or mildly deteriorated (ICRS 0-1) cartilage. High US reflection (R) was seen in ICRS OCD grade 4 lesion with exposed sclerotic bone on the bottom of the defect. After debridement and microfracture treatment picking holes could be visualized by US (Fig. 4). Moreover, UA enables detection of osteochondral lesions as well as measurement of their dimensions. UA is able to detect an OCD lesion with intact articular cartilage.
(pt 5 and 6) (Fig. 3, video). In addition, UA can demonstrate fluid between the bone-cartilage interface indicating an unstable OCD lesion necessitating surgical intervention (Fig. 3, Video).

Even with breeched and lacerated cartilage surface, US allow simultaneous visualization of deeper structures reaching the subchondral bone. Furthermore, UA enables the evaluation meniscal pathology (Fig. 2). US guided retrograde drilling of ICRS OCD Grade 2 lesion is also possible (Video). US enables accurate evaluation of depth and progression of the drilling, avoiding the cartilage surface perforation. The use of fluoroscopy can be minimized.

Discussion

UA enables imaging and accurate measurements of chondral and osteochondral lesion size, depth and quantitative acoustic morphology characteristics of cartilage (R, IRC, URI). Every region in a knee joint is achievable by UA. Thus, UA proved to be a useful adjunct when assessing and treating knee osteochondral lesions.

Although US imaging was primarily used to confirm the grades obtained by conventional arthroscopy, UA lead to a change in the ICRS grade in one out of six patient, where an ICRS OCD grade 2 lesion would have been missed by conventional means. The ability of conventional arthroscopy to differentiate ICRS 0 from 1 lesions and ICRS 2 from 3 lesions can be challenging. Unfortunately the obtained US parameters did not help in the differentiation between these ICRS grades. Nevertheless, the differentiation of these groups was possible based on the US images. This observation is supported by a recent report demonstrating a significant effect of arthroscopic ultrasound imaging on clinical cartilage grading (8). However, the interpretation of the UA images was not blinded, which probably composes a potential bias in the interpretation of the UA images. No statistically significant variation in the measured US parameters, between lesions of different severity, were found. This is due to the limited number of patients with variable cartilage conditions.

Nonetheless, UA provides advantages compared to existing techniques used in knee cartilage
evaluation and treatment. Conventional arthroscopy enables an evaluation of the superficial
cartilage by visual and probing characteristics, but no quantitative data. Furthermore, external
ultrasonography of the knee is suitable only in limited areas requiring an experienced examiner (9).

To conclude, UA was found to be readily applicable and diagnostically valuable when evaluating
the integrity of knee articular cartilage. Cartilage thickness and quality may be quantitatively
assessed providing objective information on the location and extent of lesions. Furthermore, the
stability and characteristics of OCD lesions can be evaluated with UA. US visualization of
retrograde drilling in OCD treatment is also possible and, thus, the use of fluoroscopy can be
minimized. However, further basic and clinical research on this topic is warranted. We expect that
UA might be a useful adjunct for arthroscopic surgeons in the future.
References


**Figure legends**

Figure 1. A still ultrasound arthroscopy image showing normal ICRS 0 (A, B) and nearly normal ICRS 1 (C, D) cartilage. Both surfaces produce similar ultrasound reflection (R) However, ultrasound roughness index (URI) is elevated for ICRS 1 compared to ICRS 0 articular cartilage as clearly seen in the corresponding arthroscopy images (A, C). P=patella, T=trochlea, R=ultrasound reflection coefficient (%), IRC=integrated reflection coefficient (dB), URI=ultrasound roughness index (µm).

Figure 2. A still ultrasound arthroscopy image demonstrates a decrease in ultrasound reflection (R, IRC) and a respective increase in ultrasound roughness index (URI) with progressive cartilage degradation as seen in abnormal patellar ICRS 2 (A,B) and severely abnormal femoral ICRS 3 (C,D) lesions compared to normal cartilage (Fig.1). A concomitant meniscus pathology (encircled in red) can be visualized by ultrasound (D). P=patella, T=trochlea, F=femur, Ti=tibia, m=meniscus, R=ultrasound reflection coefficient (%), IRC=integrated reflection coefficient (dB), URI=ultrasound roughness index (µm).

Figure 3. The characteristic subchondral separation (encircled) encountered in osteochondritis dissecans (OCD) lesions can be visualized with ultrasound arthroscopy (UA) as gaps of otherwise intact subchondral bone signal (A, B). Furthermore, if UA demonstrates fluid beneath the cartilage surface, an unstable OCD can be suspected (A, C). F=femur, Ti=tibia, m=meniscus, s=scope artifact, sb=subchondral bone, f=fluid, R=ultrasound reflection coefficient (%), IRC=integrated reflection coefficient (dB), URI=ultrasound roughness index (µm).

Figure 4. Ultrasound arthroscopy (UA) demonstrates high reflection and intermediate roughness values for exposed sclerotic subchondral bone (A, B). Other subchondral bone changes like microfracture picking holes can also be visualized by UA (C, D). F=femur, Ti=tibia, sb=subchondral bone, mf=microfracture picking hole, R=ultrasound reflection coefficient (%), IRC=integrated reflection coefficient (dB), URI=ultrasound roughness index (µm).
The principle of arthroscopic ultrasound imaging, and different cartilage lesions in the knee joint are shown in simultaneous arthroscopy and ultrasound views. Simultaneous ultrasound and arthroscopy videos present the non-invasive evaluation, retrograde drilling and bone transplantation for three different osteochondritis dissecans lesions in medial femoral condyle.

Table 1.

Table 1. Demographics and results of knee ultrasound arthroscopy patients. LFC=lateral femoral condyle, MFC=medial femoral condyle, OCD=osteochondritis dissecans, OA=osteoarthritis, ICRS=International Cartilage Repair Society, Gr=grade

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age (yrs)</th>
<th>Age (yrs) surgery</th>
<th>Preoperative Lysholm Knee Score</th>
<th>Affected knee</th>
<th>Open growth plates</th>
<th>Extent of the lesion (cm²), MRI</th>
<th>Location of the lesion</th>
<th>Diagnosis</th>
<th>MRI Grade</th>
<th>Ultrasound arthroscopy Grade</th>
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<tr>
<td>Female</td>
<td>25</td>
<td>25.2</td>
<td>-</td>
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<td>No</td>
<td>0.76</td>
<td>LFC</td>
<td>OCD</td>
<td>ICRS OCD Gr IV</td>
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<td>Male</td>
<td>16.4</td>
<td>28.1</td>
<td>80</td>
<td>Right</td>
<td>No</td>
<td>3.30</td>
<td>MFC</td>
<td>OCD</td>
<td>ICRS OCD Gr III</td>
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<tr>
<td>Male</td>
<td>24.1</td>
<td>24.4</td>
<td>71</td>
<td>Left</td>
<td>No</td>
<td>0.17</td>
<td>MFC</td>
<td>Posttraumatic OA, meniscus defect</td>
<td>ICRS Gr III</td>
<td>ICRS Gr III</td>
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<tr>
<td>Male</td>
<td>37.9</td>
<td>38</td>
<td>72</td>
<td>Right</td>
<td>No</td>
<td>0.43</td>
<td>Patella</td>
<td>Oberer femoral OA</td>
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<td>Male</td>
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<td>OCD</td>
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<td>11.4</td>
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<td>Left</td>
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<td>0.40</td>
<td>Both condyles</td>
<td>OCD</td>
<td>ICRS OCD Gr II</td>
<td>ICRS OCD Gr II</td>
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Table 2.

Advantages, limitations and risks of ultrasound arthroscopy (UA)

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Limitations and risks</th>
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<tr>
<td>Comprehensive accessibility</td>
<td>Not yet validated for cartilage injury classification</td>
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<tr>
<td>Quantitative cartilage measurements (e.g. cartilage thickness, lesion depth and size, US characteristics)</td>
<td>Costs (US catheter, measurement device)</td>
</tr>
<tr>
<td>Accurate cartilage lesion evaluation</td>
<td>Marginally prolonged operation time (5-15 minutes)</td>
</tr>
<tr>
<td>Accurate osteochondral lesion evaluation (e.g. intraoperative OCD stability assessment)</td>
<td></td>
</tr>
<tr>
<td>Radiation free intraoperative monitoring (e.g. cartilage, menisci, subchondral bone)</td>
<td></td>
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<tr>
<td>A possibility for US guided procedures (e.g. retrograde OCD drilling)</td>
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