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THE IMPORTANCE OF ULTRASOUND EXAMINATION IN THE DIAGNOSIS OF KNEE JOINT INJURIES IN ATHLETES (LITERATURE VIEW)

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ABSTRACT
Ultrasound imaging (US) plays a crucial role in the early diagnosis of knee joint injuries in athletes. This method enables real-time visualization of soft-tissue structures, including ligaments, tendons, menisci, the joint capsule, and periarticular tissues. Due to its accessibility, non-invasiveness, and ability to perform dynamic assessments, ultrasound has become an essential tool in sports medicine. The use of ultrasound facilitates timely identification of injury type, selection of optimal treatment strategies, and monitoring of rehabilitation progress, which is vital for an athlete's rapid return to training and competition.
KEYWORDS: *Ultrasound, Knee Joint, Sports Injuries, Diagnosis, US Imaging, Athletes, Soft-Tissue Lesions, Rehabilitation.*

INTRIDUCTION

Meniscal tears are the most widely recognized pathology of the knee joint, with an average annual incidence of 66 cases per 100,000. The menisci are critical for load transfer, shock absorption, and joint adjustment. MRI is the most accurate method for imaging soft tissue injuries, but its high cost and limited or unavailable availability are major disadvantages. Diagnostic ultrasound of the knee joint can detect meniscal abnormalities. Ultrasound, particularly B-mode ultrasound with liner transducers, has been tried for assessing meniscal damage with variable results. It is a simple, convenient, inexpensive, and noninvasive method [1].

Nowadays, we live in a society where more and more people are becoming obsessed with sports. At the recreational level, this helps reduce the emotional stress of modern life, and at the elite level, sport is now part of the entertainment industry with enormous material rewards for participants. At all levels, injuries are a constant threat, and acute and stress injuries to the knee joint occupy a leading place in the overall injury structure, forcing athletes to spend time and resources on recovery. This is supported by a study from Sheffield which found that the knee was the most commonly injured joint in sports such as football and rugby [2]. Knee injuries often not only require surgery followed by months of rehabilitation, but can also lead to premature termination of a sports career and a lifelong debilitating condition. A study conducted in Scandinavia has found that the most common cause of disability in sports is knee injury [3]. The high frequency of these injuries is due to anatomical and biomechanical characteristics: the knee joint is the largest supporting joint, which is subject to significant loads. It has a complex configuration and performs movements in three mutually perpendicular axes and planes, which explains the variety of damage to intra-articular and extra-articular structures [4]. The distal end of the femur, the proximal end of the tibia and the patella participate in its formation [5]. Significant freedom of movement in the knee joint is ensured by the pronounced incongruence of the articulating surfaces: the almost spherical condyles of the femur contact the flat plateau of the tibia, which allows for a minimal reduction in the contact area in the flexion position. The menisci can deform during movements, which allows the tibia to change the shape of the articular surface in accordance with the change in the surface of the femur. These biomechanical features require a powerful stabilizing apparatus, the function of which is performed by the menisci, the capsular-ligamentous apparatus and the muscle-tendon complexes. D. Shoyliev identifies medial and lateral stabilizing systems, each of which includes active dynamic (tendon-muscular) and passive (capsular-ligamentous) components. Passive component of the medial stabilizing system: anteromedial part of the joint capsule, tibial collateral ligament (TCL), posteromedial formation; medial meniscus. Active components of the medial stabilizing system: semitendinosus, sartorius, gastrocnemius, gracilis, medial head of the quadriceps. Passive component of the lateral stabilizing system: anterolateral part of the joint capsule, fibular collateral ligament (FCL), posterolateral formation, lateral meniscus. In addition, the anterior (ACL) and posterior (PCL) cruciate ligaments play a leading role in stabilizing the knee joint. Active components of the lateral stabilizing system: iliotibial band, biceps femoris, lateral head of the quadriceps. Stabilization of the joint in case of damage to passive elements occurs due to strengthening of the function of dynamic stabilizers [6].

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Modern ultrasound examination is becoming the most suitable method for rapid and accessible diagnosis of pathological processes in the knee joint. Thanks to new, highly informative ultrasound devices that utilize all the advances in modern computer technology, it has become possible to obtain even more precise and detailed information about pathological changes in the joint than with MRI. It is important to emphasize that the current advances in ultrasound technology in traumatology are largely due to the introduction of new computer technologies that have become commonplace in recent years. A so-called new computer ultrasound diagnostics has emerged, based on the use of high-frequency, broadband and high-density sensors, which provide high-resolution images of ligaments, tendons and menisci. Using Doppler research techniques such as energy color mapping, three-dimensional and panoramic reconstruction, it has become possible to assess the nature of the vascular reaction in the area of changes and monitor treatment. There has been a renewed interest in the use of ultrasound in diagnosing diseases and injuries of the knee joint [7].

The knee joint is one of the most complex in the human body. It also bears significant strain. It provides movement, supports weight, and cushions when walking and running. It's no wonder that knees often hurt, especially due to injuries, intense training, age-related changes, excess weight (which puts increased stress on the joints), or inflammation [8].

It is impossible to make an accurate diagnosis of knee pain without special diagnostics. To figure out what exactly went wrong, doctors prescribe instrumental examinations. One of the most accessible and safest is ultrasound examination [9].

Ultrasound examination is a method based on the properties of ultrasonic waves. They reflect at different frequencies from tissues of varying densities. Thanks to this effect, the tissues and structures through which the waves pass are visualized on the monitor. The doctor can assess the condition of the ligaments, tendons, menisci, joint capsule, and other knee structures. Ultrasound examination helps detect inflammation, fluid accumulation, soft tissue damage, and other important parameters [10].

Ultrasound examination is an absolutely safe examination method (unlike, for example, X-rays, which expose tissue to radiation). It can be performed repeatedly, which is especially important when a doctor needs to understand how a process develops dynamically (for example, pathology or recovery after treatment) [11].



Figure 1 - Knee Joint Appearance on Ultrasound Examination

The knee joint is a rather complex mechanism. It connects the femur, tibia, and patella. Inside it are cartilages, menisci, ligaments, tendons and synovial membrane.

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It is these structures that are most often damaged by stress, injury and inflammatory processes.
Let's take a closer look at which structures of the knee joint are visualized on the screen during an ultrasound examination:
• joint capsule and synovial membrane;
• tendons and ligaments;
• menisci;
• vessels and blood flow (Doppler mapping is used for their assessment);
• Hoffa's fat pad;
• cysts and neoplasms.

During the diagnosis, the doctor may also move the patient's joint and evaluate the structure's function during movement. This is especially important in cases of knee instability. It is also possible to compare two joints—the diseased one and the healthy one.

DIAGNOSTIC CAPABILITIES OF THE METHOD

Using ultrasound, a doctor can assess the structures of the knee joint in real time. In particular, this diagnostic method makes it possible to identify the following pathological changes:

• Fluid accumulation in the joint cavity — a sign of inflammation (arthritis), injury, or a degenerative process. Ultrasound helps determine the amount of fluid and, if necessary, perform aspiration under guidance.

• Meniscal injuries — ultrasound can reveal changes in shape, swelling, and signs of meniscal tears, especially if they are large. However, it should be noted that MRI remains the gold standard for diagnosing meniscal damage.

• Ligament tears and sprains — the condition of the medial (inner) and lateral (outer) ligaments, as well as the quadriceps and patellar tendons, is clearly visible. Partial or complete ruptures are easily detected by ultrasound.

• Tendon injuries — ultrasound shows inflammation, thickening, or partial tears of tendons (especially after intense physical activity).

• Baker's cysts — bulging formations that appear behind the knee as a result of inflammation or injury. Ultrasound allows assessment of the cyst's size, contents, and surrounding tissues.

• Synovitis — inflammation of the synovial membrane. Ultrasound helps determine the degree of inflammation and the associated effusion.

• Cartilage condition — unlike MRI, ultrasound does not allow full evaluation of cartilage tissue. However, irregularities, thinning, and areas of damage can be visualized.

• Hoffa's fat pad — often becomes inflamed due to overload or osteoarthritis. Ultrasound shows swelling, thickening, and uneven contours.

• Calcifications and ossifications — small calcifications in tendons or the synovial membrane, which may not be visible on X-ray, can be detected.

In addition, ultrasound allows doctors to:
• monitor healing processes;
• assess treatment results;
• perform joint injections under guidance (including for certain medications).

DISCUSSION

Early and rapid diagnosis using ultrasound allows the orthopedist to initiate a patient management plan without the usual delay associated with ordering and performing an MRI, which positively impacts the patient's recovery.

According to the study by Artul et al. [19], 34% of ultrasound reports were negative and 66% were positive. In the present study, 29% (45 knees) of ultrasound reports and 16.8% (26 knees) of MRI reports were normal.

Lee and Chow [20] reported that ultrasound is a sensitive tool for assessing knee effusion, and a minimum effusion volume of 7–10 ml can be optimally detected. According to the study by Draghi et al. [21], ultrasound demonstrated 81.3% sensitivity and 100% specificity in detecting knee effusion. In the present study, ultrasound showed a sensitivity of 91.5% and a specificity of 95.8% for detecting knee effusion. Ultrasound did not detect effusion in five knees because the fluid was minimal and located anterior to the anterior cruciate ligament. On the other hand, a possible longer interval between ultrasound and MRI may have contributed to false-positive results.

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In the relevant literature, the detection of cartilage defects is more frequently associated with trochlear cartilage. Patellar cartilage is usually not assessed using ultrasound because it is obscured by the shadow of the patella. Cao et al. [22] noted that ultrasound is a promising screening tool for assessing trochlear cartilage defects, with sensitivity ranging from 62.2% to 69.4% and specificity from 90.5% to 92.9%. In the present study, ultrasound demonstrated a sensitivity of 71.9% and a specificity of 98.4% in detecting trochlear cartilage defects. In nine false-negative cases, trochlear cartilage defects were missed due to their deep location in the intercondylar notch. All patellar cartilage defects were missed by ultrasound because they were obscured by the patellar shadow during the examination.

Unlu et al. [23] reported that anterior subcutaneous edema is a common finding (82.7%) on routine knee MRI and is significantly associated with age, overweight, and chondral changes in the patellofemoral joint. In the present study, ultrasound demonstrated a sensitivity of 77.4% in detecting subcutaneous edema.
Knee synovial plica syndrome is often overlooked as a cause of AKP [24]. Anatomically, the infrapatellar plica is the most common type, followed by the suprapatellar plica, and finally the medial patellar plica, which is considered the most symptomatic [25]. In the present study, ultrasound demonstrated 78.5% sensitivity and 100% specificity in detecting synovial plicae. The infrapatellar plica was the least common type in our study, which contradicts the findings of Kheiralla [25], likely due to the composition of our patient group with AKP symptoms.
Patellar tendinopathy is a common cause of AKP, especially in athletes, predominantly affecting the proximal portion of the tendon. The sensitivity of ultrasound in detecting patellar tendinopathy has been reported as 87% [22,26]. In our study, the sensitivity was 84%.

To the best of our knowledge, quadriceps tendon pathology is more often discussed in the context of tendon ruptures in athletes, and most studies have focused on MRI. In the present study, ultrasound demonstrated a sensitivity of 87.5%, compared with 72.5% reported by King et al. [16].

Impingement syndromes of the fat pads more commonly affect the suprapatellar and superolateral Hoffa's fat pads. These fat pads normally contribute to joint lubrication and stability. When impingement occurs due to abnormal patellar motion, increased echogenicity of the normally hypoechoic fat and increased vascularity can be observed. Gutierrez et al. [21] confirmed the ability of ultrasound to detect suprapatellar impingement. Tsavalas and Karantanas [22] reported a prevalence of 12% among patients with AKP. In our study, the prevalence of suprapatellar fat impingement was 12.3%. Ultrasound sensitivity was 84.2%, and specificity was 100%. Color Doppler revealed increased vascularity in 3 knees due to associated inflammation.

Draghi et al. [24] noted that MRI is the modality of choice for evaluating pathology of Hoffa's fat pad. Mikkilineni et al. emphasized that ultrasound may be valuable for diagnosing Hoffa's fat pad impingement, but further investigation is required. In our study, ultrasound sensitivity and specificity for diagnosing Hoffa's fat pad impingement were 66.7% and 100%, respectively.
According to Draghi et al. [24], ultrasound has 100% sensitivity and specificity in detecting deep infrapatellar bursitis. In our study, sensitivity and specificity were 66.7% and 100%, respectively.

Our results are consistent with Blankstein et al. [25] regarding the assessment of bipartite patella, with ultrasound demonstrating 100% sensitivity and specificity.

A gel stand-off pad is a water-based, flexible, readily accessible, disposable intermediate layer widely used in B-mode ultrasound for superficial or difficult-to-visualize regions. It enables the detection of peri- and intra-lesional blood flow that might otherwise be missed with Doppler [25]. In our study, no gel pad was used; instead, a thick layer of gel was applied to prevent loss of contact. Further studies are recommended to evaluate the value of using a gel stand-off pad in MSK ultrasound.

Although ultrasound demonstrated high diagnostic accuracy, a significant number of lesions were missed. The major lesions missed and subsequently detected on MRI were patellar cartilage defects (all missed) and trochlear cartilage defects (nine cases missed). Therefore, ultrasound may be used for diagnosing and screening patients with AKP and can serve as an alternative to MRI when MRI is unavailable or contraindicated. MRI is recommended in cases of clinical suspicion of patellar cartilage defects or when ultrasound findings are negative.

Our study has limitations. First, there was a wide variety of findings; some may not represent the actual cause of AKP, while others lack published data for comparison. This may reduce the generalizability of the results. However, the study represents an attempt to provide

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a comprehensive review of the diagnostic accuracy of ultrasound in AKP. Second, the high sensitivity of ultrasound in detecting effusion may have increased the overall sensitivity and masked its weaknesses in detecting other pathologies (patellar cartilage defects, infrapatellar plica). Third, all ultrasound examinations were performed by a single radiologist, which precludes assessment of intra- and inter-observer agreement. Fourth, patients were already scheduled for MRI, which may have introduced selection bias. Finally, surgical data and clinical follow-up were unavailable.

CONCLUSION

Ultrasound examination (US) is an effective and accessible diagnostic method for evaluating knee injuries in athletes with anterior knee pain (AKP). In our study, US demonstrated high diagnostic accuracy in detecting most pathological changes, including tendinopathy, fat pad impingement, tendon injuries, and synovial abnormalities. Although certain lesions, such as patellar and trochlear cartilage defects, may be missed, ultrasound provides a fast and safe screening tool for assessing knee joint pathology, thereby enabling timely initiation of treatment and faster rehabilitation for athletes.

Thus, ultrasound can serve as an alternative to MRI in cases where MRI is unavailable or contraindicated, whereas MRI remains the method of choice when patellar cartilage defects are clinically suspected or when ultrasound results are negative. Further studies are required to assess inter-operator variability and to improve the diagnostic accuracy of ultrasound for specific knee injuries.

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