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COMPREHENSIVE RADIOGRAPHIC ASSESSMENT OF EARLY-STAGE OSTEOARTHRITIS OF THE KNEE JOINT

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Abstract
Osteoarthrosis (OA) is a chronic joint disorder marked by the primary breakdown of articular cartilage, alterations in the subchondral bone structure with the formation of new bony growths called osteophytes, inflammation of the synovial membrane (synovitis), and damage to the surrounding soft tissues.Current understanding suggests that OA develops due to multiple factors, primarily involving an imbalance between the breakdown and repair processes within the cartilage and subchondral bone. This imbalance ultimately causes cartilage deterioration and typical changes in the subchondral bone. Among all degenerative joint conditions, OA represents 12.3%, making it somewhat less prevalent than inflammatory joint diseases, which constitute about 17.7% of cases.

Keywords: Osteoarthrosis, metabolism of cartilage, T2 relaxometry, multiplex assay.

Introduction

Osteoarthrosis (OA) affects between 10% and 20% of the global population, with its prevalence steadily rising over recent decades [1-5]. Approximately one-third of OA cases primarily involve the knee joints [3]. Research from both domestic and international sources [6-8] highlights that early detection of cartilage degeneration is a promising avenue for improving diagnostic and therapeutic strategies for OA.

Modern understanding of OA pathogenesis centers on the concept of auto-inflammation [1, 9]. The disease involves cellular stress and degradation of the extracellular matrix (ECM), with initial molecular-level changes eventually leading to morphological alterations across all joint tissues, which result in anatomical and functional impairments. M. A. Kabalyk and colleagues [9, 10] suggest categorizing OA into different molecular endotypes based on systemic stress responses—namely inflammatory, oxidative, and mixed types—which influence the clinical and structural features of the disease.

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Several studies have reported a strong association between inflammation and the severity of pain and musculoskeletal functional impairment [11]. According to S. Vilá [12], the role of the inflammatory mediator IL-1β in regulating apoptosis and cell proliferation across various molecular OA subtypes is well established.

A key non-collagenous protein in the articular cartilage matrix is COMP (Cartilage Oligomeric Matrix Protein), which is also present in other tissues such as ligaments, tendons, menisci, and the synovial membrane [13]. COMP's primary role is to stabilize the three-dimensional collagen fiber network within connective tissue. Elevated levels of COMP are released from the cartilage matrix in various joint diseases of differing causes and enter the bloodstream. Due to its prolonged circulation time in blood, COMP serves as a useful biomarker for reflecting cartilage metabolism changes in joint pathologies [14, 15].

The purpose of the study. To assess the potential of magnetic resonance imaging techniques, including T2-relaxometry, alongside laboratory analysis of biological markers, for diagnosing hyaline cartilage abnormalities in the early stages of knee osteoarthritis.

Materials and methods. A total of 37 individuals aged 35 to 50 years (9 men and 28 women) were examined. Inclusion criteria for the main group were: 1) complaints of intermittent pain and discomfort in the knee joints during walking and physical activity, 2) a history of symptoms lasting at least two years, and 3) no prior treatment with anti-inflammatory, chondroprotective, metabolic, or physiotherapeutic interventions. The control group included 20 age-matched individuals without any clinical signs of joint disease and who were not taking any medications at the time of the study. Exclusion criteria comprised oncological, cardiovascular, endocrine diseases, systemic connective tissue disorders, immunodeficiency, and severe musculoskeletal injuries. All participants provided voluntary informed consent for a comprehensive clinical, laboratory, and instrumental examination, conducted in accordance with the ethical guidelines outlined in the Helsinki Declaration by the World Medical Association.

Joint pain intensity was measured using a 100 mm visual analog scale. Functional status was evaluated using the Oxford Knee Score (KOSS), which involves a questionnaire of 100 key items addressing various aspects of life affected by knee injury and osteoarthritis. Radiological diagnostic methods included radiography, ultrasound, and magnetic resonance imaging (MRI) of the knee joints. X-rays were taken in a direct view with the knee maximally flexed and a lateral view with the joint flexed up to 15° in a supine position. Ultrasound examination of soft tissues was performed using a Siemens-2000 device (Germany). MRI was conducted on a 1.5T scanner (Hitachi Echelon, Japan), utilizing pulse sequences such as T1, T2, proton density (Pd) with fat suppression, and T2 relaxation mapping with color-coded imaging (T2 Relax Map program).

Results

Pain levels on the visual analog scale among patients in the main group ranged from mild to moderate. The KOSS scores in the control group were between 98% and 100%, while in the main group, they ranged from 70% to 87%. According to the KOSS questionnaire results, patients in

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the main group reported minimal discomfort in daily activities but experienced some functional limitations during more strenuous physical activity.

Instrumental examination revealed that 23 patients in the main group were at OA stages 0-1, while the remaining 14 patients were at stages 1-2, based on the J. Lawrence and J. Kellgren classification. Ultrasound examination of the knee joints in 11 patients (30%) showed nonspecific findings, such as mild synovitis (synovial membrane thickening and small joint effusion), degenerative changes in the hyaline cartilage and menisci indicated by structural heterogeneity, and moderate inflammation of periarticular tissues, including collateral ligamentitis. Overall, conventional diagnostic methods like radiography and ultrasound demonstrated limited sensitivity in detecting early degenerative changes in the knee joint.

In T2 Relax Map imaging, intact cartilage with normal morphology appeared green, whereas degenerated cartilage appeared in yellow, orange, or red hues. This color mapping clearly delineated areas of cartilage damage, allowing for more precise anatomical localization. Regions with cartilage thinning and chondromalacia, previously identified by standard MRI protocols, showed altered T2 relaxation times, likely reflecting structural disruption of the proteoglycan-collagen matrix.

Laboratory analyses revealed that patients in the main group exhibited elevated levels of cartilage extracellular matrix (ECM) biopolymers in biological fluids, alongside increased markers of inflammatory activity. Elevated serum COMP levels and increased urinary excretion of CTX-II fragments indicated enhanced catabolic activity in ECM structures.

Based on inflammatory marker profiles, the main group was divided into two subgroups: Subgroup 1, showing clear signs of inflammation, and Subgroup 2, with normal inflammatory marker levels. In Subgroup 1, patients exhibited corresponding changes in leukocyte counts, elevated ESR, increased IL-1β levels, and higher concentrations of high-sensitivity CRP. Notably, Subgroup 1 also showed a tendency toward greater accumulation of ECM degradation products in biological samples.

To explore relationships between cartilage metabolism and imaging data in early OA, correlation analyses were performed. A strong positive correlation ($R=0.83$, $p<0.05$) was found between serum COMP concentration and T2-relaxometry values. Additionally, COMP levels showed a moderate negative correlation with hyaline cartilage thickness measured by ultrasound ($R= -0.63$). Similar but slightly weaker correlations were observed between urinary CTX-II excretion and cartilage morphometry by T2-relaxometry and ultrasound ($R=0.79$ and $R= -0.59$, respectively).

Conclusion

In individuals showing early clinical signs of osteoarthritis, an imbalance between anabolic and catabolic processes in the articular hyaline cartilage leads to alterations in the composition and structural integrity of its extracellular matrix. This can be objectively assessed through a comprehensive instrumental and laboratory evaluation, which includes T2 mapping—a non-invasive and highly sensitive technique for detecting morphological changes—as well as measuring COMP levels in biological fluids and CTX-II. Correlation analysis results indicated that disruption of the three-dimensional structure of type II collagen, as revealed by MRI in early

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OA patients, is linked to elevated serum COMP concentrations and increased daily urinary excretion of CTX-II.

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