

Imaging of the Posttraumatic Knee in Pediatric Patients

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ABSTRACT: Owing to its continuous transformation, the musculoskeletal system of pediatric patients presents some unique features with respect to both anatomy and physiology. The lesional pattern of the knee in pediatric patients is both similar to and in many aspects different from the lesional pattern in adults with knee injuries. In the case of pediatric patients, meniscal, tendinous and ligamentous lesions occur most frequently as a consequence of traumatic episodes. The purpose of the present study is to emphasize the importance of MRI examinations in pediatric patients exhibiting symptoms of knee joint injury. The imaging assessment of the extent of the lesions, which can be either simple or complex alterations, can directly influence the clinical management of these cases by appreciating the growth potential of the specific segment of immature skeleton involved.

KEYWORDS: Musculoskeletal, pediatric knee injury, knee joint MRI.

Introduction

Pediatric and adult patients can present with some similarities regarding the types of lesions involved in knee injuries, which is mostly true in adolescents with growth plates that are almost completely closed. Nevertheless, differences in lesion characteristics can be significant with respect to the type, prevalence and the process through which lesions occur. The growth plate still being present and the particularities of the osseous structure are aspects that predispose the pediatric patients to a certain pattern of lesion occurrence [1].

During the MRI examinations, some normal variations have to be taken into consideration, such as the normal alterations of the bone marrow signal that appears with both ageing and cortical fibrous defects [1].

Owing to its continuous transformation, the musculoskeletal system of pediatric patients presents some unique features with respect to both anatomy and physiology. Therefore, if they appear during this period of rapid changes, the lesions of the immature skeleton are to a certain extent different from the lesions presented in adult patients [2].

In the context of the pediatric population, the joint of the knee is most frequently investigated with the help of MRI examinations [1].

Magnetic resonance is the preferred type of imaging examination and is used especially in making a pre-operative assessment of the

extension of the lesion in the meniscus and the ligaments [3].

Nevertheless, both clinical evaluation and the interpretation of the MRI examination can be occasionally difficult, which is particularly true in the case of anterior cruciate ligament (ACL) injuries due to the presence of haemarthrosis, pain and joint movement reduction, all of which are elements that lower the accuracy of the diagnosis [4,5].

Both clinicians and radiologists have to be familiar with specific lesional patterns in pediatric and adolescent patients, such as acute fractures, osseous oedema, lesions of both the meniscus and the ligaments, stress lesions, apophysitis every so often, and even osteochondral defects [6].

The purpose of the present study is to emphasize the importance of MRI examinations in pediatric patients exhibiting symptoms of knee joint injury. The imaging assessment of the extent of the lesions, which can be either simple or complex alterations, can directly influence the clinical management of these cases by appreciating the growth potential of the specific segment of immature skeleton involved (e.g. in lesions of the femorotibial joint or the femoropatellar joint). Most frequently pediatric patients examined in the imaging department complain of local pain in the femorotibial joint region as a consequence of direct traumatism (by accident) or as indirect microtraumatism (as a consequence of stress), which can occur in patients that perform sports which put additional strain on the joint.

Materials and Methods

The present study analysed pediatric patients aged 14 to 17, both male and female, who presented with pain in the knee joint region, local tumefaction, focal deformation of the joint and who could indicate a traumatic history involving the knee joint. This study does not include pediatric patients younger than 10 years old because in these patients the MRI examination cannot accurately determine lesions of the meniscus, which can be mistaken for persistent vasculature, so the golden standard in these cases is the use of arthroscopy.

The exclusion criteria for this study have taken into consideration the history of surgery for the examined joint or history of another musculoskeletal or systemic condition such as: inflammatory or infectious diseases involving the knee (osteomyelitis, synovitis, juvenile idiopathic arthritis, septic arthritis), primary and secondary neoplasms, avascular necrosis, skeletal deformities involving inferior limbs, extensive vascular defects, or neurofibromas.

To begin with, patients have had their femorotibial joints examined by conventional radiographs in order to eliminate the possibility of fractures. Due to the fact that the present study focuses on the evaluation of specific components (meniscus, ligaments, periarticular soft tissues) the examination by conventional radiography has not been included in the study since it is not specific for examining the above-mentioned articular components.

In the case of the MRI examination, several sequences were employed: T₁ or Proton Density sequence without fat saturation (PD) in sagittal plane, followed by PD sequences with fat saturation in all 3 planes (axial, coronal, sagittal), with or without STIR sequences. All

sequences had a 3mm width, with a field of view (FOV) smaller than 160mm.

Results

The clinical cases included in this study were selected during an eighteen-month period, from August 2018 to February 2020.

A number of 28 patients have met all inclusion criteria for the study.

Of all cases, 17 patients are female and 11 are male. Patients were aged 14 to 17, with a median age of 15 years and 5 months.

All patients have given a written-informed consent regarding the publication of the data, and the study was approved by the Ethics Committee of U.M.F. of Craiova.

Of all 28 patients, 6 cases (21.42%) presented simple lesions that only involved one tendinous, ligamentous or meniscal component together with the presence of subsequent fluid accumulation. The rest of 22 cases (78.58%) presented complex lesions involving at least 2 articular components.

Regarding the lesions found in femorotibial and femoropatellar joints, the following can be emphasized:

- meniscus lesions were present in 12 cases (42.85%) and these involved especially the posterior horn of the medial meniscus in 8 cases (66.66%), with horizontal or longitudinal lesions, the latter being the most frequent type (Figure 1A).

Another localization was the anterior horn of the lateral meniscus, with 4 cases (33.33%), presenting only longitudinal type lesions

(Figure 1B). In the other meniscus components (anterior horn of the medial meniscus, posterior horn of the lateral meniscus) no lesions were discovered.

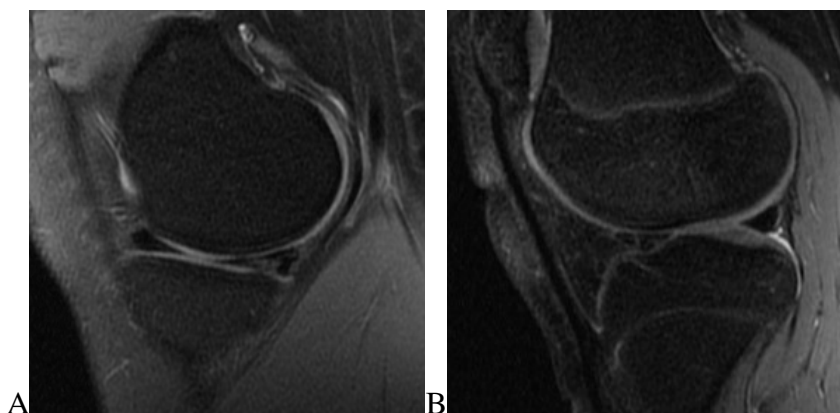


Figure 1. A PD linear hyperdensity in the posterior horn of the medial meniscus, which divides this in two parts, superior and inferior, resulting in the aspect of a linear horizontal meniscal lesion (B); the same PD linear hyperdensity in the anterior horn of the lateral meniscus, which divides this in two parts, medial and lateral, resulting in the aspect of a longitudinal meniscal lesion (B).

- tendinous and ligamentous lesions were localized in the cruciate ligaments, collateral ligaments and the quadriceps tendon. Of all these lesions, the highest incidence had the lesions in the lateral anterior cruciate ligament (ACL) (Figure 2) because all patients had a different degree of injury in this area: 1st degree

28.57%, 2nd degree 57.14%, 3rd degree 14.28%. The posterior cruciate ligament presented with a lower incidence, at 14.28%, all of them being 1st degree. Collateral ligament injury was even lower, at 7.14%. Last but not least, the quadriceps tendon was affected in 35.7% of patients.

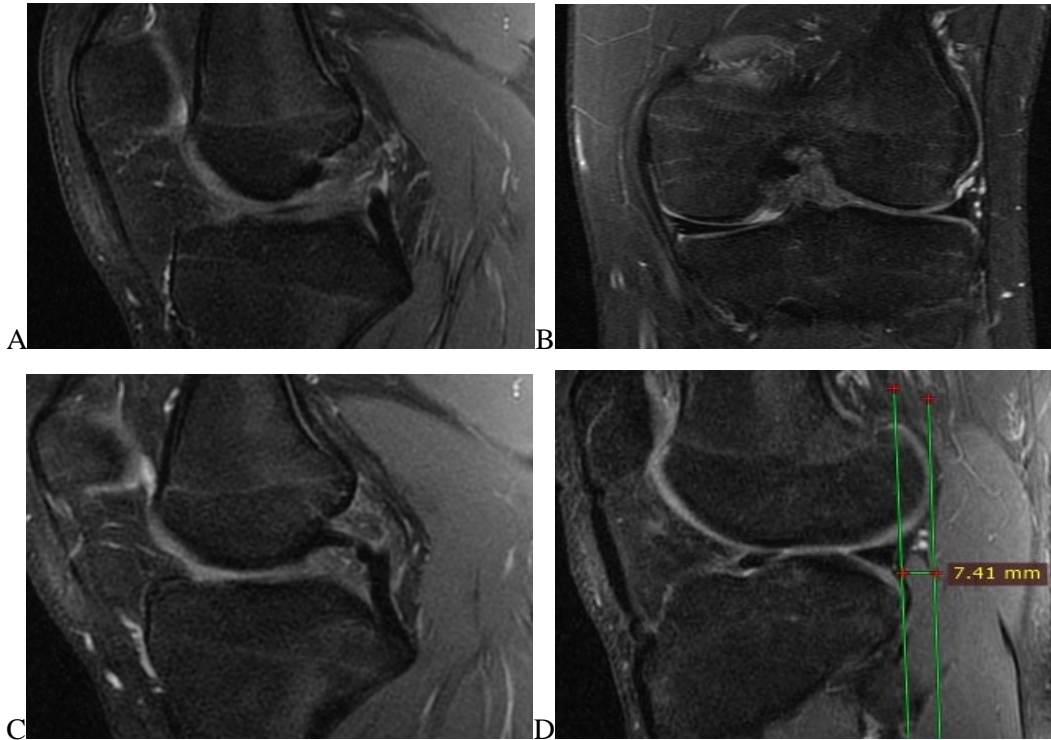


Figure 2. Anterior cruciate ligament that presents oedema, thickening in PD hyperdensity (A), aspect that is noticed also in the anteriomedial and posterolateral bundles in coronal plane (B), with signs of third grade ligamentar lesion; also noticeable in the same patient are indirect signs of ligament injury (PCL angle of 90 (C) and the presence of anterior tibial translation (>7mm) (D) that are associated.

- osseous lesions were characterized by the presence of osseous oedema in 12 cases (42.8%), with different localizations: lateral femoral condyle (33.33%), medial femoral

condyle (16.6%), lateral tibial plateau/lateral tibial condyle (16.6%), and patella (33.33%).

In 4 of these osseous oedema cases (14.28%), an occult fracture was discovered (Figure 3).

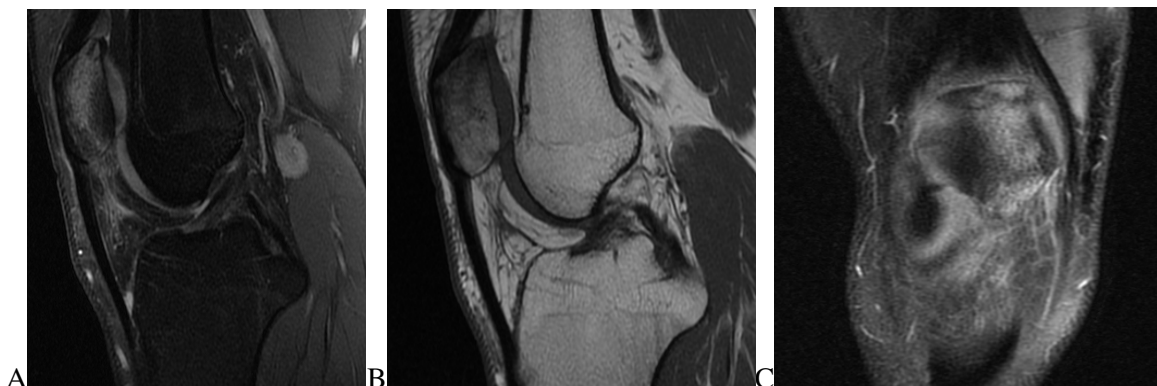


Figure 3. Osseuse contusion that presents an osseous oedema area in the patella; this osseous oedema also comprises periarticular soft tissues, more specifically in this case the Hoffa's fat pad in the infrapatellar region; the osseous oedema is visible in specific areas with PD hyperdensity and T1-weighted iso-signal, which is followed by linear images in PD and T1 hypodensity, which in posttraumatic episodes can translate into the presence of stress fractures (A-C).

- oedema in the periarticular soft tissues and also articular fluid were present in 92.8% of patients, thus these are the most common signs in this type of pathology (Figure 4).

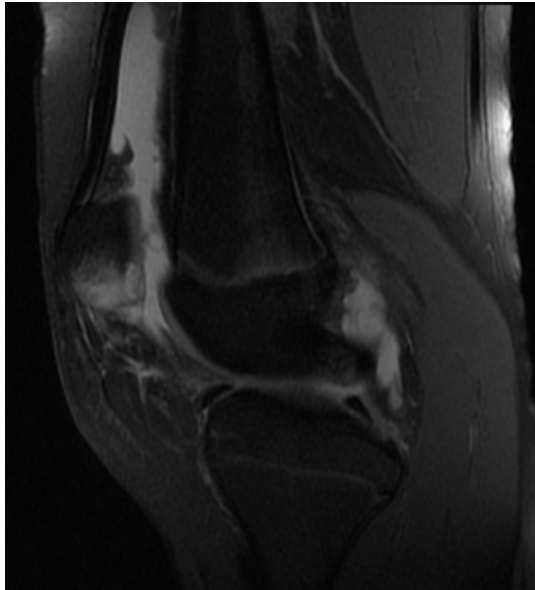


Figure 4. Articular fluid in moderate quantity, that is more visible at the retropatellar level and is associated with osseous oedema in the inferior part of the patella and oedematous infiltration of the Hoffa's fat pad.

Discussions

The present study consisted in the MRI examination of the knee joint in pediatric patients, the results of our research emphasizing the presence of lesions in different articular components such as meniscus, tendons, ligaments (especially anterior cruciate ligament), osseous lesions, as well as periarticular soft tissue associated lesions.

Meniscal tears have long been considered a rare pathology in pediatric patients, but more recently they started to become more common due to the fact that many patients practice different kinds of sports. According to data from the literature, the lesions often involve the medial meniscus, which is also what Mark S. Zobel *et al* show in their study [7], as they found that the higher incidence was in medial meniscus lesions, especially in the posterior horn of the medial meniscus. Our findings can also relate to literature data, as 42.85% of patients (12 cases) presented with lesions in the medial meniscus and, of these, in 66.66% of patients (8 cases) the lesions were found in the posterior horn of the medial meniscus.

Longitudinal types of lesions are mostly recurrent in young patients and these are usually a consequence of traumatic episodes. In patients

with meniscal tears, the most common type of lesion was longitudinal/vertical and this finding is correlated with data from other studies (Bellisari G. Samora W *et al*) [8] where the authors have found a 78% incidence of longitudinal lesions in pediatric patients. The MRI criteria for the diagnosis of meniscal tears in these patients are the same as in adult patients, with linear hyperintensity areas on the articular surface in Protein Density (PD) sequences, abnormal morphology or the visualization of meniscus fragments in at least two contiguous images [2,9].

At birth, the meniscus is a structure that shows both a high cellularity and a rich vascularization, so that linear hyperintensity PD images that do not reach the articular surface of the meniscus are considered high vascularization areas, but, as patients approach the age of 10, the meniscus is considered to already present an adult morphology, with lower, vestigial vascularization that comes from a network of perimeniscal capillaries which are supplied with blood from the lateral and medial geniculate arteries. [2,6].

Due to this type of vascularization, the meniscus is divided in two areas, one peripheral “red area” with a high blood supply, and one central “white area” that is avascular, therefore the lesions localized in the “red area” having a higher rate of healing compared to the avascular area [9]. Meniscal lesions are often associated with cruciate ligaments lesions and the most common area where this happens is the posterior horn of the medial meniscus [1].

With regards to **the cruciate ligaments'** lesions, the most frequent in pediatric patients are the ones that involve the anterior cruciate ligament (ACL). Our findings are correlated with literature data, as all patients in the present study presented with lesions of different degrees involving the anterior cruciate ligament. Lesions in this area are comparable in both adolescents and adults, with the presence of primary and secondary signs. [10]. Primary (direct) signs are characterized by the discontinuity of ligament fibers, altered course and abnormal signal in the area of the ligament (Figure 2 A,B) [11].

Secondary (indirect) signs can be: the increase in the angulation and the abnormal vertical position of the posterior cruciate ligament (PCL), the anterior shift of the tibia, the denudation of the posterior horn of the lateral meniscus, “kissing”-type contusions in both the lateral femoral condyle and the lateral tibial plateau (Figure 2 C&D) [11,12].

Partial tears of the anterior cruciate ligament (ACL) are most frequent in patients with immature skeletons [1], in our study 85.71% of the patients presenting with partial tears of different degrees (1st degree-28,57%, 2nd-57,14%) and only 14.28% with complete tears (3rd degree lesion). These findings are in line with data reported by other authors who found the highest incidence in 1st/2nd degree lesions that have an elongative-contusive aspect due to articular laxity (Vito Bordoni et al) [13].

In the acute phase of the anterior cruciate ligament (ACL) tear, MRI examinations show a local hyperintensity area which is due to the presence of intra-articular haematoma, hypersignal that is moderate in T₁ and PD sequences, whilst in the T₂ sequences it appears to be more intense [11].

This hyperintensity should not be mistaken for intra-articular fluid that is in contact with the ligament, which gives it a more pronounced hyperintensity appearance in the T₂ sequences [11].

The differentiation between a complete anterior cruciate ligament tear and a partial tear is essential because partial tears are treated in a more conservative approach, whereas complete tears require surgery to be performed [1].

Posterior cruciate ligament tears are not very common in children and these lesions often occur as a result of knee hyperextensions or in the case of multiple ligament lesions that appear after a knee dislocation. This was also confirmed in our study, as 14.28% of patients presented with 1st degree lesions in the posterior cruciate ligament. Moreover, the incidence of lesions in collateral ligaments was even lower, with 7.14% of patients presenting this type of lesion.

In MRI examinations, *osseous contusions* appear as poorly delimited areas that present a low intensity signal in T₁ sequences and a high intensity signal in T₂ fat suppressed (T₂ FAT SAT) sequences. Although literature findings show different opinions regarding osseous contusions, their aspect has been largely correlated with a certain degree of internal derangement of the articulation, which has been suggested as an indicator for the degree of articular involvement and also as an indicator regarding the prognosis. Numerous studies have been conducted on the relationship between osseous contusion and anterior cruciate ligament tear in adult patients, but only a few of them studied this in pediatric patients, although these patients present a different degree of ligamentous laxity, which could show different

lesional patterns in comparison with adult patients [13].

Patients in our study presented osseous oedema in the lateral femoral condyle (33,33% of cases), medial femoral condyle (16,6% of cases), lateral tibial plateau (lateral tibial condyle) (16,6% of cases), and in the patella (33,33% of cases), but no correlation can be made between osseous oedema pattern and a certain articular lesion. This is unlike the case of the classic “kissing” contusion aspect involving the posterior lateral tibial plateau and the medial region of the lateral femoral condyle, which is a pathognomonic sign in the case of anterior cruciate ligaments’ tears [2].

Apart from osseous oedema, during the MRI examinations of the patients in the current study we could find areas with occult fractures in 14.28% of cases (4 patients).

The significance of MRI examinations of the knee is supported by data from the literature, researchers reporting a diagnostic accuracy of 48% to 94% in lesions of the meniscus and an accuracy of 90% to almost 100% in anterior cruciate ligament (ACL) lesions. By comparison, the clinical examination diagnostic accuracy is 64% to 85% in meniscus lesions and 90% to 100% in anterior cruciate ligament lesions. In spite of all these variables, MRI examinations present with the advantage of detecting the osseous oedema and the periarticular soft tissue alterations and can even help understand how the lesion occurred [3].

Conclusions

By analyzing the results of this study together with those of other authors, it is clear that the lesional pattern of the knee in pediatric patients is both similar to and in many aspects different from the lesional pattern in adults with knee injuries. In the case of pediatric patients, meniscal, tendinous and ligamentous lesions occur most frequently as a consequence of traumatic episodes. This hypothesis is endorsed by the presence of osseous contusions and the associated articular fluid. Therefore, during MRI examinations every aspect of the lesion has to be described in detail in the case of both simple and complex alterations due to the fact that the results of this exam can significantly influence the treatment plan. Moreover, the incidence of anterior cruciate ligament (ACL) tears found in children and adolescents constantly increases due to the ever-rising number of young athletes and thanks to more accurate methods of diagnosis.

Conflict of interests

None to declare.

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