Arthroscopic correlation of knee injuries observed in a low-field MRI (0,35T)

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Purpose

Assess the diagnostic efficacy of knee studies performed in an open low-field MRI (0.35T) by correlating the conclusions in the radiological report and the arthroscopic findings from the intervention afterwards.

Check possible differences in the diagnostic precision depending on analyzed intraarticular anatomic element, evaluating separately the medial (MM) and lateral meniscus (LM), the anterior cruciate ligament (ACL), and the hyaline cartilage of the three compartments: patellofemoral (PF), medial tibiofemoral (MTF) and lateral tibiofemoral (LTF).

Analyze through images the causes which have generated radiological-surgical discordance most frequently, in order to improve the diagnostic efficiency.
Methods and Materials

A retrospective study was performed, starting from the knee arthroscopies records carried out in the Trauma and Orthopaedics Department of our hospital for 5 months (January to June 2011) and retrieving the MRI examinations afterwards. From a total of 137 arthroscopies recorded in that period of time, we were able to retrieve 108 radiological reports as the other 29 had been performed in other medical centres.

The MRI examinations were performed on an open low-field Signa Ovation system operating at 0.35T MRI, using a surface coil appropriate for knee MRI.

Patients were examined using two different protocols, depending on the radiologist in charge (in many cases not belonging to our department), which included the sequences shown in Figure 1; the great majority of the studies were performed using protocol A, and a few of them using protocol B.

Of the 108 MRI examinations performed in our radiology department, we analyzed 83 in the work stations; we had to discard the other 25 because of the lack of accurate arthroscopic data or examinations being performed during the PACS implementation phase in our department (may 2010), when the images were not linked to the patient's radiological records. We used these 83 examinations for the detailed analysis of the anatomic structures, and compared the original conclusions in the radiological report with the arthroscopic register data (where the injured structures and the surgical technique were recorded). We assessed as true (T) or false (F) each finding (in MM, LM, ACL and PF, MTF and LTF cartilage), according to the arthroscopic correlation.

This systematic way of sorting out information makes it possible, up to a certain point, to counteract the variability in report style and make a more objective estimation of:

- The test's global correlation in a given patient: by adding the true or false value of findings in different structures. We considered separately the medial and lateral meniscus and ACL (because of their greater therapeutic significance), and cartilaginous injury in the three compartments.
- Diagnostic performance by structures: true reported findings percentage for each anatomic component to analyze.
- Test precision or accuracy for the diagnosis of rupture of the medial and lateral meniscus and ACL, including: sensitivity, specificity, positive predictive value and negative predictive value.
To calculate diagnostic precision or accuracy, we took into account not only the findings (positive or negative) explicitly reported (informed findings), but also the non reported ones, considering these last ones as true negatives only when they were not mentioned in the arthroscopy either. We didn't take into account the informed findings which couldn't be confirmed because of the lack of surgical information (non checked findings).

In the case of the radiological reports without conclusions, these were deduced from the report's body by two general radiologists with special - although not exclusive - dedication to musculoskeletal MRI. The same radiologists were the ones who revised all the images in the work stations, noting down by general consent possible findings and interpretations regardless of the original report, according to the established meniscal criteria, ACL and cartilaginous injury in MRI (Table 1), and its correlation. They also selected the most illustrative cases depending on special frequency, discordance or concordance degree, or other reasons. However, the analysis was only based on the original reports, and not on this later revision, which was done with no blind conditions and having only a didactic purpose. We have few arthroscopic images because intervention videos or photographic recordings were not a standard practice in the Traumatology Department at that moment (Figs 2 and 3).
Fig. 1: Pulse sequences used: A - most of the explorations, B - occasionally.

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<table>
<thead>
<tr>
<th><strong>Meniscal Tear</strong></th>
<th>Intrameniscal high-signal contacting with the articular meniscal surface in one (possible) or more than one (probable) MRI image, consecutive or not, in the same or different sequences.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Meniscal morphology distortion.</td>
</tr>
<tr>
<td></td>
<td>Displaced meniscal material.</td>
</tr>
<tr>
<td><strong>Complete ACL Tear</strong></td>
<td>Ligamentous hyperintensity with irregular borders.</td>
</tr>
<tr>
<td></td>
<td>Ligamentous shrink.</td>
</tr>
<tr>
<td></td>
<td>Non recognizable ligament.</td>
</tr>
<tr>
<td><strong>Partial ACL Tear</strong></td>
<td>Ligamentous hyperintensity with intact borders.</td>
</tr>
<tr>
<td><strong>Cartilaginous Injury</strong></td>
<td><strong>I</strong> – Patched signal  <strong>II</strong> – Superficial Irregularity  <strong>III</strong> – Ulceration  <strong>IV</strong> – Denudation</td>
</tr>
</tbody>
</table>

**Table 1:** Established meniscal, ACL and cartilaginous injury criteria in knee MRI.

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**Fig. 2:** Fig. 2 - Medial meniscus' posterior horn oblique tear.

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**Fig. 3:** Fig. 3 - Medial meniscus' tear in arthroscopy (same patient as in Figure 2).

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Results

Of the 83 studies selected for the retrospective revision, there were 49 males (59%) and 34 females (41%). The ages ranged from 14 to 79 years (average = 47).

The test's global correlation in a given patient was complete in 46 cases (55.4%), partial (correct in at least half of the informed findings) in 23 (27.7%) and null in 14 (16.9%). There were no significant differences in this aspect depending on the time interval between MRI and arthroscopy, which was very variable (from 1 to 15 months, average = 5 months). There are two examples of complete (Figure 4) and null correlation (Figure 5).

We didn’t take into account the following findings for the radiological - surgical correlation: posterior cruciate and collateral ligament injuries, synovial periarticular cysts, parameniscal cysts, intra and juxtaarticular ganglions, not subchondral bony cysts and patellofemoral dysplasia or external patellar friction syndrome.

The count of the reported findings for each intraarticular structure and their confirmation or discordance with the arthroscopy provided the performance figures shown in Table 2. The higher percentage of informed and arthroscopy-confirmed findings (71.4%) and also of general informed findings corresponded to the medial meniscus. The lower correlation percentage (52.2%) corresponded to the patellofemoral cartilage, often mentioned in the reports, and to the lateral tibiofemoral cartilage (53.8%), rarely informed.

We would like to highlight the high number of findings referring to these same articular components (patellofemoral and lateral tibiofemoral cartilage) which were considered as non-checked (imprecise arthroscopic record) and, as our radiologists mentioned, the difficulty to detect at a later stage chondropathy signs found in the arthroscopy (Figures 6 and 7), and to correctly grade the articular degenerative disease in mild phases (Figure 8), but not the obvious changes of the severe disease (Figures 9 and 10).

A high number of error and imprecision related to the cartilage were due to generic reports like "patellar chondromalacia", based on cartilage global thickness or heterogeneous signal, or to tibiofemoral subchondral bony marrow signal changes which were not clearly related to visible chondral abnormalities.

For this reason, we calculated the diagnostic precision only for the meniscus and ACL, obtaining the data shown in Table 3, and starting from them, values shown in Table 4.
The technique is quite accurate for meniscal tear diagnosis, especially in medial meniscus (Sensitivity = 79.3%, Positive Predictive Value=88.6%): Figure 11.

Sensitivity was lower in lateral meniscus (64.3%), in which 5 out of 14 tears were not diagnosed (Figures 12 and 13).

In both meniscus, the strict application of accepted rupture criteria (particularly the "Two-Slice-Touch" Rule of De Smet y Tuite) allowed the correct diagnosis in many cases (Figures 14 and 15), and the diagnostic accuracy would have improved if it had been applied in others (Figures 16 and 17).

The test accuracy for the complete native (non-operated) ACL tear diagnosis was very high (Figures 18 and 19).

The low positive predictive value for ACL tear (45.4%) was due to 5 cases reported as "partial tear", which were not confirmed in the arthroscopy (performed in all the cases with another concomitant reason as meniscal tear, chondral injury or clinical situation). In only one arthroscopy, performed after radiological report of "partial monofascicular ACL tear and LM rupture", no injury was found (Figure 20).

The frequent ACL blurriness in 3D SPGR sequence didn't lead to wrong interpretations such as complete tear when the sequences as a whole were analyzed (Figures 21 and 22). The only case of false positive of complete ACL tear was the one shown in Figure 23.

The absolute diagnostic efficacy (100%) for the ACL graft tear is conditioned by the small number of patients with ACL reconstruction (3) included in our study. We are presenting two of these three cases, correctly diagnosed as graft integrity (Figure 24) and disintegration (Figure 25) respectively.

In some other cases of operated knees, the accuracy for meniscal remainder after meniscectomy diagnosis was more variable (Figure 26).

Finally, we also performed a secondary analysis of diagnostic performance by structures and ages, dividing our patients into two groups - younger and older than 45 - because of higher degenerative injuries prevalence in the latter one. The results are shown in Table 5.
Fig. 4: Full concordance of findings in an operated knee (from left to right): medial meniscus’ post-surgical changes without visible tear; ACL graft rupture; and severe degenerative articular disease with manifest changes in the internal compartment.

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Fig. 5: Discordance in radiological -surgical findings in the same knee. Sagittal serie and coronal image of a discoid LM with tear criteria in images and radiological report. In return, during the surgery a medial meniscus tear was found (reported in MRI as degenerative - right inferior box).

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<table>
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<tr>
<th></th>
<th>MM</th>
<th>LM</th>
<th>ACL</th>
<th>PF</th>
<th>MTF</th>
<th>LTF</th>
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<tr>
<td>Total number of reported findings</td>
<td>70</td>
<td>24</td>
<td>14</td>
<td>44</td>
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<tr>
<td>Confirmed findings</td>
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<td>14</td>
<td>9</td>
<td>23</td>
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<tr>
<td>Non-confirmed findings</td>
<td>17</td>
<td>9</td>
<td>5</td>
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<tr>
<td>Non-checked findings</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>6</td>
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<td>3</td>
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<tr>
<td>Diagnostic Performance(%)</td>
<td>71.43%</td>
<td>58.33%</td>
<td>64.28%</td>
<td>52.27%</td>
<td>71.79%</td>
<td>53.84%</td>
</tr>
</tbody>
</table>

Table 2

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**Fig. 6:** Grade II internal condyle chondropathy not reported and not evident in posterior revision either. Lateral meniscus degenerative hyperintensity.

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Fig. 7: Insensitivity of 0.35T MRI in hyaline cartilage pathology: medial tibiofemoral and patellofemoral chondromalacia, not detected in a 33 year-old female with medial meniscus tear.

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Fig. 8: New medial meniscus tear after partial meniscectomy and grade III osteochondral injury in medial femoral condyle and tibial plateau, reported as post-surgical meniscal changes and mild articular degenerative disease (ADD): technique limitations in operated knee and for graduating moderate ADD.

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Fig. 9: Articular degenerative disease, with grade IV medial condyle osteochondral injury and without visible patellofemoral injury in MR - arthrography. Patellar cartilage contrast is higher in axial echo-gradient than in STIR images, although no abnormalities are detected in either of them.

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Fig. 10: Grade IV medial condyle osteochondral injury associated with medial meniscus tear. Cartilage thickness loss in B, C and D and subchondral bony marrow signal alteration, reported as "subchondral edema": example of concordance in severe chondropaties, in spite of the variability in describing radiological findings.

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<table>
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<th>MRI</th>
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<tbody>
<tr>
<td></td>
<td>Torn</td>
<td>Not torn</td>
<td>No data</td>
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<tr>
<td><strong>Medial Meniscus (n=83)</strong></td>
<td>39</td>
<td><strong>5</strong></td>
<td>2</td>
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<tr>
<td>Torn</td>
<td><strong>10</strong></td>
<td>26</td>
<td><strong>1</strong></td>
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<tr>
<td>TOTAL</td>
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<td>31</td>
<td>3</td>
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<td><strong>Lateral Meniscus (n=83)</strong></td>
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<tr>
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<tr>
<td>TOTAL</td>
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<td>69</td>
<td>0</td>
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<td><strong>Native ACL (n=80)</strong></td>
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<td>0</td>
</tr>
<tr>
<td>Not torn</td>
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<td>69</td>
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<tr>
<td>TOTAL</td>
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<td>75</td>
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<td><strong>ACL graft (n=3)</strong></td>
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<tr>
<td>Not torn</td>
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<td>1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

*/// One (*) or two (**) cases with previous meniscectomy included

Table 3

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Table 4
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![Table 4](image)

Fig. 11: Typical bucket-handle MM tear of left (above) and right (below) knees of two different patients, correctly reported. Horizontal arrow in coronal images point out the displacement vector of the meniscal fragment (also recognizable in sagittal plane as a hypointense band) towards the articulation center. The arthroscopic report only mentioned the above case as bucket-handle tear, although the parallelism is obvious.

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**Fig. 12:** Tear of both meniscus in arthroscopy, after radiological report of medial meniscus tear and degenerative lateral meniscopathy. The extension of abnormal signal to the inferior surface of the lateral meniscus only seems to exist retrospectively in the coronal sequence (yellow arrow). A grade III chondral lesion (previously not MRI - reported) was found in the same patient's arthroscopy.

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**Fig. 13:** ACL tear (thick arrow) associated to external condyle microfracture (asterisk) and visible tear of both meniscus posterior horns; the external one was ignored in the radiological report. The meniscal tear's semiology is similar in both meniscus, although better defined in the medial one.

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Fig. 14: True positive and true negative for medial and lateral meniscus, respectively: the posterior horn's hyperintensity reaches the medial meniscus surface (arrows) in at least two sagittal planes, unlike the lateral one.

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**Fig. 15:** Coronal plane value for the meniscal tears: confirmed medial meniscus tear, better shown in coronal sequence (arrow).

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Fig. 16: Posterior horn of medial meniscus tear (arrow), preoperatively reported as degenerative meniscopathy. The tear is recognizable afterwards in different sequences and planes, rigorously applying the De Smet - Tuite rule.
**Fig. 17:** Small lateral meniscus tear ("cracking", by MRI), not confirmed in arthroscopy. The meniscal surface interruption (arrow) was only visible in this coronal image, highlighting the importance of the strict application of the lesion criteria in order to avoid false positives.

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**Fig. 18:** Direct and indirect confirmed ACL tear signs, with proximal third ligament interruption (arrow) and bony edema in lateral condyle and external tibial plateau (asterisk). There were also mild chondral degenerative changes, not reported.

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Fig. 19: Evident complete acute ACL tear (*) in a 27 year-old skier, associated to medial meniscus tear (arrow), not reported as such in MRI. In these circumstances, a horizontal meniscal hyperintensity is likely to correspond to an acute horizontal tear, in spite of the absence of visible discontinuity in the meniscal surface.

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Fig. 20: False positive of monofascicular ACL tear (negative arthroscopy) in a patient with lateral meniscus tear diagnosis, also wrong. The blurry aspect of the anteromedial tibial ligament insertion (first two images, 3D GR and STIR in the same plane), could have been attributed to plane selection artifacts, especially in a low-field equipment.

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Fig. 21: Fig. 21 - Pseudo ACL tear in sagittal 3D sequence, correctly recognized as such in STIR, in a patient with articular degenerative disease. In case of persistent doubt, additional sagittal or oblique coronal FSE T2 sequences of lesser thickness could have been added.

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Fig. 22: Fig. 22 - Video fragment of sinovial toilette in the same patient of fig. 21, in which a complete ACL can be observed.

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**Fig. 23:** MRI-reported ACL tear, not confirmed in arthroscopy, in a 61 year-old male with medial meniscus tear.

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Fig. 24: Complete ACL graft, correctly diagnosed in MRI.

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Fig. 25: Desintegrated ACL graft, not recognizable in the intercondylar space.

Fig. 26: "Re-tear" (or postoperative meniscal remainder tear), correctly diagnosed by the presence of lineal hyperintensities in communication with the meniscal surface (arrows), along with the diffuse signal changes and apparent reduction in meniscal size secondary to meniscectomy.

Table 5

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Conclusion

In our study, low-field MRI (0.35T) has been shown to be a useful tool in the MM and ACL injury diagnosis, and to a lesser extent, in the LM injuries; its efficacy can still be improved by optimizing the application of the injury criteria. In return, it is not very accurate when assessing the hyaline cartilage, except for severe chondropaties.

There are some important methodological limitations in our study (the MRI-arthroscopy interval, a difference in both previous experience and radiological reporting style, arthroscopic report detail degree, patient selection, and using the arthroscopy as gold standard), which may be avoided partially by a prospective study design in order to confirm these results.
References


