# Radiographic exploration in athletic children

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There has been an increase in sports-related trauma in children during the past decade. Musculoskeletal injuries in child and adolescent athletes may be related to acute trauma or excessive repetitive load.

Similar to the adult population, acute trauma may lead to fractures or dislocations. However, dislocations are quite rare in younger children. Fractures from a direct impact are quite particular since they risk damaging the growth plate and occur most often in skeletons with a thick periosteum composed of a strong cartilaginous component.

Acute lesions of the soft tissues, ligaments, and tendons are less frequently encountered in children and require particular attention during diagnostic evaluation [1]. Bony structures and physes are weaker than the ligaments and tendons, thus accounting for the differences in the proportions of these injuries in the pediatric population. Furthermore, the growth plate is especially fragile during growth spurts and around the time of fusion.

Injuries secondary to excessive and repetitive load on an immature skeleton are often due to inapproprate training regimens in the context of high-level competition sports. There is often associated overinvestment from the family in the child's sporting career [1].

Imaging modalities must be chosen depending on the suspected diagnosis and the anatomic location of interest. Different imaging techniques assess different anatomical structures, possess specific limitations, and are not equally accessible, all of which must be taken into consideration when choosing an imaging modality.

**Conventional radiographs** are generally the primary modality of choice and are the standard for the evaluation of bony structures. These are obtained after a thorough physical exam, thus justifying the need for complementary investigations. Requests for imaging must be made in a written format and must abide by public health regulations, thereby favoring dialogue between the requesting physician and the radiologist. Conventional radiographs may be used for the diagnosis of acute fractures, lesions secondary to excessive load, or guide the diagnosis toward an infectious or tumoral cause. Radiographs must be of good quality and undertaken only after proper pain management has been prescribed. Two orthogonal views are required and are eventually completed with complementary views depending on the physical assessment. Comparative radiographs are not recommended. In case of doubt on a pathological finding, references containing the different anatomical variants must be consulted instead. If there is a doubt depending on the child's skeletal age (appearance of the epiphysis and ossification centers), the findings should instead be compared to other radiographs found in the picture archiving and communications systems (PACS) of the imaging department. The skeletons of children differ from those of adults due to the secondary ossification centers at the epiphyses and the apophyses. The growth plate separating the epiphysis from the metaphysis and the apophysis must not be misdiagnosed as fractures. Their aspect may lead to confusion especially on oblique views. Similarly, certain synchondroses, secondary ossification centers (figure 1), or accessory bones such as sesamoids (figure 2) may further lead confusion [2,3].

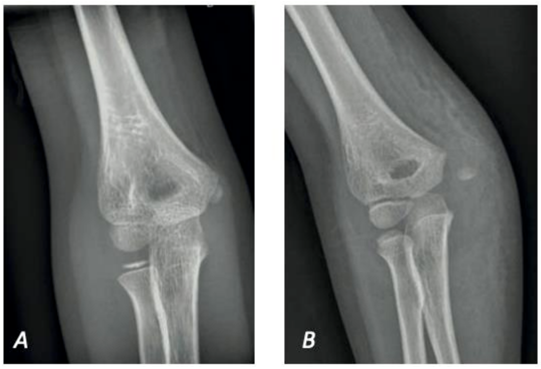



***Figure 1**: Anteroposterior radiographs of the right elbow of a 6-year-old girl; A) Normal aspect of the medial epicondyle not to be interpreted as a fracture; B) The medial epicondyle is displaced from the epiphysis with surrounding soft tissue edema leading to the diagnosis of a fracture.*

***Figure 2**: Right ankle radiograph of a 17-year-old boy. Presence behind the talus of an os trigonium.*

Of all the synchondroses, the ischiopubic synchondrosis, a simple anatomical variant, is most often the source of confusion in symptomatic patients. In fact, its radiographic appearance may sometimes be confused with a stress injury.

Secondary ossification centers, especially at the level of the elbow, may lead to misdiagnosis. Knowledge of the age of appearance of these ossification centers is of great importance (table 1).

**Table 1:** Age of appearance of ossification centers

| Ossification center | Age of appearance (years) |
|---|---|
| Capitellum | 1-3 |
| Radial head | 5-6 |
| Internal condyle | 5-8 |
| Trochlea | 11 |
| Olecranon | 10-13 |
| External condyle | 10-12 |

Concerning the secondary ossification centers, the pelvis is an anatomical region containing a large number of apophyses which may be the source of acute or chronic avulsions (figure 3)

***Figure 3**: Anteroposterior radiograph centered over the right hip in a 14-year-old boy. Presence of an acute avulsion fracture of the secondary ossification center of the ischium.*

Apophyses generally appear on radiographs between 13 and 15 years of age [4]. Acute avulsions are easily diagnosed, but when the diagnosis is missed, healing takes place with an extensive callus which may be mistaken for a tumor. As a result, knowledge of the age of appearance and fusion of the apophyses is of great clinical value. Every apophysis is the site of muscular insertions that are stressed by specific movements during sports (table 2).

**Table 2:** Pelvic apophyses: Muscular insertions and specific activities leading to avulsion fractures.

| Apophysis | Muscles | Sport |
|---|---|---|
| Anterior superior iliac spine | Sartorius and tensor fasciae latae | Sprinting |
| Anterior inferior iliac spine | Rectus femoris | Football (Soccer) |
| Ischial tuberosity | Semimembranosus, semitendinosus, biceps femoris | Jumping, hurdling, gymnastics |
| Iliac crest | Internal and external oblique, transverse abdominis, Gluteus medius, tensor fasciae latae | Jumping, hurdling, gymnastics |
| Lesser trochanter | Iliopsoas | Jumping, dancing, gymnastics |

Accessory ossicles of the ankle and foot are frequent findings and must not be misdiagnosed as avulsion fractures. The absence of edema and a periosteal reaction on follow-up radiographs can make the distinction.

Stress fractures must be recognized on conventional radiographs. The proximal tibia is the most frequent site of stress fractures in children and adolescents, whereas the 2$^{nd}$ metatarsal is more frequently encountered in adults. The fracture line is generally visible as a dense metaphyseal line that lies orthogonal to the axis of the tibia (figure 4).

***Figure 4**: Anteroposterior radiograph of the left tibia in a 6-year-old boy. The dense metaphyseal line orthogonal to the axis of the tibia makes the diagnosis of a stress fracture.*

These fractures may be accompanied by a periosteal reaction that may be misdiagnosed as an Ewing's sarcoma. The diagnosis may be more difficult if the fracture line is not visualized initially. In such cases, an MRI may be of use.

Not all lesions require extensive explorations in order to make their diagnosis. Such lesions include periosteal desmoids (microtraumatic lesions at the distal insertion of the 3rd adductor tendon situated at the posteromedial aspect of the distal femoral metaphysis) and osteochondroses. The essential osteochondroses include those located at the tip of the patella (Sinding-Larsen-Johansson syndrome), tibial tuberosity (Osgood-Schlatter disease) (figure 5), insertion of the Achilles tendon on the calcaneus (Sever's disease), metatarsal heads (Frieberg disease), and navicular bone (Köhler disease) [5].

***Figure 5****: Lateral Radiograph of the left knee in a 13-year-old football (soccer) player presenting with chronic mechanical pain at the tibial tuberosity. The patellar tendon is thickened at its insertion on the tibial tuberosity. This appearance confirms the clinical diagnosis of Osgood-Schlatter disease.*

Certain repetitive microtraumatic lesions may be responsible for osteochondritis in athletic children, most notably at the level of the elbow in pitchers, as well as the knee [5,6]. The diagnosis is made on conventional radiographs. Complementary imaging using MRI or an arthro-scanner may be required if radiographs are non-diagnostic and symptoms suggest an injury to the articular cartilage. Similarly, repetitive stress of the growth plate may lead to irregular thickening, as is frequently found at the distal ends of both bones of the forearm in gymnasts [7].

The diagnosis of myositis ossificans circumscripta (heterotopic proliferation of bone and cartilage within muscular structures) should be made on conventional radiographs. A previous traumatic injury is found in half of patients and is accompanied by pain and edema. Conventional radiographs may initially be normal, but rapid progression toward calcifications with a zonal phenomenon (mineralization at the periphery with progression toward the center of the lesion) is observed. These two characteristics make the diagnosis of myositis ossificans circumscripta. Initially, CT-scans may be used to better display the zonal phenomenon (figure 6).

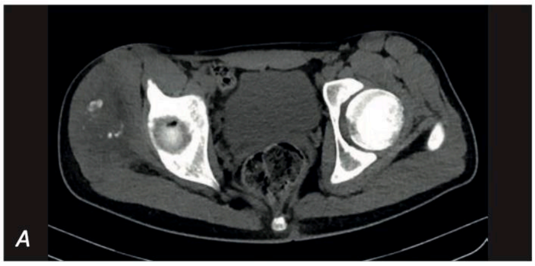
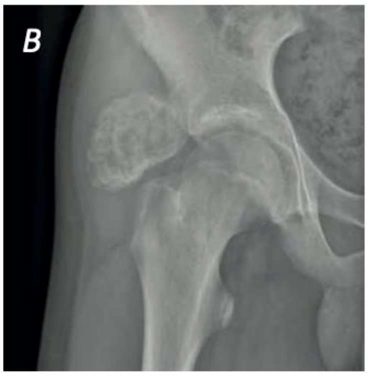



***Figure 6**: A) CT-scan with slices passing through the roof of the right acetabulum in a 12-year-old boy presenting with supra-trochanteric inflammatory swelling. The diagnosis of myositis ossificans circumscripta may be made based on peripheral calcifications of an ill-defined mass of the gluteus medius effacing the fascia.*




*B) Anterolateral radiograph of the right hip one month after the CT-scan confirming the diagnosis due to its zonal effect and the rapid ossification of the lesion.*

The diagnosis on MRI is made using the same criteria as previously. Gradient echo sequences are useful for the visualization of peripheral ossification. Furthermore, a severe inflammatory reaction may be found and should not rule out the diagnosis of myositis ossificans circumscripta.

Knowledge of the characteristics of the disease on conventional radiography avoids misdiagnosing normal variants as pathological or the false diagnosis a tumor leading to unnecessary complementary examinations, or even biopsies, which may be troublesome for pathologists with limited experience in musculoskeletal pathologies.

Follow-up radiographs should be ordered after a period of physical inactivity and immobilization with clinical follow-ups. Nevertheless, cartilaginous structures and soft tissue injuries (tendons, ligaments, and muscles) are not directly visualized on conventional radiographs.

**CT-scans** are also widely available, and most patients do not require sedation. Certain anatomical locations may be difficult to assess on conventional radiographs and require secondary evaluation by CT-scans, including the skull, spine, pelvis, hindfoot, shoulder, and wrist. Certain comminuted, complex fractures are also better analyzed using CT-scans [8]. One example is a triplane fracture of the ankle (figure 7).

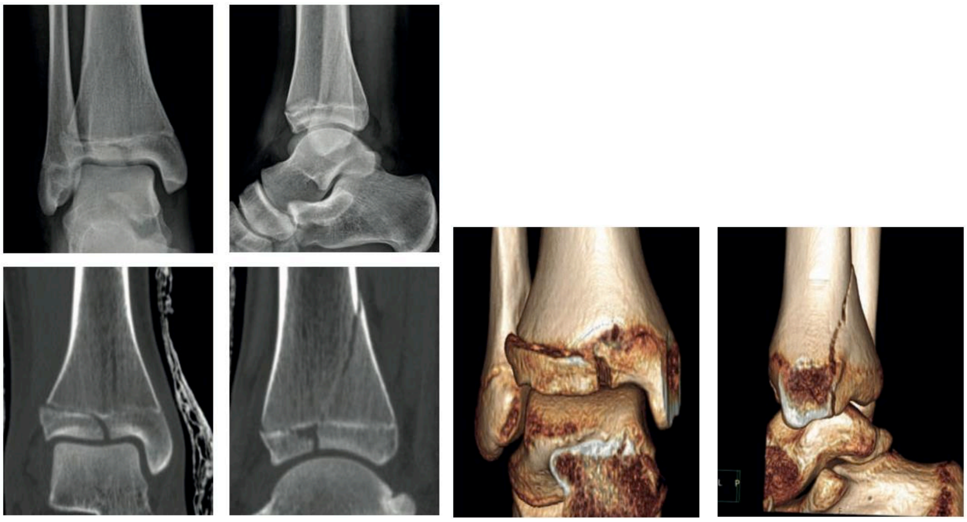


***Figure 7**: 15-year-old boy presenting with a triplane fracture of the right ankle. A) Anteroposterior and B) lateral radiographs; C) CT-scan with coronal and D) lateral reconstructions; E) Anterior and F) lateral views of a 3D reconstruction using CT-scanning. Multiplane and 3D reconstructions allow for a more detailed evaluation of the relationships between the different fragments and that of the joint line.*

CT-scans allow for a better pre-operative surgical evaluation. It also visualizes any intra-articular loose bodies and may also confirm the diagnosis of a stress fracture. CT-scans may be useful in certain avulsion fractures of the posterior apophyseal ring of the spine (limbus), thus differentiating it from a herniated disc, a rare occurrence in children and young adolescents. CT-scans may be ordered in order to evaluate spinal deformities and spondylolysis. Even though it is a powerful tool for the study of cortical bone, it exposes to extremely high doses of ionizing radiation. Moreover, it is limited in the study of muscles, tendons, ligaments, and both hyaline and fibrous cartilage. When MRI is contra-indicated, the evaluation of cartilage requires an arthro-scan, a powerful diagnostic tool.

**Ultrasonography** has multiple advantages: widely available, inexpensive, and based on ultrasounds rather than ionizing radiation. It is often considered as complementary to the physical exam allowing the evaluation in real-time of the area of interest and allows both dynamic maneuvers and comparative views. It is very useful in the assessment of joint effusion, hematomas, and soft tissue injuries (figure 8).

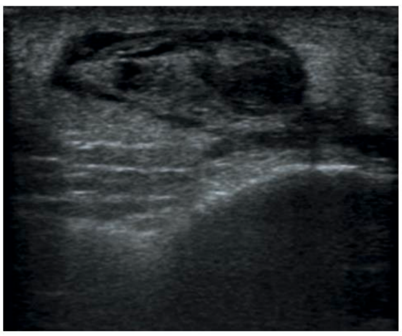


***Figure 8**: 16-year-old boy. Axial image using ultrasonography of the tibia showing a hematoma of the antero-medial aspect of the left tibia after a football (soccer) game.*

Ultrasonography is under-employed since it requires the presence of a trained radiologist during image capture. Soft tissue lesions are generally rare in pediatrics since bones in children are weaker than the surrounding muscles and tendons, and the tendons of a large number of muscles do not insert directly on the bone at this age, but via an apophysis. Even though they are rare, muscle injuries can be identified by ultrasound. These lesions are more easily identified after a delay of 24 to 48 hours to the traumatic incident. During the first few hours follow the traumatic incident, soft tissue lesions may be isoechoic, which could be falsely reassuring [9]. Muscular lesions in older adolescents may be analyzed as in adults. Depending on the mechanism of injury, two types of lesions must be differentiated: extrinsic lesions responsible mostly for contusions, hematomas and dilacerations; intrinsic lesions secondary to muscular stretching. These injuries may be responsible for injuries either at the level of the connective tissue, ranging from thickening of the muscular septum to ruptures of said connective tissue, or of the tendon-bone junction, ranging from simple modifications of muscle structure without disruption, to stripping or even avulsion and hematoma formation [9]. Ultrasound may also allow the grading of lesions [10]. Findings on sonography are generally conveyed by specialized sonographers.

Sonography is sometimes requested by specialized teams in order to assess the severity of a ligamentous injury and to guide management. This modality may sometimes diagnose certain fractures but may also misdiagnose certain bony lesions. As a result, in the assessment of bony injury, ultrasonography should be considered as a complementary technique to radiography.

MRI is a technique that does not rely on ionizing radiation and, due to its high spatial resolution and excellent contrast resolution, is the best available all-in-one method for the exploration of anatomical structures in their entirety, especially when radiographs are non-diagnostic. Due to its excellent contrast resolution, it may differentiate cartilaginous structures (joint cartilage, epiphysis, fibrocartilage, and growth plate). It is routinely utilized in the evaluation of the knee and, more particularly, in the assessment of meniscal (figure 9) and ligamentous injuries. These injuries are similar to those found in adults, and their frequency may vary according to sex; injury to the anterior cruciate ligament is less frequently encountered in girls compared to boys [11].

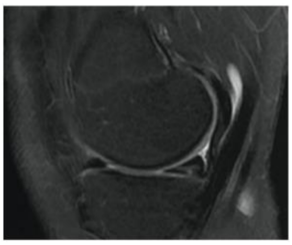


***Figure 9****: MRI of the knee in a 15-year-old boy. Sagittal view using proton density and fat saturation images passing with slices passing through the medial meniscus. A linear meniscal tear is seen extending toward the free edge of the meniscus.*

MRI also allows better visualization of traumatic osseocartilaginous lesions that are frequently encountered at the level of the knee. At the level of the hip, osseous lesions (osteochondritis, slipped capital femoral epiphysis) have been thoroughly studied, but no relations to sports have as of yet been elucidated. However, labral tears have shown a clear association to sports, and may be evaluated using MRI [12]. MRI is an effective technique for the exploration of the spine, even though CT-scans may be used but limited in their utility. It is the modality of choice in the exploration of spinal cord and nerve root injuries, especially when neurological signs are encountered on physical exam. MRI is particularly useful for the assessment of pathologies of the intervertebral discs and the limbus. As a result, MRI may differentiate between a herniated disc and an avulsion fracture of the posterior apophyseal ring. MRI is generally not the imaging modality of choice for the evaluation of muscles in general except for the muscles of the shoulder and pelvic girdles, especially in patients complaining of pain in the inguinal area [13]. It is also indicated in patients presenting with pain refractory to conservative treatment. Moreover, MRI is useful in the diagnosis of bony contusions and may provide insight in patients presenting with chronic pains without identifiable lesions (figure 10).

***Figure 10**: 16-year-old girl presenting with right knee pain 3 months after initial trauma without identifiable bony lesions. Coronal view using T2-weighted sequences with fat saturation, more specifically Short-Tau Inversion Recovery (STIR). An isolated bony contusion is identified explaining the pain experienced by this patient.*

MRI is an essential technique when an incidental finding of a potentially aggressive lesion is made on conventional radiographs in the setting of sports-related trauma and must also precede any biopsies. Contrarily, immediate use of an MRI instead of conventional radiographs may lead to misdiagnosis and unnecessary complementary examinations, including biopsy. These may prove difficult to analyze by pathologists and may lead to further errors in diagnosis (e.g. stress fractures and myositis ossificans).

Even though the demand for MRI is increasing, urgent accessibility remains limited. It also requires a cooperative child since certain positions during acquisition may be uncomfortable. This technique is very sensitive, and the quality of the image may be altered by numerous artefacts, two of the most frequent being movement artefacts and artefacts due metallic foreign bodies. Absolute contra-indications to MRI (electronic materials, metallic bodies susceptible of being dislodged or causing burns) must be eliminated before the exam is undertaken. T1-weighted images are obtained in order to verify bone marrow signal, a signal that normally varies with age due to fatty infiltration of the bone marrow. The most sensitive sequence for the detection of bony and soft tissue lesions is Short Tau Inversion Recovery (STIR): T2-weighted sequence associated with fat saturation. The majority of these lesions have a decreased signal intensity on T1 and an increased signal intensity on T2-weighted images. T2* allows for a better visualization of the cartilages and, more specifically, the growth plate. Proton density with fat saturation are optimal in the assessment of the different joints.

Injection of contrast material has not been approved in France for use in children. As a result, pediatric orthopedic surgeons working in France avoid ordering arthro-MRIs. Intravenous injections of gadolinium are generally not necessary but may be useful in the analysis of tissue perfusion, especially when the diagnosis of osteonecrosis is considered, or the vascular supply of the growth plates or related pathologies must be evaluated. When infection or malignancy is shown, IV injection of contrast is recommended.

In conclusion, imaging modalities that provide digital slices of the body have become common practice in the exploration of a large number of clinical scenarios related to sports in pediatric patients. However, as a rule, radiography remains the initial imaging modality. Ultrasonography is utilized for the exploration of muscular and tendinous lesions, rare findings in the pediatric population, CT-scanning is limited in its indications, and MRI has excellent contrast resolution and its radiation-free nature has many uses.