ISSN 0030-5987. Orthopaedics, traumatology and prosthetics. 2023. № 2

# DIGEST AND REVIEWS

УДК 616.728.3-073.432.19(048.8)

DOI: http://dx.doi.org/10.15674/0030-598720232101-109

## Diagnostic capabilities of ultrasound examination of the knee joint at the current stage (literature review)

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*Ultrasound examination (ultrasound) of the knee joint left is one of the main methods of diagnosing its diseases and injuries, which are constantly improved thanks to the use of more accurate diagnostic equipment. Objection. Analyze modern scientific and practical information regarding the possibilities of ultrasound examination of the knee joint and determine pathological changes in its tissues, for the diagnosis of which this technique can be used. Methods. Selected and analyzed scientific articles for the last 6 years, in which the use of knee joint ultrasound is given from the Google search engine, scientific metrics databases PubMed, Medline and other relevant sources scientific and medical information. Results. Analyzed modern literature on the use of knee joint ultrasound in medical practice. Defined orthopedic pathological diseases and areas of the knee joint which investigated by ultrasound. This technique is used for diagnosis of gonarthrosis, synovitis, assessment blood circulation and fluid in the knee joint, Backer's cyst, neoplasms, pathology of menisci, injuries and inflammations ligaments, tendons and muscles. Most doctors and patients prefer the ultrasound technique due to its mobility, without heartburn, almost complete absence of contraindications to carrying out. Today, this research is necessary and an effective method of diagnosing orthopedic pathology traumatic diseases, including knee joint, both individually and in combination with other methods (radiography, computer tomography, magnetic resonance tomography, etc.). It should be noted that the method ultrasound becomes indispensable in case of contraindications to the procedure magnetic resonance imaging. Conclusions. Ultrasound of the patient of diseases and injuries of the knee joint is modern and effective by the method of express diagnostics and can be used both independently and in combination with other methods of diagnostics of pathological changes in the tissues of this localization.*

*Ультразвукове дослідження (УЗД) колінного суглоба залишається одним з основних методик діагностики його захворювань і травм, яке постійно вдосконалюють завдяки застосуванню точнішої діагностичної апаратури. Мета. Проаналізувати сучасну науково-практичну інформацію щодо можливостей ультразвукового дослідження колінного суглоба та визначити патологічні зміни в його тканинах, для діагностики яких цю методику можна застосовувати. Методи. Відібрані та проаналізовані наукові статті за останні 6 років, в яких наведено застосування УЗД колінного суглоба із пошукової системи Google, науковометричних баз даних PubMed, Medline та інших релевантних джерел науково-медичної інформації. Результати. Проаналізовано сучасну літературу щодо використання УЗД колінного суглоба в медичній практиці. Визначено ортопедо-травматологічні захворювання та зони колінного суглоба, які досліджено за допомогою УЗД. Цю методику використовували для діагностики гонартрозу, синовіїту, оцінки кровообігу та рідини в колінному суглобі, кісти Беккера, новоутворень, патології менісків, ушкоджень і запалень зв'язок, сухожилків і м'язів. Більшість лікарів і пацієнтів віддають перевагу техніці УЗД через її мобільність, безпечність, практично повну відсутність протипоказань до проведення. На сьогодні це дослідження є необхідною та ефективною методикою діагностики патології ортопедотравматологічних захворювань, у тому числі колінного суглоба, як окремо, так і в разі поєднання з іншими способами (рентгенографія, комп'ютерна томографія, магнітно-резонансна томографія тощо). Слід відмітити, що методика УЗД стає незамінною у разі протипоказань до проведення магнітно-резонансної томографії. Висновки. УЗД захворювань і травм колінного суглоба є сучасною та ефективною методом експрес-діагностики і може бути використаною як самостійно, так і в комбінації з іншими способами діагностики патологічних змін у тканинах цієї локалізації. Ключові слова. Ендопротезування, колінний суглоб, гонартроз, ускладнення, нестабільність.*

**Key words.** Arthroplasty, knee joint, gonarthrosis, complications, instability

## Introduction

Ultrasound examination (US) is successfully used for examination of joints [1, 2], soft tissues [3] and peripheral nerves of limbs [4]. Some authors also describe the possibility of examining the spine using this method [5–7]. The knee joint is one of the most frequently studied by ultrasound [8–10]. Today, the most widely used technique for examining the knee joint is radiography, which gives a possibility to see the condition of the bones that make it up and assess the width of the joint gap [11–14]. But, usually, correct assessment of the state of the knee joint requires visualization of its other components, which cannot be seen with the help of radiography (ligaments, menisci, muscles, the presence of fluid, etc.) [12, 14]. Magnetic resonance imaging (MRI) remains the «gold standard» for diagnosing knee joint disorders, which is indispensable for diagnosing cruciate ligament abnormalities, the initial stages of aseptic condylar necrosis, patellar cartilage diseases, etc. An alternative method of express diagnosis is ultrasound, which continues to be improved by developing new models of ultrasound devices [12, 13, 16]. The knee joint is one of the joints best visualized by ultrasound, given the superficial location of most anatomical structures [12, 15, 17]. It should also be noted that ultrasound has its advantages over MRI, namely:

– possibility of researching active and passive movements in real time;

– cheaper equipment;

– availability of portable ultrasound devices and those that can be connected to a smartphone (image). Their small size allows performing ultrasound at home and in the field [14, 19, 20];

– US due to the pressure of the sensor (sonopalpation), allows medical practitioners to more clearly localize and visualize the location of pain in the patient [12, 14, 19].


**Figure.** Portable ultrasound machine

This study will help orthopedic traumatologists, surgeons, rheumatologists, sports medicine doctors to determine the role of ultrasound diagnosis for the analysis of knee joint diseases.

*Purpose:* to analyze modern scientific and practical data on the possibilities of ultrasound examination of the knee joint and to determine abnormal changes in its tissues, for the diagnosis of which the technique can be used.

## Material and methods

Publications from the Google search engine, scientific and metric electronic databases PubMed, Medline and other relevant sources of scientific and medical information were analyzed. Articles from the last 6 years (from 2017 to 2022) were selected, in which the use of ultrasound of the knee joint is reflected.

## Results and their discussion

By searching the literature in electronic sources for this area of research, 20 prospective IV and V levels of evidence were found, 9 articles on research methods and treatment procedures under ultrasound control, 6 of the «case-control» type, 4 literature reviews, and 1 research on autopsies. The majority of studies (48.7 %) are prospective with I and II levels of evidence. Unfortunately, we did not find any meta-analysis.

To understand the problem, each publication was analyzed, and a table was compiled based on the research. It lists all works for the selected period with an indication of the author, year of publication, type of scientific research, number of patients, studied abnormality and anatomical structures of the knee joint.

In different years, the number of published works on the use of ultrasound for the diagnosis of knee joint diseases was almost the same (from 4 in 2019 to 10 in 2020), that is, the interest of researchers in this topic remained approximately at the same level.

An interesting observation was made by O. A. Buryanov with co-authors. [8], who studied cyst-like formations (CLF) of the knee joint. As a result of the study, calf-semimembranous bursitis (Baker's cyst) was diagnosed in 31 patients.

Manifestations of bursitis in other areas of the knee joint were observed with the following frequency: hygroma (bursitis) of the medial section — 4, cyst of the external meniscus — 2, prepatellar bursitis — 4, infrapatellar bursitis — 3, intra-articular ganglionic CLF — 2. During examination of patients with CLF areas of the knee joint, it became known that most of the patients have the II

*Table*

**Examination of the knee joint using ultrasound**

| Author, year of study | Type of study | Number of patients | Structures of the knee joint being studied | Abnormality |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| Buryanov O.A., 2017 [8] | Prospective comparative | 38 | Cyst-like formations | Cyst-like formations (CLF): prepatellar, infrapatellar deep and superficial bursitis, «crow's foot» bursitis, meniscal cysts, intra-articular CLF |
| Marushko T.V., 2017 [9] | Literature review | Not specified | Cartilage of the condyles of the femur, the presence of fluid, thickening of the synovial membrane, Baker's cyst | Gonarthrosis, changes in the case of rheumatoid arthritis |
| Dong B. Q. et al. 2021 [11] | Prospective comparative | 100/100 | Tendon thickness | Gonarthrosis |
| Novotny T. et al. 2021 [12] | Methodological | Not specified | Collateral ligaments, popliteal area, upper turn | Damage to bypass ligaments, Baker's cyst, synovitis |
| McCumber T. L. et al. 2019 [13] | Methodological (conductive anesthesia) | 5 corpses | Anterior and lateral femoral cutaneous nerves | Conductive anesthesia after endoprosthetic repair |
| Cunha J. S. et al. 2017 [14] | Case-control | 1 | Articular cartilage and femur | Intra-articular fracture of the femoral condyle |
| Hughes T. et al. 2021 [15] | Case-control | 1 | Soft tissues (subcutaneous tissue, tumor, fascia, muscles) | Malignant tumor of soft tissues |
| Moraux A. et al. 2020 [16] | Prospective | 4 | Soft tissues (subcutaneous tissue, lateral retainer of the kneecap, iliotibial tract), veins of the lateral retainer of the kneecap | Thrombosis of the vein of the lateral retainer of the kneecap |
| Kandemirli G. C. et al., 2020 [17] | Prospective | 99 (198 knee joints) | Cartilage of femoral condyles, presence of fluid, Baker's cyst | Intensity of pain in gonatrosis |
| Abate M. et al., 2020 [18] | Prospective | 130 | Baker's cyst | Baker's cyst in gonarthrosis |
| Okano T. et al., 2019 [19] | Literature review | Not specified | Articular cartilage, femur and tibia, muscles, ligaments, menisci, Baker's cyst | Synovitis, Baker's cyst, osteophytes, articular cartilage changes |
| Kozaci N. et al., 2022 [20] | Prospective | 92 | Femur, tibia, fibula bones, kneecap | Fractures of the knee joint, fluid, hematoma, hemarthrosis |
| Ishii Y. et al., 2020 [21] | Prospective comparative | 12 | Medial meniscus | Protrusion of the medial meniscus during walking in patients with gonarthrosis |
| Samanta M. et al., 2018 [22] | Prospective | 409 | Articular cartilage | Determination of the thickness of articular cartilage |
| Rizvi M. B. et al., 2018 [23] | Case-control | 1 | Presence of fluid | Determination of fluid |
| Cushman D. M. et al., 2022 [24] | Prospective | 52 (104 knee joints) | | |
| Sadeghi N. et al., 2017 [45] | Method of performing a puncture of the knee joint with ultrasound for anesthesia | Not specified | Quadriceps tendon, suprapatellar fat pad, suprapatellar bursa, femur | Determination of the suprapatellar bursa for anesthesia |

*Продовження таблиці*

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Sukerkar P. A. et al., 2022 [25] | Literature review | Not specified | Thickness of articular cartilage, tibia and femur | Gonarthrosis |
| Husseini J. S. et al., 2018 [26] | Tendon research methodology | Not specified | Tendons | Normal and abnormal tendons |
| Gallina A. et al., 2018 [27] | Study of changes in the structures of the knee joint in different positions and gender | 20 | Medial head of the quadriceps muscle | Structure of the medial head of the quadriceps muscle |
| Faisal A. et al., 2018 [28] | Study of the thickness of articular cartilage using the method of mathematical modeling | Not specified | Articular cartilage | Thickness of articular cartilage |
| Chiba D. et al., 2020 [29] | Prospective | 53 (106 knee joints) | Cartilage, bones, presence of fluid | Determination of fluid |
| Chiba D. et al., 2017 [30] | Prospective comparative | 270 | Medial meniscus, medial section | Determination of medial meniscus extrusion |
| Ahmed H. H. et al., 2020 [31] | Case-control | 1 | Soft tissues (subcutaneous tissue, tumor, fascia, muscles), Doppler examination of vessels of the lower limb | Malignant tumor of the calf muscle |
| Hung C. Y. et al., 2017 [32] | Case-control | 1 | Ligaments and cavity, blood supply formation | Soft tissue formation (nodular fasciitis) |
| Kudo S. et al., 2017 [34] | Prospective | 20 (40 knee joints) | Lateral head of the quadriceps muscle | Deformation of the lateral head of the quadriceps muscle during movements in the knee joint |
| Papernick S. et al., 2020 [35] | Prospective comparative | 25 | Femoral cartilage | Thickness of femoral cartilage |
| Zappia M. et al., 2018 [36] | Study on autopsies | 8 knee joints | Anterolateral ligament | Visualization of the anterolateral ligament |
| Nelson A. E. et al., 2020 [37] | Literature review | Not specified | Articular cartilage, femur and tibia, muscles, ligaments, menisci, Baker's cyst | Synovitis, Baker's cyst, osteophytes, articular cartilage changes |
| Saito M. et al., 2022 [38] | Prospective | 1667 | Articular cartilage, femur and tibia bones, menisci | Synovitis, extrusion of the medial meniscus, osteophytes, changes in articular cartilage |
| Abicalaf C.A.R.P. et al., 2021 [39] | Prospective | 100 (194 knee joints) | Articular cartilage, femoral and tibial bones, muscles, ligaments, menisci, Baker's cyst | Synovitis, Baker's cyst, osteophytes, articular cartilage changes, tendinitis of the patellar ligament, bursitis of the «crow's foot» |
| Nevalainen M. T. et al., 2018 [40] | Prospective | 57 | | Synovitis, osteophytes, changes in the articular cartilage of the femoral condyles |
| Mitra S. et al., 2019 [41] | Prospective comparative | 27 patients, 54 volunteers | Femoral cartilage | Thickness of femoral cartilage |
| Geannette C. et al., 2018 [42] | Prospective | 6 | Femur and tibia bones, muscles, ligaments and tendons | Examination of the knee joint after endoprosthetic repair and injection under ultrasound control |

*Продовження таблиці*

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Adamiak P. et al., 2022 [43] | Methods of performing a puncture of the knee joint with ultrasound | Not specified | Quadriceps tendon, suprapatellar fat pad, suprapatellar bursa, femur | Determination of the suprapatellar bursa for anesthesia |
| Ozcakar L. et al., 2019 [46] | Case-control | 1 | Lateral bypass ligament, lateral meniscus, tendons and bones of the lateral division | Ossification of the proximal part of the lateral bypass ligament |
| Jiménez Díaz F. et al., 2020 [44] | Methods of study and determination of disorders of the iliotibial tract | Not specified | Iliotibial tract | Abnormal changes in the iliotibial tract |
| Morag Y. et al., 2022 [33] | Methods of study of myxofibrosarcoma | Not specified | Soft tissues (subcutaneous tissue, tumor, fascia, muscles), Doppler study of tumor vessels | Myxofibrosarcoma of soft tissues of the thigh |
| Jacobson J. A. et al., 2017 [47] | Review article | Not specified | Articular cartilage, femoral and tibial bones, muscles, tendons, ligaments, menisci | Synovitis, Baker's cyst, osteophytes, articular cartilage changes, patellar tendonitis, gout, menisci disorders |
| Lutz P. M. et al., 2020 [48] | Prospective | 65 volunteers (79 joints without abnormalities) | The width of the joint gap in the medial part | The width of the joint space in the medial section with and without load, taking into account age, gender and body mass index |
| Roth J. et al., 2021 [49] | Prospective | 8 | Articular cartilage, femur and tibia bones, muscles, tendons, ligaments | Synovitis with deposition of heterogeneous contents, enthesopathy with severe thickening of the quadriceps tendon |

and III stages of the disease, which suggests the low effectiveness of conservative treatment, taking into account the structural changes that have occurred in the bone.

T. Novotnu et al. [12] described the main planes and positions for imaging the most common knee diseases: medial ligament injuries, Baker's cyst, and synovitis.

T. L. McCumber et al. [13] proposed visualization of anterior and lateral femoral cutaneous nerves in the area of the knee joint with the help of ultrasound in order to perform anesthesia of the latter after endoprosthetic surgery. It is noted that ultrasound is one of the main methods of vascular research. In particular, A. Moraux et al. [16] reported that they had diagnosed thrombosis of the veins of the lateral patellar retainer in 4 patients, with MRI showing only subcutaneous edema.

We highlighted two publications that evaluated the reliability of the ultrasound method. N. Kozaci et al. [20] conducted a prospective study involving 92 patients with injuries of the knee joint, who underwent X-ray examination and ultrasound (according to the POCUS protocol). Fractures in the area of the knee joint (distal parts of the femur and proximal parts of the tibia, condyles of the femur, proximal part of the fibula and kneecap) were determined in 40 (43 %) patients by ultrasound, in 32 (35 %) by X-ray examination. Also, with the use of ultrasound, hematoma and swelling of soft tissues were diagnosed in 34 (37 %) patients, hemarthrosis in 33 (36 %). An interesting article was published by J. S. Cunha with co-authors [14], in which the authors described a case US diagnosis of an intra-articular fracture of the femoral condyle, which was not visualized by radiography.

It is necessary to note the possibilities of ultrasound in patients with gonarthrosis. In particular, B. Q. Dong et al. [11] studied the condition of the tendons of the knee joint in patients with arthrosis and found thickening of the tendons in patients compared to healthy people of the same age. US examination was used to determine the influence of changes in the soft tissue structures of the knee joint on the intensity of pain in patients with gonarthrosis — the thickness of the cartilage of the femoral

condyles, the presence of fluid and Baker's cyst, with the largest contribution of the latter [17]. This was confirmed in the study by M. Abate et al. [18], who analyzed the condition of the knee joints in 130 patients with gonarthrosis and sonographically determined the presence of Baker's cyst in 33 of them. The authors proved that the presence of Baker's cyst worsens the symptoms of gonarthrosis in the average follow-up period (6 months). They emphasize the role of ultrasound in detecting the early stages of gonarthrosis and accompanying soft tissue abnormality of the knee joint [19], protrusion of the medial meniscus during walking [21].

Some of the publications discuss ultrasound examination methods, namely: for measuring the thickness of articular cartilage in the knee joint [22, 25], the state of tendons under conditions of pathological changes in the knee joint (tendinopathies, traumatic injuries, etc.) in comparison with healthy volunteers [26], of the medial bundle of the quadriceps muscle, depending on the gender and position of the joint [27]. It is necessary to note that ultrasound can be performed not only in a static position. In particular, three methods of determining the fluid in the knee joint are described and compared: in a static position, under conditions of contraction of the quadriceps femoris muscle and parapatellar compression. The most accurate was the study under the conditions of contraction of the quadriceps thigh muscle [24].

With the help of ultrasound and mathematical modeling, changes in the thickness of the articular cartilage of the knee joint were studied and it was proved that they can be visualized during the dynamic examination of the patient [28].

A prospective study using ultrasound revealed a direct relationship between the degree of severity of gonarthrosis and the presence of fluid in the knee joint in patients, a decrease in muscle mass of the lower limb [29], and it was also proven that the level of extrusion of the medial meniscus is directly correlated with the progression of gonarthrosis [30] .

Ultrasound also helps to detect soft tissue tumors. T. Hughes et al. [15] described a case of diagnosing a malignant neoplasm (myxoid fibrosarcoma) of soft tissues of the knee joint (confirmed histologically). H. H. Ahmed et al. [31] cited a clinical case in which a myxoid fibrosarcoma of the calf muscle in the area of the knee joint was detected in a patient using ultrasound and vascular dopplerography. A case-control case was also described in which the patient was diagnosed with a non-vascularized soft tissue mass in the area of the cruciate ligaments of the knee joint using ultrasound, and after arthroscopic resection, the diagnosis of «nodular fasciitis» was established [32]. In the review article, the ultrasound picture of several cases of myxofibrosarcoma in the area of the knee joint is given [33].

Using ultrasound, the deformation of the lateral head of the quadriceps femoris muscle was determined [34], the thickness of the articular cartilage of the femoral condyles in volunteers was studied (3D-ultrasound and MRI 3 T) [35].

A study on autopsies showed a clear visualization of the anterolateral ligament of the knee joint using ultrasound [36].

A review article that analyzed publications on the use of ultrasound for the diagnosis of gonarthrosis, proves that the method is currently more sensitive than radiography for the detection of osteophytes, which indicate the early stages of arthrosis. In addition, ultrasound provides detailed visualization of the soft tissues of the knee joint and is a faster and more economical method than MRI [37]. An article with a large number of researched subjects (1,667) proved the diagnostic value of ultrasound (detection of osteophytes and protrusion of the medial meniscus) in the early stages of gonarthrosis [38].

In a prospective study involving 100 patients with II–IV stages of gonarthrosis, the most frequent abnormalities were as follows: synovitis, «crow's foot» bursitis, Baker's cyst, and tendinitis of the knee ligament [39].

Based on the comparison of the results of ultrasound, radiography and intraoperative findings in patients with terminal stages of gonarthrosis, ultrasound was found to be sensitive in diagnosing damage to the cartilage of the medial condyle of the femur in 92 %, and only in 58 % of the lateral condyle, and 46 % in the intercondylar zone. During the diagnosis of fluid and synovitis, the sensitivity of the technique was 97 %, of osteophytes of the medial part of the knee joint — 90–95 % [40].

Ultrasound can help diagnose juvenile rheumatoid arthritis (JRA). M. B. Rizvi et al. [23] reported the data of a patient with fluid in both knee joints, which was diagnosed by ultrasound, and the diagnosis of JRA was established. In a prospective study (27 patients and 54 volunteers), the authors measured the thickness of the articular cartilage of the wrist, knee joint, and bones using ultrasound in JRA patients and found significant cartilage thinning in the studied areas compared to the control group [41].

In the postoperative period, ultrasound also helps to determine changes in the knee joint. For example, C. Geannette et al. [42] described impingement of the hamstring tendon by an osteophyte di-

agnosed using this technique in patients after knee arthroplasty.

Ultrasound can be used not only for diagnosis, but also for monitoring of various medical procedures (punctures, blockades, etc.). In particular, a new anterior access for intra-articular injections into the knee joint using ultrasound [43], the possibility of diagnosing and treating (local injections) iliotibial tract syndrome [44], the introduction of anesthetic into the suprapatellar bursa (during bending of the knee joint to 90° its visualization improves) [45].

L. Ozsakar et al. [46] described a patient with lateral knee pain who was diagnosed with ossification of the proximal lateral collateral ligament by ultrasound.

An interesting study in which the width of the medial joint space was measured using ultrasound depending on age (in the results, it decreased with increasing age) and body mass index and gender found no dependence [48].

## Conclusions

With the help of ultrasound, it is possible to examine all the soft superficially located anatomical structures of the knee joint: the tendons of the quadriceps and biceps muscles, the «crow's feet», the iliotibial tract; all muscles of the area — quadriceps, biceps, popliteus, «crow's feet»; ligaments — medial and lateral bypass, proper knee ligament, lateral and medial retainers of the knee, surface parts of the lateral and medial menisci, including the surface of the bones and fluid determination (in the upper turn, suprapatellar, infrapatellar, Baker's cysts).

Ultrasound makes it possible to diagnose most abnormal changes in the soft tissues of the knee joint and some types of fractures (distal femur, proximal tibia, femoral condyles, proximal fibula and kneecap) and vascular disorders (thrombi and aneurysms). At the same time, changes in the intra-articular ligaments (anterior, posterior cruciate), parts of the menisci and bones, which are not available for ultrasound imaging, require examination with the help of CT and MRI.

The conducted research showed that ultrasound of the knee joint currently remains one of the main and most frequently used methods of diagnosing its disorders. The improvement of the technique is associated with the development of devices with greater capabilities, such as transducers with a high scanning frequency (over 18 MHz). There was a chance to create a panoramic image of the examined area with the device, a better and cleaner look of an ultrasound scan that conveys a clearer image of various structures, energy and color Doppler, 4D images, elastography, which helps to determine the density of anatomical structures. A modern review of the literature can help doctors determine the indications for ultrasound and its possibilities in the diagnosis of knee joint disorders.

**Conflict of interest.** The authors declare no conflict of interest.

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The article has been sent to the editors 12.05.2023

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# DIAGNOSTIC CAPABILITIES OF ULTRASOUND EXAMINATION OF THE KNEE JOINT AT THE CURRENT STAGE (LITERATURE REVIEW)

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