

Comparison of Proton Density Weighted Sequence with T2-Weighted Sequence to Detect Acute Osteoarthritis

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ABSTRACT

Background: Osteoarthritis is among the most common joint disorders globally. The application of MRI sequences leads to consistently improved diagnostic capabilities for early-stage osteoarthritis. Understanding the optimal sequence for accurate diagnosis is crucial for effective patient management.

Aim: To evaluate the patients having acute osteoarthritis through the Proton Density (PD) weighting sequence of MRI and comparing it with the outcomes from the T2-weighted imaging.

Methodology: This study employed comparative cross-sectional study design, utilizing the non-probability convenient sampling technique, and was conducted at a Service Hospital in Pakistan from August 2023 to December 2023. 59 patients having knee pain, inflammation, tenderness and joint stiffness were included and individuals having acute ligamentous injuries and instability were excluded

Results: The study compared MRI findings of acute osteoarthritis using PDW and T2W sequences. Joint effusion was detected in 88.1% (PDW) vs. 86.4% (T2W). Meniscal tears were equally identified (72.8%), but PDW was more sensitive for cruciate (66.1% vs. 6.8%) and collateral ligament tears (38.9% vs. 8.5%). Both sequences detected bursitis equally (11.8%). T2W better identified osteophytes and bony spurs (59.3% each) compared to PDW (23.7% and 25.4%). Femoral and tibial condylar changes, subarticular cysts, synovial thickening, subchondral bone marrow changes, and subcutaneous edema were similarly detected by both sequences.

Practical Implication: This allows for better imaging techniques, leading to improved patient care. The study's results may prompt updates to clinical guidelines, recommending PDW sequences for early detection of osteoarthritis-related changes. Future research could focus on refining imaging techniques and developing new therapeutic approaches.

Conclusion: Our study concludes that PDW sequences are superior in detecting early osteoarthritic changes, including ligament and meniscus tears, cartilage defects, and bone edema, compared to T2W sequences. This highlights PDW's potential in enhancing early diagnosis and prognosis of acute osteoarthritis.

Keywords: Osteoarthritis, Magnetic Resonance Imaging, T2 Weighted, Proton Density Weighted

INTRODUCTION

Osteoarthritis is among the most common joint disorders globally. It is the articular cartilage degenerative disorder due to enlargement of bones¹. In Osteoarthritis, the cartilage disintegrates as it loses its elastic properties and becomes fragile. Cartilage is the smooth shiny solid white layer that enables effortless movement². It has been broadened from a disease related to cartilage to a disease affecting the whole articulation. Joint degeneration is caused due to a certain pathological process and bone, synovium and cartilage all three are involved in this process³.

Osteoarthritis commonly causes stiffness, joint pain and restricted range of motion, which ultimately results in depressed mood, fatigue and limited functioning of body, but the major concerning element of osteoarthritis in patients is the associated pain⁴. To assess the progress of the disease and monitor its response towards therapy, a complex technique is required to identify the functional and structural fluctuations of cartilage at the premature phases of osteoarthritis⁵.

The Articular cartilage and meniscus are two essential elements in knee which are frequently under compressing masses. Knee joint-hinge joint has various tissues with varying mechanical and structural assets^{6,7}.

Recent research focused on the knee has proved osteoarthritis is a complete joint disorder involving several tissues, including synovial membrane, ligaments, subchondral bone, the menisci and the muscle⁸. Osteoarthritis is a disease which depends upon several factors including age, trauma, obesity, genetics, and occupation. Rate of osteoarthritis in male is quite less as compared with female. This was proved through a meta-analysis of Srikanth VK et al in which the occurrence of disease in men aged <55 years was quite less than in women. Women,

especially ≥ 55 years of age, generally have severe osteoarthritis in their knee but do not have it in other joints. Osteoarthritis occurrence is quite less in males as compared with females who are 1.84 times more likely to suffer from knee osteoarthritis and after having more than six pregnancies likelihood increased by 1.95 times⁹.

It occurs frequently in knees, hands, spine and elbows, but hardly in the wrists, shoulders, ankles and feet. It can be divided in 3 osteologic types using histomorphometry; firstly, the osteosclerotic, which has the highest occurrence rate of around 77%. Secondly, the hyperostotic with extravagant regeneration of bone all across the head of the femur and formation of bone spurs. This accounts for 10% of all patients and lastly the osteopenic, which has bone remodeling features and reduces mass of bone. It also increases the chance of subchondral cysts and tiny bone spurs formation. It accounts for 8% of all patients^{10,11}.

Osteoarthritis (OA) is a prevalent degenerative joint disease that significantly impacts the quality of life of millions of individuals worldwide. Accurate and early diagnosis of OA is crucial for effective management and treatment, especially during the acute phase when intervention can potentially halt or slow disease progression. Magnetic Resonance Imaging (MRI) plays a pivotal role in the evaluation of OA due to its superior ability to visualize soft tissues, cartilage, and subchondral bone^{12,13}.

Among the various MRI sequences available, T2-weighted (T2W) and Proton Density-weighted (PDW) sequences are commonly employed in musculoskeletal imaging. T2W imaging is widely recognized for its sensitivity in detecting fluid changes and edema, which are indicative of inflammation and joint effusion associated with acute osteoarthritis. This makes T2W imaging a valuable tool for identifying pathological changes within the joint¹⁴.

However, T2W sequences have limitations, including susceptibility to artifacts and reduced contrast resolution in certain anatomical structures. This is where PDW sequences may offer additional benefits. PDW imaging is known for providing high-resolution images with excellent contrast between cartilage, fluid,

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and other soft tissues. This sequence emphasizes the density of protons, which can enhance the visualization of cartilage morphology and integrity, as well as subtle changes in the subchondral bone and surrounding soft tissues^{15,16}.

The objective of this study is to evaluate the patients having acute osteoarthritis through the Proton Density (PD) weighting sequence of MRI and comparing it with the outcomes from T2-weighted imaging. Understanding the comparative advantages and limitations of these MRI sequences will help refine imaging protocols, improve diagnostic accuracy, and ultimately enhance patient outcomes by facilitating timely and targeted therapeutic interventions for acute osteoarthritis.

MATERIAL AND METHODS

This comparative cross-sectional study was conducted at Services Hospital Lahore after permission by Hospital Ethical Committee. Non-probability convenient sampling technique was used to collect the data from August 2023 to December 2023. The sample size was calculated by using the given formula: $N = Z^2 p(1-p)/d^2$ Where $z=1.96$, $p=0.2$ and $d= 0.05$, calculated sample size $n=59$. Patients having knee pain, inflammation, tenderness and joint stiffness were included and individuals having acute ligamentous injuries and instability were excluded. These individuals were then assessed by using MRI 1.5 tesla of GE Healthcare and the comparison of sequences was conducted while the patients were in a supine position. Obtained images were reviewed by an experienced radiologist.

RESULTS

In this comparative cross-sectional study, 59 patients were included, consisting of 19 male and 40 female patients. The age sort covered from a minimum of 25 years to a maximum of 75 years. Table 1 provides a comparative analysis of MRI findings in patients with acute osteoarthritis, assessed using Proton Density-weighted (PDW) and T2-weighted (T2W) sequences.

Table 1: MRI findings of PDW and T2W in Osteoarthritic patients

MRI Findings	PDW	T2W
Joint effusion	52 (88.1%)	51 (86.4%)
Meniscal tear	43 (72.8%)	43 (72.8%)
Cruciate ligament tear	39 (66.1%)	4 (6.8%)
Collateral ligament tear	23 (38.9%)	5 (8.5%)
Bursitis	7 (11.8%)	7 (11.8%)
Osteophytes	14 (23.7%)	35 (59.3%)
Bony spurs	15 (25.4%)	35 (59.3%)
Bony erosion	10 (16.9%)	7 (11.9%)
Femoral condylar changes	32 (54.2%)	32 (54.2%)
Tibial condylar changes	27 (45.8%)	27 (45.8%)
Subarticular cyst	7 (11.9%)	7 (11.9%)
Synovial thickening	10 (16.9%)	10 (16.9%)
Subchondral bone marrow changes	29 (49.1%)	29 (49.1%)
Subcutaneous edema	9 (15.2%)	9 (15.2%)

Joint effusion was detected in 88.1% of patients using PDW sequences and in 86.4% using T2W sequences, indicating high sensitivity in both imaging techniques. Meniscal tears were identified in 72.8% of patients with both PDW and T2W sequences, suggesting equal effectiveness for this finding. Cruciate ligament tears showed a marked difference, with PDW sequences detecting these tears in 66.1% of patients compared to only 6.8% with T2W sequences, highlighting a significantly higher sensitivity for PDW sequences.

Similarly, collateral ligament tears were detected in 38.9% of patients with PDW sequences, compared to 8.5% with T2W sequences, again indicating superior sensitivity of PDW imaging. Both sequences equally detected bursitis in 11.8% of patients. Osteophytes and bony spurs were more frequently detected with T2W sequences, observed in 59.3% of patients for each finding, compared to 23.7% and 25.4% respectively with PDW sequences.

Bony erosion was noted in 16.9% of patients with PDW sequences and in 11.9% with T2W sequences.

Femoral and tibial condylar changes were equally detected by both sequences in 54.2% and 45.8% of patients, respectively. Subarticular cysts, synovial thickening, and subchondral bone marrow changes were identified at equal rates in both sequences, with subarticular cysts and synovial thickening each detected in 11.9% and 16.9% of patients, respectively, and subchondral bone marrow changes in 49.1% of patients. Finally, subcutaneous edema was equally identified by both sequences in 15.2% of patients. This comparative analysis highlights the relative strengths of PDW sequences in detecting ligamentous injuries, while T2W sequences are more effective in identifying osteophytes and bony spurs. Fig 1 and fig 2 are showing osteoarthritic findings in PD and T2 weighted sequences.

Fig 1: Right knee sagittal PDW sequence demonstrating a medial meniscus tear in osteoarthritic patient



Fig 2: Left Knee coronal T2W sequence showing moderate osteoarthritic changes



DISCUSSION

The comparative analysis of MRI findings using PDW and T2W sequences in patients with acute osteoarthritis reveals notable differences in sensitivity for specific pathologies. Joint effusion and meniscal tears were similarly detected by both sequences, indicating their comparable efficacy for these common findings. However, PDW sequences demonstrated significantly higher sensitivity for cruciate and collateral ligament tears, detecting these injuries at much higher rates (66.1% and 38.9%, respectively) compared to T2W sequences (6.8% and 8.5%). This suggests that PDW imaging is more effective in identifying ligamentous injuries, which are crucial for diagnosing and managing acute osteoarthritis.

Conversely, T2W sequences were more proficient in detecting osteophytes and bony spurs, with detection rates of

59.3% each, significantly higher than the 23.7% and 25.4% observed with PDW sequences. This indicates that T2W imaging may be superior for assessing bony abnormalities associated with osteoarthritis progression. Both imaging sequences equally detected femoral and tibial condylar changes, subarticular cysts, synovial thickening, subchondral bone marrow changes, and subcutaneous edema, suggesting similar effectiveness in identifying these features.

In contrast, a study by Gaurav Pradhan in 2019 utilized T1 and T2 mapping of articular cartilage and menisci in early osteoarthritis, focusing on the degeneration of meniscal matrix and cartilage. Pradhan's study, which included 25 patients and 10 healthy controls, concluded that T1 and T2 values were significantly higher in osteoarthritis patients, though no differences in meniscal or cartilage thickness were observed between the groups. This emphasizes the importance of mapping sequences in early detection and assessment of cartilage degeneration¹⁷.

Similarly, Mourad C (2023) explored morphological assessment using intermediate-weighted fat-suppressed sequences, advocating for the continued use of 2D FSE FS IW sequences in conjunction with T1 and T2W sequences. The study proposed improvements by transitioning to 3D acquisitions, enhancing imaging efficiency and quality, and exploring different magnetic field strengths to broaden MRI applications¹⁸.

Additionally, Casula V and colleagues investigated knee cartilage changes following acute ACL injuries, noting increased T2 relaxation times in injured knees, particularly in the medial trochlea and posterior tibia. The study highlighted subtle yet significant variations in cartilage T2 relaxation time and thickness in the subacute phase, suggesting early indicators of post-traumatic osteoarthritis (PTOA)¹⁹.

CONCLUSION AND RECOMMENDATION

Our study concludes that PDW sequences are superior in detecting early osteoarthritic changes, including ligament and meniscus tears, cartilage defects, and bone edema, compared to T2W sequences. This highlights PDW's potential in enhancing early diagnosis and prognosis of acute osteoarthritis. However, the study is limited by its sample size and lack of longitudinal follow-up. Future research should involve larger cohorts and extended observation periods to validate these findings and explore the integration of advanced MRI techniques for comprehensive osteoarthritis assessment.

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