Evaluation of the diagnostic accuracy of MRI in detection of knee cartilage lesions using Receiver Operating Characteristic curves

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Abstract. Medical treatment, and especially surgical procedures, is carefully planned and executed based on various diagnostic methods. Physical examination provides preliminary information about the patient’s health; however, when orthopaedic surgery is concerned, more accurate radiological evaluation is necessary. MRI is perceived as a state-of-the-art radiological modality. In this study, we have evaluated MRI efficiency in detecting chondral lesions in the knee joint requiring surgical treatment. The evaluation of selected diagnostic methods used in the assessment of joint cartilage damage was carried out based on statistical indicators and ROC (Receiver Operating Characteristic) curves. The indicators were determined using Statistica and Matlab software. 95 patients underwent knee arthroscopy subsequently after performing MRI for various intraarticular lesions. Chondral lesions estimated with the use of the ICRS scale were divided into two groups, one requiring surgical treatment ICRS grade 3-4, and selected for conservative treatment ICRS grade 0-2. Results were evaluated with the use of ROC curves. MFC was the most common lesion site, where chondral lesions requiring surgical intervention were found in nearly 50% of patients. LTC was affected only in 9 patients, which was the rarest location for chondral lesions. The diagnostic efficiency for each anatomical location was evaluated. The highest diagnostic accuracy was found on MFC followed by LTC. The lowest diagnostic accuracy was found for PFJ. The AUC ranged from 0.8438 for MFC to 0.55 for PFJ. LFC and MTC showed similar accuracy with AUC respectively 0.6419 and 0.6623. To sum up, MRI is a gold standard for cartilage evaluation, however, its accuracy differs among various anatomical locations, therefore requires a thorough assessment prior to surgical planning.

1. Introduction
Currently, the development of medical technology allows obtaining large data sets, represented by many variables describing the state of health of patients. The aim of the clinical diagnosis is to detect the occurrence of anatomical or functional disorders that threaten the health or life of patients seeking medical advice [1,2]. Appropriate selection of diagnostic tests can have a large impact on the course of the treatment process, its duration, and consequently, generated costs. One of the tasks of data analysis is to find a set of rules to assign an object or state to one of many classes [3,4]. Classification models
are used in diagnostics to assign patients to corresponding risk groups, assess the chances of complications after surgery, and as a tool to facilitate the choice of the most appropriate therapy [3–10]. In the case of imaging diagnostics, databases containing images of physiological and pathological changes occurring within the body are created. The use of statistical methods in conjunction with the possibility of performing analyses using computer techniques leads to the creation of procedures to support decision-making and evaluation of the usefulness of individual diagnostic tests. The ROC (Receiver Operating Characteristic) curves are used to assess the clinical usefulness of individual diagnostic tests, which are used to assess the correctness of the classifier, providing a summary of its sensitivity and specificity. They can also be implemented to compare the diagnostic value of different tests [5,7,11]. Chondral defects are a common cause of knee dysfunction found in over 60% of patients scheduled for arthroscopy [12]. Cartilage poor healing capacity and the progressive nature of chondral defects irreversibly lead to osteoarthritis, if untreated [13,14]. Cartilage damage can be a result of an injury, overuse, sports, or systemic diseases [15–17]. The only non-invasive modality appropriate for the detection of cartilage lesions is the magnetic resonance imaging (MRI). However, the sensitivity of the examination differs grossly in literature ranging from 45% up to even 94% [18,19] concerning articular cartilage. Detection and estimation of cartilage defect size, grade, and location have a great impact on treatment, whether one should proceed conservatively or indicate surgical intervention [20,21]. However, some authors suggest that information obtained by MRI does not change scheduled arthroscopic surgery and does not affect overall treatment costs [22]. Regarding that MRI is a costly examination, waiting time is often long, information about actual diagnostic accuracy seems important for daily practice. This study was conducted to estimate the diagnostic performance of MRI regarding chondral defects treatment decision-making.

2. Materials and methods
Among patients scheduled for arthroscopic surgery in the Orthopaedic Department of Łęczna Hospital, 96 patients were enrolled in the study. All patients included in the study provided images and written reports from the MRI examination. Patients were scheduled for arthroscopy due to meniscal, ligamentous, and chondral lesions. Written MRI reports as well as MRI scans were stored for further evaluation. Arthroscopy was performed by an orthopaedic specialist with interest in knee surgery with 10 years of professional experience. All arthroscopies were performed with the use of a standard 30-degree scope introduced through anteromedial and anterolateral portals. If necessary additional portals were established to ensure proper visualisation of joint structures. Chondral status was evaluated accordingly to the International Cartilage Repair Society [ICRS][23] with grades of chondral lesions 0-4. All structures were visualised and evaluated with an arthroscopic probe (figure 1-2). Photographic documentation was collected from each surgery. For the purpose of this study, chondral lesions were grouped into two categories. The first group was a conservative treatment group where chondral status was evaluated during arthroscopy 0-II. Grades III and IV were treated as one as they require surgical treatment. The study was approved by the Bioethical Committee by Medical University in Lublin with the number of approval KE- 0254/262/2019.

2.1. Statistical analysis
Statistical analysis of the obtained results was carried out using Dell Statistica version 13.1 (2019), Microsoft Excel (2013), and MATLAB software (2020). To describe the distribution of basic response characteristics, classical statistical measures were used. The ROC (Receiver operating characteristic) curve analysis was used to compare the diagnostic properties of different methods. To compare different ROC curves, 95% confidence intervals were used for the areas under the ROC curve. The sensitivity and specificity may take values from a closed range of 0 to 1 so the maximum value of the area under the curve is 1. The AUC field, standard error (SE), and confidence interval for AUC shall be calculated using the non-parametric DeLong method [24,25].
Figure 1. Arthroscopic visualisation of medial knee compartment.  

Figure 2. Arthroscopic visualisation grade IV chondral lesion.

The larger the area under the curve, the more accurately we classified objects into a group based on the diagnostic variable under analysis. The course of the ROC curve along the diagonal corresponds to a probability of 0.5, which means that the parameter under test has no discriminatory properties [6]. The sensitivity and specificity of each study were calculated from the ROC curves. Statistically significant were those results which were significant at a typical level of significance (i.e. when p < 0.05).

3. Results

Chondral lesions were found in 69 patients. Most of the patients presented lesions in multiple anatomical locations, however, the most common location was the medial femoral condyle (MFC), where lesions were found in 61 patients. Also, the medial tibial condyle was affected more often than the lateral compartment. MTC presented chondral defects in 53 patients. Lateral tibial and femoral condyles as well as a notch, for 45 patients presented concomitant meniscal lesions apart from chondral defects. The mean patient’s age was 44.6 years. There was an even patients’ distribution regarding sex with 51% represented by females and 49% by males. Also, there was no statistical difference between dominant and non-dominant limb (48% vs. 52%). An equal number of patients had right, and left knee operated. Sensitivity for detecting chondral lesions requiring surgical treatment was highest on MFC, where it reached 96%. The lowest sensitivity was found in the patella-femoral joint reaching only 31%.

Table 1. Diagnostic performance of MRI in the detection of chondral lesions requiring surgical treatment.

|                | AUC   | SE    | Inferior Boundary Value | Superior Boundary Value | z    | p      | Sensitivity | 1-specificity |
|----------------|-------|-------|--------------------------|-------------------------|------|--------|-------------|---------------|
| MFC            | 0.8440| 0.0410| 0.7640                   | 0.9240                  | 8.409| 0.000  | 0.963       | 0.275         |
| LFC            | 0.6420| 0.1030| 0.4390                   | 0.8440                  | 1.374| 0.1695 | 0.400       | 0.116         |
| MTC            | 0.7410| 0.0700| 0.6030                   | 0.8780                  | 3.434| 0.0006 | 0.600       | 0.118         |
| LTC            | 0.7170| 0.1300| 0.4610                   | 0.9720                  | 1.66 | 0.0968 | 0.500       | 0.067         |
| PFJ            | 0.5500| 0.0820| 0.3900                   | 0.7100                  | 0.613| 0.5397 | 0.313       | 0.213         |
The diagnostic performance of MRI in the lateral compartment was rather low. The sensitivity for LFC was only 40% and for LTC 50%. In contrast, the specificity was highest in the lateral compartment especially on the lateral tibial condyle reaching 83%. The lowest specificity was found in MFC reaching 72.5%. Overall diagnostic performance was weak, and AUC surpassed 0.8 only in MFC. Other anatomical locations showed AUC ranging from 0.55 to 0.74. The results are shown in table 1 and a graphical presentation is shown in figure 3.

Figure 3. ROC curves showing the diagnostic performance of MRI for each anatomical location regarding surgical or conservative treatment.

4. Discussion
Articular cartilage is one of the most important tissues of every synovial joint. It is responsible for the painless and smooth movement of joints [26,27]. Chondral lesions are one of the most common findings during arthroscopy. The only non-invasive modality for cartilage evaluation is MRI. Great divergence among MRI results concerning sensitivity and specificity is found in the literature [28–33]. In our study, we have found chondral lesions more frequently than showed by Curl et al. [12]. It can be caused by waiting time between the primary injury to arthroscopic treatment. The most accurate chondral description was found in the medial femoral condyle, however, even in this location, 37.5% of results were underestimated in MRI, which strongly influenced surgical treatment. Figueroa et al. [18] showed that the diagnostic performance of MRI increases significantly with increasing chondral damage grade. And as shown by Kohl et al. [34], the diagnostic performance of MRI increases with lesion grade also in 3-T MRI. Similar findings were shown in our study; however, the correlation was not statistically significant. In our study, the best diagnostic performance was found in the medial femoral condyle, which stays in opposition to findings described by Figueroa, who proved that the best diagnostic performance can be found in the patella-femoral joint. We believe that divergence of our results is caused by the fact that MFC was most commonly affected with grade IV and III lesions among all anatomic locations. In our study, AUC surpassed 0.8 only in MFC, which shows that lateral compartment and patella-femoral lesions are at risk of not being diagnosed correctly. Also, a recent review performed by Quatman et al. [35] proves that the lateral compartment is poorly visualised by MRI in regard to articular cartilage. No measures taken had any positive influence on visualisation, neither did 3T coils utilisation. [36]. Some authors suggest even that osteoarthritis detection in MRI should be based on other findings, including bone marrow lesions or synovitis [37]. Our study, as well as literature, proves that even though MRI is the best diagnostic modality for cartilage evaluation it should be taken with caution, especially in the lateral compartment. MRI is a costly and time-consuming examination with a long waiting time. Therefore, when moderate to poor diagnostic performance of MRI concerning cartilage evaluation is taken under consideration it seems clear that new imaging protocols or even techniques should be implemented in the diagnostic protocol to reduce costs and examination waiting time. These results show that new modalities should be implemented in daily practice.
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