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Review Article

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Strategies for X-ray utilization in the evaluation of knee injuries

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ABSTRACT

Knee injuries are prevalent among young athletes, and an accurate diagnosis is essential for effective treatment. Knee pain is a widespread issue among adolescent athletes. About 50% of athletes experience knee pain every year, and an estimated 2.5 million sports-related knee injuries occur annually in young athletes. The study discusses common knee injuries, including fractures, cartilage damage, patellar injuries, and meniscus tears. It highlights the Ottawa knee rules (OKRs) as a valuable clinical decision tool for guiding the necessity of knee X-rays, emphasizing their high sensitivity and potential cost savings. Prevention strategies for youth athletes, such as injury prevention programs and neuromuscular training, are also discussed. Additionally, the review underscores the importance of radiation exposure and patient safety when utilizing diagnostic imaging, emphasizing adherence to radiation safety principles and the ALARA principle. In conclusion, this review emphasizes multifaceted role of X-rays in diagnosing knee injuries and importance of evidence-based decision rules, prevention strategies, and radiation safety in adolescent knee healthcare.

Keywords: X-rays, Knee injuries, Fractures, Patellar injuries, Meniscus tears

INTRODUCTION

The knee joint is comprised of four key bones: the femur proximally, the tibia and fibula distally, and the patella anteriorly (Figure 1).[1] This joint functions primarily as a hinge, facilitating flexion and extension movements, with a minor degree of rotation possible. It is held together by four primary ligaments: the anterior and posterior cruciate ligaments (ACL and PCL), as well as the medial (tibial) and lateral (fibular) collateral ligaments. Extension strength is provided by the quadriceps and patellar tendons, while the hamstring muscle groups enable flexion. Articular cartilage covers the bones, and within the joint, two cartilaginous discs known as the medial and lateral meniscus offer cushioning and stability. The patella articulates with the trochlear groove of the femur, and any

factors causing misalignment of the patella may result in anterior knee pain or patellar instability.

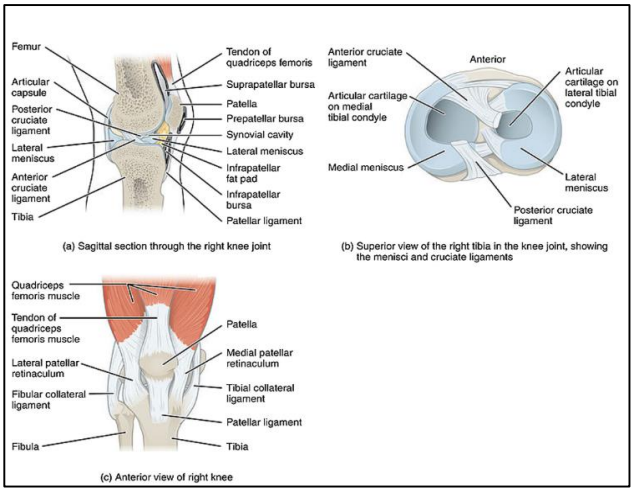

Figure 1: Knee anatomy.[1]

Knee pain is a widespread issue among adolescent athletes. About 50% of athlete's experience knee pain every year, and an estimated 2.5 million sports-related knee injuries occur annually in young athletes.[2-4] These injuries can be severe, with 60% of surgeries related to sports injuries in high school athletes involving the knee. While acute injuries are common, approximately half of all knee injuries are due to overuse.

The risk factors for knee injuries in adolescents can vary depending on the specific injury, but there are common factors to consider. These include single sport specialization, year-round training in one sport, and high training loads, all of which have been linked to an elevated risk of knee injury.[2,5,6] For instance, specializing in 1 sport increases relative risk of patellofemoral-related pain by 1.5 times and raises the risk of specific conditions like Osgood-Schlatter disease (OSD), Sinding-Larsen-Johansson (SLJ), and patellar tendinitis by fourfold when compared to athletes involved in multiple sports.[6] Other factors associated with an increased risk of injury include being female, having stronger quadriceps relative to hamstrings, experiencing joint malalignment, and having an increased Q angle.[4,5,7] Additionally, participating in sports that involve high-impact and rapid directional changes, such as football, basketball, volleyball, and soccer, also heightens risk of knee injuries.[5,7-9]

Appropriate X-ray use is essential in diagnosing knee injuries because it helps healthcare professionals assess the underlying structures of the knee joint, identify potential fractures or abnormalities, and determine the extent of injury.[10] While X-rays are not always primary imaging modality for knee injuries, they play a crucial role in diagnostic process. They are highly effective in early detection of bone fractures and dislocations in knee joint, which is essential for determining an appropriate treatment plan and assessing fracture's severity.[11] X-rays also facilitate assessment of knee joint alignment, aiding in identification of ligamentous injuries and instability, such as those seen in ACL/PCL injuries.[12] Additionally, X-rays are valuable for evaluating degenerative changes and arthritis in knee, revealing signs like joint space narrowing and osteophytes.[13] They serve purpose of ruling out other conditions that may mimic knee symptoms, including tumors or foreign bodies. Lastly, X-rays are instrumental in follow-up and monitoring of knee injuries, tracking healing progress and guiding adjustments in treatment plans as necessary. These multifaceted roles of X-rays in knee healthcare contribute significantly to accurate diagnosis and effective management. Aim of this study is to review and discuss different strategies in X-ray imaging with regards to clinical assessment of knee trauma.

LITERATURE SEARCH

This study is based on a comprehensive literature search conducted on October 18, 2023, in Medline and Cochrane databases, utilizing the medical topic headings (MeSH) and combination of all available related terms, according to database. To prevent missing any possible research, a manual search for publications was conducted through Google Scholar, using the reference lists of the previously listed papers as a starting point. We looked for valuable information in papers that discussed decision rules for X-ray use in knee injuries. There were no restrictions on date, language, participant age, or type of publication.

DISCUSSION

Common injuries

Bone

Fractures around the knee joint in young athletes tend to fall into two main categories: Salter-Harris fractures of the distal femur or proximal tibia and avulsion fractures at sites of tendon/ligament attachments. These fractures can result from either traumatic contact/ noncontact injuries and typically present with symptoms such as significant pain, swelling, and difficulty bearing weight. Diagnostic tools such as X-rays, CT scans, or MRIs may be necessary to assess severity and displacement of injury.[1]

Figure 2: X-ray equipment.[10]

Salter-Harris fractures

Salter-Harris fractures are further classified into five classes (I to V) based on severity, with increasing class numbers indicating more severe fractures and generally poorer prognoses.

Lower-grade Salter-Harris fractures (I, II), which are nondisplaced, can often be managed with a knee immobilizer or cylinder cast, along with limited weight bearing. These injuries typically heal within 4 to 6 weeks. In contrast, higher-grade Salter-Harris fractures (III, IV, and V) pose a greater risk to the physis (growth plate) and articular surface. As a result, they are more likely to require surgical fixation and may take a longer time to heal completely.

Avulsion fractures

Avulsion fractures are a specific kind of injury that happens when tendons or ligaments detach from bones at certain points. These fractures typically occur when a strong force is exerted on the tendon or ligament, and they are more prevalent in young athletes because the attachment site, known as the apophysis, is relatively weaker compared to the surrounding tendon and bone. In the context of the knee joint, there are two common types of tendon avulsion fractures: the patellar sleeve fracture and the tibial tubercle fracture. The patellar sleeve fracture occurs at the upper attachment of the patellar tendon to the patella, while the tibial tubercle fracture happens when a significant force is applied to the lower patellar tendon where it attaches to the upper part of the tibia. These fractures typically lead to significant symptoms such as swelling, pain, reduced range of motion, strength loss, and difficulty bearing weight. Diagnosis of avulsion fractures is typically done through X-rays, which can often reveal displaced bone fragments and an elevated patella (patella alta) with laxity observed in the avulsed tendon. In some cases, a CT scan or MRI may be necessary for a more detailed evaluation.[1]

Cartilage

The articular cartilage in youth athletes differs from that in adults, as it is generally thicker and more vascular. This difference contributes to a lower likelihood of youth athletes developing chronic conditions like osteoarthritis unless other factors such as systemic illness, radiation exposure, or chronic medication use are involved. However, youth athletes are susceptible to isolated chondral injuries, commonly referred to as osteochondral defects or Osteochondritis Dissecans (OCD). OCD injuries can result from a range of factors, including sudden impacts causing bone and cartilage bruises or repeated stress over time. These injuries typically show symptoms such as knee pain, swelling within the joint, and, in cases of unstable lesions, problems like the knee catching or locking, limited range of motion, or a feeling of something loose in the joint. Although X-rays may sometimes detect these lesions, they might be concealed, requiring an MRI for confirmation and to evaluate the lesion's stability.

Patella

Patellofemoral pain syndrome

Patellofemoral pain syndrome (PFPS) is a common condition characterized by anterior knee pain, affecting approximately 7% to 20% of adolescents. It is more frequently observed in females and adolescents who have recently undergone a growth spurt. Several risk factors, including pelvic width, internal tibial torsion, an increased Q angle, quadriceps dominance, and hormonal fluctuations during puberty, may contribute to the development of PFPS.

The exact cause of PFPS is not fully understood, but it is believed to result from a combination of factors, including patellar malalignment and activities that lead to inflammation of the synovial lining and increased pressure within the bone. Common symptoms of PFPS include pain around or behind the patella, which can be exacerbated by activities such as prolonged sitting, climbing stairs, running, or deep knee flexion. Patients may also report sensations like popping, clicking, or a feeling of instability in the knee. Clinical examination findings may reveal limited knee extensor strength, a positive patellar grind test, the presence of a J sign, crepitus during passive range of motion testing, poor mechanics during a single-leg squat, and weakness in the hip abductors and external rotators. The diagnosis of PFPS is typically based on clinical assessment, and imaging is not usually required.[1]

Patellar instability/dislocation

Patellar instability and dislocation are relatively uncommon but significant knee injuries. They account for about 3% of total knee injuries and typically occur in adolescent females aged 10 to 16. Several risk factors contribute to these conditions, including trochlear dysplasia, patella alta or tilt, an increased Q angle, connective tissue disorders, and congenital laxity of the medial patellofemoral ligament (MPFL).[4,7]

Patellar instability or dislocation can result from various mechanisms, including eccentric contraction of the quadriceps, direct trauma to the knee, or noncontact movements involving planting and twisting. Importantly, the risk of recurrence following a single dislocation is relatively high in individuals under 18 years of age, ranging from 15% to 38%. After experiencing a second dislocation, the risk of recurrence significantly increases from 90% to 95%.

Clinical examination findings after a patellar dislocation may include knee effusion, difficulty bearing weight, patellar laxity, pain along the lateral femoral condyle or medial knee capsule, and crepitus. Provocative tests such as the patellar apprehension test, J sign, or tenderness over

the MPFL (Basset's sign) may be positive, indicating instability. X-rays are usually conducted to evaluate the injury's scope and to exclude substantial osteochondral injuries. If there is still a strong suspicion of significant joint damage, an MRI may be requested to offer more comprehensive insights into the condition of the knee structures. Swift and precise diagnosis, followed by suitable treatment, is crucial to prevent the recurrence and potential long-term complications linked to patellar instability and dislocation.[1]

Meniscus tears

Meniscus tears in youth present unique challenges and considerations compared to the adult population. The development and structural changes in the meniscus during growth play a significant role in the incidence and characteristics of these injuries.[14,15] While the exact prevalence of meniscal tears in youth remains unknown, it is clear that they are often associated with high-energy athletic activities and acute trauma, with lateral meniscus tears being more common due to their sports-related nature. These injuries may manifest with various clinical symptoms, necessitating diagnostic measures such as X-rays to rule out other conditions and MRI as the gold standard for diagnosis.[14] X-rays should be performed to rule out a fracture or an osteochondral dissecans lesion.

Discoid meniscus

Discoid meniscus is a congenital anatomical variation found in a portion of the population, with a prevalence of 3%-5% in the general population and a higher incidence of 15% in Asian populations.[14,16,17] This variation is more commonly observed in the lateral meniscus, but it can be bilateral in around 20% of cases. The discoid meniscus is characterized by its thicker and differently structured shape compared to the traditional meniscus, making it more prone to mobility and potential breakage. While some individuals may remain asymptomatic, it can cause various symptoms such as painful snapping, discomfort, limited range of motion, and joint tenderness. Diagnosis often involves X-rays and is confirmed through MRI imaging.[14,17] X-rays may demonstrate characteristic widening of the joint line, squaring of the lateral femoral condyle, or hypoplasia of the tibial spine.

The OKRs are a valuable tool for healthcare professionals when managing acute knee injuries. Implementing these rules in appropriate clinical situations can help decrease the need for unnecessary X-rays, streamline patient care processes, and result in significant cost savings. While originally designed for use in adults, some research suggests that these rules might also be applicable to pediatric patients.

The OKRs, initially developed and validated in Ottawa, Canada, aim to reduce the unnecessary ordering of knee X-rays following trauma, all while maintaining the quality of patient care. These rules are detailed in Table 1. Patients who do not meet the criteria outlined in the OKRs are highly unlikely to have clinically significant fractures and can safely postpone knee X-rays.

Table 1: Ottawa rules for knee X-rays.[18]

S. no.	Indications for Knee X-ray
1	Age 55 years or older
2	Tenderness around the fibular head
3	Isolated tenderness in the patella area
4	Inability to achieve knee flexion of 90 degrees
5	The term "inability to bear weight" is defined as the incapacity to take four steps (two steps on each leg) at the time of presentation without exhibiting any limping. These indications help guide healthcare professionals in determining the necessity of X-ray imaging to assess potential fractures and ensure accurate diagnosis and appropriate management of knee injuries

The OKRs have notable strengths when it comes to evaluating knee injuries. They consistently exhibit a high level of sensitivity, ranging from 84.6% to 100% in various studies.[19-23] Any instances of lower sensitivity observed in trials are often linked to implementation errors.[18] This remarkable sensitivity leads to a significant decrease in the necessity for knee X-rays following acute knee injuries. This reduction has the potential to lower costs, streamline patient care, minimize unnecessary radiation exposure, and enhance the allocation of medical resources. These advantages are especially crucial in regions with limited healthcare resources, such as rural areas.

Furthermore, the OKRs demonstrate strong interobserver agreement, guaranteeing consistent and replicable results regardless of the expertise of the examiner conducting the assessment. While initially designed for adults, there is a growing recommendation to extend their use to the pediatric population, potentially sparing many children from unnecessary radiation exposure during radiographic investigations.

However, despite their effectiveness, the implementation of OKRs remains inconsistent across different regions. Some clinicians may continue to order knee X-rays routinely due to patient expectations or medicolegal concerns. This approach is problematic because many acute knee injuries involve soft tissues not visible on X-rays, and normal-looking X-rays don't rule out fractures. Proper communication with patients and clinical follow-up is essential to ensure appropriate care in these situations. Efforts to raise awareness and promote the widespread use of OKRs could further enhance their benefits in clinical practice.[18]

Prevention

Preventing knee injuries in youth athletes is a critical endeavor, and although not all injuries can be completely avoided, evidence-based strategies have demonstrated significant success in reducing the risk. Knee injury prevention programs, with an emphasis on proprioceptive training and neuromuscular strengthening, have been particularly effective, showcasing a 26.9% reduction in overall knee injuries and an impressive 50.7% reduction in ACL injuries.[24] These programs, tailored to individual sports, focus on proper mechanics during crucial movements like jumping, landing, and cutting. The use of hinged knee braces for collateral ligament protection and patellar stabilizer braces for patellar stability also play a role. Additional preventive measures include promoting multisport participation, maintaining appropriate workload ratios, and incorporating neuromuscular training, general physical activity, and dynamic joint stabilization exercises into athletes' training regimens. By implementing these strategies, we can significantly enhance the well-being and athletic longevity of youth athletes.

Radiation exposure and patient safety

Radiation exposure and patient safety are critical considerations when using diagnostic imaging, including X-rays and CT scans, in the evaluation of knee injuries. These imaging techniques are invaluable for diagnosing and assessing knee conditions, but it is essential to minimize radiation exposure to protect patients from potential harm. The "As low as reasonably achievable" (ALARA) principle is fundamental, emphasizing the need to keep radiation exposure as low as possible while still obtaining diagnostic-quality images.[25] Additionally, campaigns like "image gently" and "image wisely" advocate for responsible use of medical imaging, especially in pediatric and adult populations, by adjusting radiation doses based on patient characteristics and clinical indications. Radiation dose monitoring programs in radiology departments ensure that doses remain within safe limits. Education and training of radiologic technologists and healthcare providers are crucial in ensuring safe and efficient imaging procedures, reducing the risk of unnecessary radiation exposure.

CONCLUSION

Knee injuries are common among adolescent athletes and require careful consideration for effective management. X-rays are essential for diagnosing fractures, assessing joint alignment, and identifying ligament injuries. The OKRs offer a valuable tool with high sensitivity, benefiting cost-efficiency and reducing radiation exposure, especially in resource-limited settings. Preventive measures, including injury prevention programs and patient safety, are critical in safeguarding young athletes from knee injuries. Adherence to the ALARA principle and responsible radiation management ensures safe diagnostic imaging practices.

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