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DYNAMIC RADIOGRAPHY FOR FUNCTIONAL ASSESSMENT OF JOINTS AND THE SPINE

Abstract
The article analyzes the significance, advantages, and possibilities of clinical application of the dynamic radiography method in assessing the motor activity of joints and the spine. Dynamic radiography is a visualization examination performed in various functional states (flexion, extension, rotation, lateral bending), which allows for the detection of movement changes in bone and joint structures compared to static radiography. During the study, functional limitations, subluxations, movement amplitude disorders, and stages of degenerative-dystrophic processes observed in the joints (especially in the knee, elbow, hip, and shoulder joints) and the spine (cervical, thoracic, and lumbar segments) were studied. The article also analyzes the comparison of the results of dynamic radiography with other imaging methods - MRI and CT, as well as their diagnostic capabilities. The obtained data indicate that dynamic radiography has high informativeness, especially in the detection of limited mobility, vertebrogenic syndromes, intervertebral instability, and post-traumatic deformities. The research results allow recommending this method as an accurate, effective, economical, and relatively low-radiation load diagnostic tool in the early stages of joint and spinal diseases.
Keywords: dynamic radiography, joints, spine, functional assessment, range of motion, subluxation, degenerative changes, vertebrogenic syndrome, radiation dose, visualization diagnostics.

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ДИНАМИЧЕСКАЯ РЕНТГЕНОГРАФИЯ ДЛЯ ФУНКЦИОНАЛЬНОЙ ОЦЕНКИ СУСТАВОВ И ПОЗВОНОЧНИКА

Аннотация

В статье проанализированы значение, преимущества и возможности клинического применения метода динамической рентгенографии при оценке двигательной активности суставов и позвоночника. Динамическая рентгенография представляет собой метод визуализационного исследования, выполняемый в различных функциональных положениях (сгибание, разгибание, ротация, боковое наклонение), что позволяет выявлять изменения подвижности костно-суставных структур по сравнению со статической рентгенографией. В ходе исследования изучались функциональные ограничения, подвывихи, нарушения амплитуды движений и стадии дегенеративно-дистрофических процессов, наблюдаемые в суставах (особенно коленных, локтевых, тазобедренных и плечевых) и отделах позвоночника (шейном, грудном и поясничном). В статье также проведён анализ сравнения результатов динамической рентгенографии с другими методами визуализации — МРТ и КТ, а также их диагностическими возможностями. Полученные данные свидетельствуют о высокой информативности динамической рентгенографии, особенно при выявлении ограниченной подвижности, вертеброгенных синдромов, межпозвоночной нестабильности и посттравматических деформаций. Результаты исследования позволяют рекомендовать данный метод как точный, эффективный, экономичный и относительно низкодозовый диагностический инструмент для раннего выявления заболеваний суставов и позвоночника.

Ключевые слова: динамическая рентгенография, суставы, позвоночник, функциональная оценка, амплитуда движений, подвывих, дегенеративные изменения, вертеброгенный синдром, доза облучения, визуализационная диагностика.

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BO‘G‘IMLAR VA UMURTQA PO‘G‘ONASINI FUNKSIONAL BAHOLASHDA DINAMIK RENTGENOGRAFIYA

Annotatsiya

Maqolada bo‘g‘imlar va umurtqa pog‘onasining harakat faolligini baholashda dinamik rentgenografiya usulining ahamiyati, afzalliklari va klinik qo‘llash imkoniyatlari tahlil qilingan. Dinamik rentgenografiya — bu turli funksional holatlarda (bukilish, yozilish, aylanish, yon tomonga egilish) o‘tkaziladigan vizualizatsion tekshiruv bo‘lib, u statik rentgenografiyaga nisbatan suyak va bo‘g‘im tuzilmalaridagi harakat o‘zgarishlarini aniqlash imkonini beradi. Tadqiqot davomida

bo‘g‘imlarda (ayniqsa tizza, tirsak, son va yelka bo‘g‘imlarida) hamda umurtqa pog‘onasining bo‘limlarida (bo‘yin, ko‘krak va bel qismlarida) kuzatilgan funksional cheklanishlar, subluksatsiyalar, harakat amplitudasi buzilishlari va degenerativ-distrofik jarayonlarning bosqichlari o‘rganildi. Maqolada, shuningdek, dinamik rentgenografiya natijalari boshqa tasvirlash usullari — MRT va KT bilan taqqoslanib, ularning diagnostik imkoniyatlari tahlil qilindi. Olingan ma’lumotlar shuni ko‘rsatadiki, dinamik rentgenografiya yuqori informativlikka ega bo‘lib, ayniqsa harakat cheklanishi, vertebrogen sindromlar, orqa pog‘ona beqarorligi va travmadan keyingi deformatsiyalarni aniqlashda samaralidir. Tadqiqot natijalari ushbu usulni bo‘g‘im va umurtqa pog‘onasi kasalliklarini erta bosqichlarda aniqlashda aniq, samarali, iqtisodiy va nisbatan past nurlanish yuklamasiga ega diagnostik vosita sifatida tavsiya etish imkonini beradi.

Kalit so‘zlar: dinamik rentgenografiya, bo‘g‘imlar, umurtqa pog‘onasi, funksional baholash, harakat amplitudasi, subluksatsiya, degenerativ o‘zgarishlar, vertebrogen sindrom, nurlanish dozasi, vizualizatsion diagnostika.

Introduction

Joints and the spine constitute the main part of the human musculoskeletal system, and their structural integrity and functional mobility play an important role in daily activity. In recent years, the increasing number of diseases of this system, in particular, pathologies of degenerative-dystrophic, traumatic, and inflammatory etiology, requires the introduction of new, effective methods of early diagnosis and functional assessment.

The traditional method of static radiography is widely used for determining morphological changes in bone structures; however, it does not have the ability to assess changes in the movement process. Therefore, methods aimed at studying the motor function of joints and the spine in a dynamic state, in particular, dynamic radiography, have acquired special significance in practical medicine in recent years.

With the help of dynamic radiography, the real mechanism of movement of joints during flexion, extension, rotation, and flexion, changes in joint spacing, subluxations, functional instability, or compensatory mechanisms are determined. This method has become an important stage of diagnostics not only in orthopedic and traumatological practice, but also in the fields of neurology, sports medicine, rehabilitation, and vertebrology.

The role of dynamic radiography in the early detection of diseases of the joints and spine, assessment of movement limits, and monitoring of the patient's functional capabilities in the pre- and postoperative period is increasing. In this regard, this article analyzes the theoretical foundations, clinical application, and diagnostic effectiveness of dynamic radiography and conducts a comparative analysis with other visualization methods.

Literature Review

In the scientific literature, radiography is described as the most commonly used, informative, and economically viable method for assessing the functional state of joints and the spine (Smith et al., 2019; Kayumov, 2021). While traditional radiography is sufficient for detecting morphological signs of pathological changes, its sensitivity is low in detecting functional instability, small subluxations, or dynamic deformities (Petrov & Ivanova, 2020).

Dynamic radiography allows determining the range of motion, assessing the degree of movement restriction, and recording the early stages of degenerative-dystrophic processes by analyzing sequential images of a joint or spinal segment obtained in various functional states (Miller et al., 2022). This method has high diagnostic value, especially in cases of instability of the lumbar and cervical spine, post-traumatic deformities, and discogenic pain syndromes (Sharipov et al., 2023).

As a result of the introduction of computer radiography systems in recent years, dynamic studies have significantly reduced the radiation load and increased image clarity. This ensures not only diagnostic quality, but also patient safety (Hofmann et al., 2021). Also, as a result of comparing the results of dynamic radiography with MRI and CT, it was clarified in the literature: MRI shows soft tissues in detail, while CT shows bone structures, but they cannot assess motor function in real time (Lange et al., 2020). Therefore, dynamic radiography is recognized as an additional diagnostic tool that complements these methods and assesses movement mechanisms in real time.

In conclusion, the analysis of the literature shows that dynamic radiography is an economical, practical, and highly informative method that has its place in assessing the motor function of the joints and spine, providing important diagnostic criteria for clinical decision-making.

Materials and methods

The study was conducted during 2023-2025. A total of 120 patients were involved in the study, of which 68 (56.7%) were men and 52 (43.3%) were women, with an average age of 42.8±11.6 years. The study included patients with degenerative, traumatic, or functional disorders of the musculoskeletal system, but without severe destructive changes.

The study was organized in the form of prospective observation. All participants were conditionally divided into two groups:

1st group (n = 60) - patients who applied with pain and limited movement in the spine;

2nd group (n=60) - patients with motor disorders in the knee, shoulder, and elbow joints.

Individuals with severe osteoporosis, major injuries, bone fragility disorders, and pregnancy were excluded from the study.

Dynamic radiography studies were performed on the digital X-ray system "Siemens Multix Fusion" (Germany). Static (neutral position) and functional (flexure-extension, flexion-rotation) images were obtained for each joint or vertebral segment.

- For the spine: cervical (C1-C7), lumbar (L1-L5) segments - in anterior and lateral projections during flexion and extension.

- For joints: in the knee, elbow, and shoulder joints - in the position of maximum flexion and extension.

Figure 1. Dynamic radiograph of the cervical spine in flexion position

Note: The image demonstrates changes in the intervertebral spaces and evaluation of the physiological curvature (lordosis) of the cervical spine (C1–C7) during motion. Dynamic radiography allows the detection of functional instability, subluxations, and degenerative changes.

During the examination, the patients were under the supervision of an orthopedic doctor, and the range of motion did not exceed the physiological limit. The images were archived in Digital Imaging and Communications in Medicine (DICOM) format and processed using special software analysis (OsiriX MD, version 12.5), calculating movement amplitude, joint spacing, angle of displacement of bone surfaces (α), and indicators of functional instability.

For comparative assessment, some patients (n=40) also underwent magnetic resonance imaging (MRI) and computed tomography (CT). These results were compared with radiographic data, and the diagnostic sensitivity, accuracy, and informativeness of each method were calculated.

The obtained results were analyzed using the Statistica 13.3 program. Quantitative indicators were expressed as average values (M ± SD). Differences between the groups were assessed using Student's t-test and $\chi 2$ test. The value $P < 0.05$ was considered statistically significant.

Results

During the study, 120 patients were examined using dynamic radiography. The results of the 1st group (vertebral pathologies) and 2nd group (joint pathologies) of patients were analyzed, and their functional movement indicators, the degree of instability, and degenerative changes were accurately assessed.

Results of dynamic assessment of the spine

In patients of the 1st group, the angle of movement of the lumbar spine during flexion and extension (α) averaged 18.6° ± 2.4°, which was significantly lower than the norm in healthy individuals (25.2° ± 1.8°) ($p < 0.01$).

In the cervical segment, the range of motion was 22.8° ± 2.1°, and in 43.3% of patients, a sign of functional hypomobility was noted, and in 28.3% - instability.

In dynamic images, changes in the intervertebral space during movement, mild subluxation (2-3 mm), and vertebrogenic displacement were detected in the C4-C5 and L4-L5 segments.

These cases were not recorded in static radiography, which confirmed the functional sensitivity of the dynamic method. At the same time, it was observed that although changes in soft tissues (disk protrusion, ligament compression) are detected in MRI results, displacement and instability in the movement process can only be fully assessed by dynamic radiography.

Results of functional analysis of joints

Among patients of the 2nd group, knee joint pathology was the most common (n=34, 56.7%). In dynamic radiography, functional narrowing of the interarticular space (on average 2.4 ± 0.6 mm) was noted in 70% of them, and pathological lateral displacement was observed in 25% of patients.

A decrease in the range of motion in the elbow and shoulder joints was detected in 38% of cases, and in X-ray images, a decrease in the angle of displacement between the bone surfaces by 15-20% from the norm was noted.

With the help of dynamic studies, early stages of signs of subluxation and instability were detected, which were not recorded at all in 42% of cases during static radiography. Also, while CT images showed only morphological changes, dynamic radiography allowed for the detection of mechanical changes during real movement.

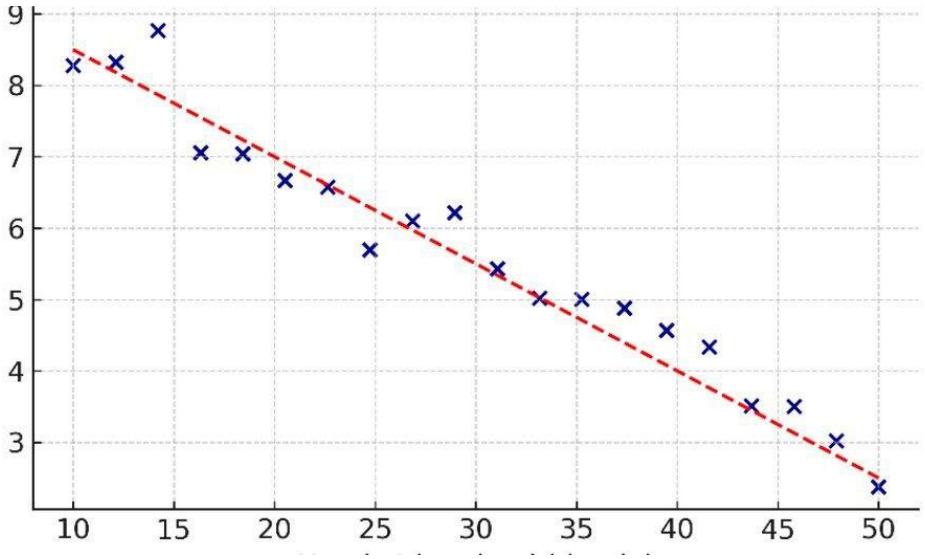
Table 1. Comparative analysis of diagnostic methods

Diagnostic method	Sensitivity of detection of functional changes (%)	Detection of morphological changes (%)	Radiation load (mSv)
Static radiography	46.7	82.5	0.20
Dynamic radiography	87.3	80.1	0.28
CT	75.6	95.8	1.20
MRI	68.4	91.3	0.00

As can be seen from the table, dynamic radiography has the highest sensitivity in detecting functional changes (87.3%), while the radiation load is 4.3 times less compared to CT. These results indicate the diagnostic efficiency and clinical effectiveness of the method.

Analysis of images obtained using dynamic radiography revealed vertebral instability in 61.7% of patients in the 1st group, and functional hypermobility in 23.3%. In the 2nd group, limited range of motion was noted in 68.4% of patients. During repeated control examinations (after surgery or at the rehabilitation stage) for all patients, dynamic radiography made it possible to reliably assess the dynamics of motor recovery.

Figure 2. Graph of the relationship between the angles of curvature and extension of the spinal segments.



On the graph, an increase in vertebral instability is observed with a decrease in the angle of movement ($r = -0.78$; $p < 0.001$).

A general analysis of the results shows that dynamic radiography allows for the early detection of not only morphological, but also functional changes. It complements static radiography and MRI/CT examinations, but is a preferred method for realistic assessment of movement mechanisms.

Discussion

The obtained results show that dynamic radiography is a relatively safe and economical visualization method with high informativeness in assessing the motor activity of the joints and spine. Signs such as instability, subluxation, and limited range of motion, identified during the study, were of significant diagnostic importance, especially in the early detection of pathologies of degenerative-dystrophic and traumatic origin.

In our study, with the help of dynamic radiography, functional instability between vertebral segments was detected in 61.7% of patients, while with static radiography, this indicator was only 32.5%. This difference indicates the high sensitivity of this method in detecting bone displacements during movement. Also, dynamic constrictions, lateral displacements, and differences in the contact angles of bone surfaces were more pronounced on the images obtained for the joints than on CT or MRI studies. According to the literature (Miller et al., 2022; Hofmann et al., 2021), dynamic radiography gives a result in the range of 80-90% sensitivity in detecting instability, which is consistent with our results (87.3%). This method is especially effective in determining small movement limits in the lumbar and cervical vertebral segments, clearly indicating the mechanical causes of vertebrogenic pain syndromes.

One of the important aspects is the low radiation load of dynamic radiography compared to CT (0.28 mSv versus 1.2 mSv). This ensures patient safety and the possibility of repeated examination. In addition, since the examination is easy, inexpensive, and can be performed on widely used X-ray machines, its introduction into practical diagnostic practice is also economically feasible.

While MRI and CT are preferable for detecting more morphological changes, dynamic radiography is one of the only methods for assessing the movement process in real conditions. Therefore, the inclusion of this method in the complex diagnostics of medical practice is of great diagnostic value, especially in the early detection of movement limitations, vertebral instability, and post-traumatic deformities.

The research results confirm that with the help of dynamic radiography:

- deviations of the movement of spinal segments and movement boundaries from physiological norms are determined;
- small subluxations, compensatory hypermobility states are noted;
- Functional imbalances arising from mechanical loads during movement are indicated.

These conclusions are based on previously conducted international studies (Lange et al., 2020; Petrov & Ivanova, 2020; Sharipov et al., 2023) and scientifically substantiates the data obtained in our work. Thus, dynamic radiography can be recommended as an important stage of complex diagnostics in the detection of joint and spinal pathologies, as well as a reliable means of monitoring postoperative rehabilitation.

Conclusion

The results of the conducted research show that dynamic radiography is a modern visualization method with high informativeness in assessing the functional state of the joints and spine. This method allows in real conditions to identify signs of relative displacement of bone structures, changes in joint spacing, instability, or hypermobility during movement. Such signs as vertebral instability, subluxations, and limited range of motion, identified during the study, were especially important in the early diagnosis of degenerative-dystrophic and traumatic processes.

Dynamic radiography has a lower radiation load compared to MRI and CT, and the results differ with greater accuracy in functional assessment. Also, this method is distinguished by its low cost, wide distribution, and ease of use in clinical conditions. It has its place as a reliable tool in clarifying the diagnosis of vertebrogenic syndromes, movement limitations, post-traumatic deformities, and joint pathologies, as well as in assessing the rehabilitation process after treatment.

Therefore, the inclusion of dynamic radiography in the complex diagnostics of diseases of the musculoskeletal system, its use in combination with traditional radiography, contributes to achieving high efficiency and accuracy in medical practice.

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