



ULTRASOUND DIAGNOSIS OF KNEE JOINT INJURIES AND OPTIMIZATION OF REHABILITATION APPROACHES

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Abstract: This article studies the role of ultrasound diagnostics (UTT) in optimizing the rehabilitation process in injuries of the internal structures of the knee joint. The study was conducted in a clinical-functional direction and was based on prospective observation and dynamic assessment methods. Patients were monitored stepwise (T0–T3) by ultrasound examination, and indicators such as synovitis, bursitis, hemarthrosis, meniscal changes, ligamentous stability, and muscle condition were assessed.

The results showed that individual adaptation of the rehabilitation program based on UTT led to clinical and functional improvement in 70–75% of patients, the diagnosis was clarified in 80–85% of cases, and treatment tactics were changed in 60% of patients in a timely manner. Dynamic ultrasound monitoring allowed for precise management of the rehabilitation process, early detection of complications, and reduction of recovery time.

The cost-effectiveness of ultrasound diagnostics has also been proven: a decrease in diagnostic costs, a reduction in treatment time, and a decrease in days of disability were observed. The results of the study confirm that the individual rehabilitation model based on ultrasound control is an effective and innovative approach to knee joint injuries.

Keywords: knee joint, ultrasound diagnostics, rehabilitation, dynamic monitoring, synovitis, bursitis, hemarthrosis, meniscus injury, ligament injury, individual rehabilitation, functional recovery, UTT, musculoskeletal pathology.

Introduction. The knee joint is one of the most complex and functionally loaded joints of the human musculoskeletal system. Due to the complexity of its anatomical structure, the wide range of motion, and the fact that this joint is responsible for weight-bearing vital functions, injuries of various degrees of the internal structures of the knee joint are one of the most common traumatological problems in clinical practice.

According to the World Health Organization, knee joint injuries account for 45–50% of all musculoskeletal injuries, and among those who regularly play sports, this figure reaches 60–70%. In recent years, the Republic of Uzbekistan has also seen a sharp increase in knee joint pathologies, in particular, meniscus, ligament and soft tissue injuries, which requires innovative approaches in diagnostic and rehabilitation services [1].

Injuries to the internal structures of the knee joint—the medial and lateral menisci, anterior and posterior cruciate ligaments, collateral ligaments, articular surfaces, synovial membrane, and periarticular soft tissues—are often difficult to diagnose clinically.

The probability of making an incorrect or incomplete diagnosis based on the results of the initial clinical examination may be more than 25–30%. In particular, meniscal tears, incomplete partial ligament ruptures, soft tissue changes such as synovitis and bursitis, and early degenerative processes are among the conditions that are not fully expressed by clinical signs [2].

Therefore, modern instrumental diagnostics, in particular ultrasound (UTT), are widely used in the diagnosis of knee joint pathologies. In recent years, the development of high-frequency (7–18 MHz) sensors, Doppler examination, elastography, real-time assessment capabilities, dynamic functional tests, and tissue monitoring during movement have significantly increased the diagnostic value of UTT.



A number of international studies have shown that the sensitivity of UTT in detecting meniscus injuries is 85–92%, and the specificity is 80–90%, which in many cases indicates that it is almost equal to MRI. There is information that the accuracy of ultrasonography in detecting ruptures or loosening of the cruciate ligaments reaches 90–95% [3].

The main advantages of ultrasound diagnostics are its safety, non-radiation, low cost, speed, and the possibility of repeated monitoring. It is the availability of repeated and dynamic UTT studies that is a very important factor for monitoring the rehabilitation process in knee joint injuries. Because the tissue regeneration process in knee joint injuries is individual and closely related to the patient's age, general condition, level of load, connective tissue properties and type of injury.

According to current scientific literature, up to 60% of cases of damage to the internal structures of the knee joint can be restored without surgical intervention, with the help of a properly designed rehabilitation program. However, the effectiveness of the rehabilitation process depends on the correctly selected functional load, a gradual increase in muscle strength, control of edema and inflammation, restoration of joint stability and re-formation of intermuscular balance.

Improper or premature loading during rehabilitation can lead to complications such as exacerbation of synovitis, bursitis, hemarthrosis, meniscus degeneration, additional microtrauma, arthrofibrosis, and chronic pain syndrome within the joint. Therefore, each stage of rehabilitation must be scientifically based and controlled.

The role of ultrasound in improving the effectiveness of rehabilitation is manifested precisely in this: with the help of UTT, the thickness of the synovial membrane, the amount of exudate, the elasticity of muscle tissue, the regression of the inflammatory process, the condition of the ligamentous apparatus, the contour of the meniscus, cysts, hemarthrosis, muscle atrophy, and fibrotic changes in the periarticular tissue are accurately assessed in real time. Dynamic monitoring allows you to adjust the rehabilitation program to the patient's recovery rate and the real state of the tissues [4].

Complications after knee joint injuries - synovitis (up to 80-90%), bursitis, hemarthrosis, meniscus cysts, meniscus degeneration, muscle atrophy, and decreased ligament stability - significantly reduce the effectiveness of the rehabilitation process. Given that the rehabilitation approach for each complication is different, the development of an individual rehabilitation algorithm is becoming one of the most important tasks of modern medicine [5].

However, in practice, many rehabilitation protocols are applied in a general, uniform manner for all injuries. This may not correspond to the type of injury, severity, dynamics of complications, and functional load on the joint, which may prolong the recovery period or increase the risk of re-injury. Therefore, there is a need to optimize the individual rehabilitation approach based on ultrasound in knee injuries.

The relevance of this study is determined by the increasing incidence of knee injuries, the high percentage of post-injury complications in clinical practice, the advantages of ultrasound in diagnostic and rehabilitation control, but the lack of a single standard rehabilitation algorithm based on this method. In addition, in the conditions of Uzbekistan, there is a lack of comprehensive scientific research on optimizing the rehabilitation process for knee injuries based on UTT [6].

Therefore, the main scientific and practical significance of this study is to develop an optimized, individualized, step-by-step controlled rehabilitation model based on ultrasound diagnostics to prevent the development of complications in injuries to the internal structures of the knee joint and scientifically manage the rehabilitation process.



Purpose of the research. Introduction of innovative diagnostic methods in healthcare and improvement of the organization of medical radiology services in the centers:

1. Study of the possibilities of ultrasound diagnostics in identifying complications of injuries of the internal structures of the knee joint
2. Evaluation of the diagnostic value of the ultrasound examination method in the rehabilitation of complications of injuries of the internal structures of the knee joint using magnetic resonance imaging
3. Development of an individual observation and control algorithm in the rehabilitation of complications of injuries of the internal structures of the knee joint
4. Determination of the effectiveness of the developed individual observation and control algorithm in the rehabilitation of complications of injuries of the internal structures of the knee joint using ultrasound examination and rehabilitation tests.

The fact that the rehabilitation process in injuries of the internal structures of the knee joint is accompanied by many complications, and standard rehabilitation protocols for various degrees of injury are insufficient in practice, is a problem. Therefore, there is a need to widely use the capabilities of ultrasound in monitoring rehabilitation, accurately assess the stages of recovery, and individually determine functional loads [7].

As part of this study, an innovative model for optimizing the rehabilitation process based on ultrasound diagnostics is being introduced. This model allows for the assessment of synovitis, bursitis, hemarthrosis, meniscus changes, and muscle condition at each stage of rehabilitation using ultrasound, and to change the intensity of the load and exercises depending on the results. Also, dynamic ultrasound monitoring makes it possible to identify complications early and reduce the risk of re-injury.

Thus, the introduction of an individual rehabilitation algorithm based on ultrasound control into clinical practice is an innovation that improves the quality of recovery in knee joint injuries, reduces treatment time, and increases efficiency.

This study is a practical experimental study of a clinical and functional nature, aimed at optimizing rehabilitation based on ultrasound diagnostics in injuries of the internal structures of the knee joint. The study design includes elements of prospective observation and dynamic assessment [8].

During the trial, patients are assessed at baseline (T0) based on ultrasound and clinical functional indicators. Then, the rehabilitation process is monitored stepwise (T1, T2, T3) under UTT control. At each stage, rehabilitation protocols are individually modified based on ultrasonographic criteria such as synovitis, exudate, muscle thickness, meniscus contour, and ligament stability.

The novelty of the trial design is that the rehabilitation process is guided not by classical clinical signs, but by real-time ultrasound indicators. The study introduces a new algorithm that allows modeling the intensity of functional loading with UTT data, early detection of complications, and optimization of the rehabilitation program.

This design is aimed at increasing the effectiveness of rehabilitation, reducing recovery times, and reducing the risk of injury recurrence, allowing for the implementation of an individual approach to knee joint injuries.

The process of selecting patients for study is one of the most important stages of scientific research and clinical trials. A properly selected group of patients and diagnostic methods ensure the reliability of the trial and allow generalization of the results. Several factors are taken into account when selecting patients, all of which depend on the objectives of the study, the type of



trial, and its design. This study presents the results of UTT and examination of patients undergoing treatment in the rehabilitation department [9].

Dynamic ultrasound monitoring is used as the main object in ultrasound diagnostics and optimization of the rehabilitation process in injuries of the internal structures of the knee joint. Modern ultrasonographic technologies allow for accurate assessment of changes in soft tissues, menisci, ligaments and synovial structures in real time. This approach allows for precise monitoring of the patient's recovery process, early detection of complications and individual formation of a rehabilitation program.

Regular recording and analysis of UTT results is important for monitoring the dynamics of the injury. Ultrasound data obtained during each examination are entered into special electronic monitoring cards and changes that occur between rehabilitation stages are analyzed. This integrated approach allows the doctor to quickly manage the rehabilitation process, correctly distribute the functional load and change treatment tactics in a timely manner.

Dynamic UTT monitoring improves the quality of medical care provided to patients with knee joint injuries. Because remote, real-time assessment of changes within the joint can improve rehabilitation effectiveness, shorten recovery time, and reduce the risk of re-injury. This scheme creates a significant advantage in ensuring effective rehabilitation of knee injuries, especially in regions with limited centralized diagnostic capabilities [10].

The study analyzed the results of ultrasound assessment of complications after injuries to the internal structures of the knee joint and dynamic monitoring of the rehabilitation process. UTT examinations demonstrated significant diagnostic superiority in key parameters such as synovitis, bursitis, hemarthrosis, changes in the contour of the meniscus, ligament stability, and muscle thickness.

Individual adaptation of the rehabilitation program based on dynamic ultrasound monitoring led to an increase in the rate of recovery in patients, a decrease in pain syndrome, regression of inflammatory signs, and early restoration of joint function. Changes recorded by UTT at each stage allowed for the correct selection of the rehabilitation load and early elimination of complications.

Results and discussion. The results of the study also showed that ultrasound, due to the possibility of accurate assessment in real time, reduces the likelihood of clinical errors in the rehabilitation process and accelerates recovery compared to standard approaches. The degree of regression of complications and accurate recording of changes inside the joint at each stage served to increase the effectiveness of rehabilitation.

In general, the results obtained confirmed that the rehabilitation model based on ultrasound diagnostics significantly improves the quality and speed of recovery in knee joint injuries.

During the study, the effectiveness of the rehabilitation process carried out under ultrasound control in injuries of the internal structures of the knee joint was assessed according to several key clinical and instrumental criteria. The results obtained among patients (124 people, 130 joints) are summarized as follows:

- **Diagnostic accuracy:** Based on the results of ultrasound, the initial clinical diagnoses were corrected or clarified in 80–85% of patients. This was especially evident in the detection of synovitis, hemarthrosis, meniscus cysts and bursitis.
- **Positive dynamics in the rehabilitation process:** With the help of dynamic ultrasound monitoring, regression of inflammatory signs, reduction of exudate, reduction of pain syndrome and improvement of joint function were observed in 70–75% of patients.



- Timely adjustment of treatment tactics: Based on the changes noted in the UTT during rehabilitation, the rehabilitation program was updated or the load was adjusted in 60% of patients, which accelerated the recovery process.

- Functional recovery criteria: Range of motion, muscle strength, and joint stability indicators significantly improved in more than 70% of patients.

These indicators confirm the effectiveness of the individual rehabilitation model based on ultrasound, allowing for precise management of the rehabilitation process in knee joint injuries.

Statistical analysis of the obtained data was carried out based on standard clinical recommendations for calculation. Analysis of clinical examination data was carried out in Microsoft Excel office applications. In this case, the arithmetic mean value (M), standard error of the mean (m), reliability level (p) and Student's criterion of the studied indicator were calculated. The reliability level of $r < 0.05$ was taken into account as statistically significant parameters of the data.

During the study, the informativeness of ultrasound diagnostics in injuries of the internal structures of the knee joint and its advantages in managing the rehabilitation process were scientifically evaluated. The results of rehabilitation measures based on dynamic UTT monitoring showed significant clinical and functional advantages compared to traditional clinical approaches.

Firstly, the ability of ultrasound to determine inflammation, exudate volume, meniscus contour, and ligament stability in real time created conditions for an accurate assessment of the patient's condition and rapid change in rehabilitation tactics. The fact that in 60% of patients during the study, the need to change the rehabilitation program based on the results of the UTT was confirmed by the practical significance of this method.

Secondly, the individual rehabilitation algorithm based on the UTT significantly accelerated the dynamics of recovery in patients. Regression of inflammation, reduction of pain syndrome, increase in muscle strength, and restoration of joint mobility showed higher efficiency in 70–75% of patients compared to traditional rehabilitation. This process made it possible to manage rehabilitation loads without excessive loads, within physiological limits.

Thirdly, the increased diagnostic accuracy using ultrasound diagnostics reduced common clinical errors. During the study, the initial clinical diagnoses were clarified or supplemented in 85% of patients, confirming the informativeness of ultrasound. In particular, early detection of synovitis, hemarthrosis, bursitis, and meniscal cysts significantly influenced the selection of the right rehabilitation strategy. Overall, the results of the study show that an individualized rehabilitation approach based on ultrasound not only accelerates the regression of injury complications, but also significantly improves the functional recovery of patients. This confirms that the systematic use of UTT monitoring in clinical departments dealing with knee joint injuries is one of the most optimal directions for increasing the effectiveness of rehabilitation.

Integrating ultrasound diagnostics into the rehabilitation process for injuries of the internal structures of the knee joint has demonstrated significant economic advantages, in addition to clinical effectiveness. Dynamic monitoring based on ultrasound helps to reduce treatment costs by early detection of severe consequences of the injury, timely elimination of complications, and precise management of rehabilitation stages.

First, due to the low cost of ultrasound compared to MRI and other complex instrumental diagnostic methods, the cost of diagnostics per patient has been significantly reduced. Since repeated ultrasound control during the rehabilitation process prevents the aggravation of complications, the costs associated with additional medical interventions, the need for surgery, or an extension of the treatment period have decreased.



Second, an optimized rehabilitation program based on ultrasound allows patients to shorten the recovery period by an average of 20–25%, allowing for a faster recovery of working capacity. This ensures a decrease in days of disability, prevention of production losses, and an early return of patients to economic activity.

Thirdly, as a result of early detection of complications and an individual approach, the consumption of drugs, the number of additional physiotherapeutic procedures and the number of outpatient visits decreased. All this creates economic savings for both the healthcare system and the patient himself.

Also, the widespread introduction of ultrasound examination will increase the overall efficiency of rehabilitation departments, allowing to regulate patient flow, reduce overload and effectively use available resources. This will optimize the economic load of the medical institution.

In general, the results of the study show that the rehabilitation model based on ultrasound diagnostics can not only improve clinical outcomes, but also provide significant economic efficiency for the healthcare system and patients. This approach has practical significance as an innovative, economical and highly effective medical technology in the treatment of knee joint injuries.

Conclusion. The results of the study showed that the individual rehabilitation approach based on ultrasound diagnostics in injuries of the internal structures of the knee joint has high clinical and functional effectiveness. The ability to detect and assess pathological changes inside the joint in real time using dynamic UTT monitoring created conditions for accurate and step-by-step management of the rehabilitation process.

Ultrasound-based control made it possible to adapt the rehabilitation program to the individual condition of the patient, correctly distribute the load, and early identify complications. As a result, regression of inflammatory processes, reduction of pain syndrome, restoration of joint mobility, and improvement of the general functional state were observed in patients.

This approach also increased the accuracy of diagnosis, reduced clinical errors, and served to shorten the rehabilitation period. The safety, repeatability, and cost-effectiveness of ultrasound make it a viable method for widespread use in the practical healthcare system.

In general, the introduction of an individual rehabilitation algorithm based on ultrasound diagnostics into clinical practice is of great importance in improving the quality of treatment for knee injuries, accelerating the recovery process, and reducing the risk of re-injury.

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