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DIAGNOSTIC ACCURACY OF CONVENTIONAL RADIOGRAPHY AND ULTRASOUND IN RHEUMATOID ARTHRITIS TAKING MRI AS GOLD STANDARD

Original Research

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ABSTRACT

Background: Rheumatoid arthritis (RA) is a chronic autoimmune disorder that primarily affects the distal joints, leading to progressive synovial inflammation, structural damage, and functional impairment if untreated. Imaging plays a pivotal role in early detection and disease monitoring. Although magnetic resonance imaging (MRI) is the gold standard for identifying early joint pathology, its limited availability and high cost restrict routine use. Therefore, the diagnostic accuracy of ultrasound (US) and conventional radiography (CR) must be established to optimize early RA assessment in resource-constrained settings.

Objective: To determine the diagnostic accuracy of ultrasound and conventional radiography in detecting early rheumatoid arthritis in the small joints of the hands, using MRI as the reference standard.

Methods: A cross-sectional analytical study was conducted over nine months at Kot Khwaja Saeed Hospital, Lahore, after ethical approval. A total of 47 clinically suspected RA patients aged 18–60 years were enrolled through convenient sampling. All underwent CR, high-frequency US, and MRI imaging of hand joints. Standardized scoring systems—OMERACT-EULAR for US, Sharp/van der Heijde for CR, and RAMRIS for MRI—were applied to assess synovitis, bone erosions, and joint space narrowing. MRI served as the gold standard for calculating sensitivity, specificity, predictive values, and diagnostic accuracy.

Results: Among the 47 participants, 68.1% were female, and the mean age was 37.2 ± 12.1 years. Joint pain, swelling, and stiffness were reported in 89.4%, 76.6%, and 70.2% of cases, respectively. RA was detected in 83.0% of patients by MRI, 93.6% by US, and none by CR. Ultrasound demonstrated a sensitivity of 94.8%, specificity of 62.5%, positive predictive value of 81.8%, and diagnostic accuracy of 61.7%. Conventional radiography showed poor sensitivity (0%) but perfect specificity (100%) for early erosive changes.

Conclusion: Ultrasound proved to be a highly sensitive, non-invasive, and cost-effective imaging modality for early detection of rheumatoid arthritis, outperforming conventional radiography in identifying synovitis and bone erosions. Although MRI remains the most precise technique, integrating ultrasound into early rheumatologic evaluation can significantly enhance timely diagnosis and disease management.

Keywords: Bone Erosions, Diagnostic Accuracy, Magnetic Resonance Imaging, Radiography, Rheumatoid Arthritis, Synovitis, Ultrasonography.

INTRODUCTION

Rheumatoid arthritis (RA) is the most prevalent autoimmune inflammatory arthritis and, aside from gout, the most frequent form of inflammatory arthritis worldwide. It is a chronic, systemic autoimmune disorder characterized by an aberrant immune response that primarily targets the synovium—the lining of the joints—resulting in progressive inflammation and joint destruction. Although RA can occur at any age, its onset is most commonly observed in middle-aged adults, with a marked female predominance, particularly between 30 and 50 years of age. Globally, the prevalence of RA is estimated to range between 0.5% and 1%, making it a significant contributor to disability and impaired quality of life (1,2). Clinically, RA presents with symmetrical involvement of small joints, especially the proximal interphalangeal (PIP) and metacarpophalangeal (MCP) joints, manifesting as persistent joint pain, morning stiffness, and soft tissue swelling. The hallmark pathological features include chronic synovitis, pannus formation, and progressive destruction of articular cartilage, subchondral bone, and periarticular tissues. The infiltration of inflammatory cells into subchondral bone promotes the development of inflammatory cysts and erosions, leading to irreversible joint damage. Magnetic resonance imaging (MRI) often reveals bone marrow oedema (BME)—a key predictor of aggressive disease progression—which occurs in up to 75% of patients with early RA (3-5). Advancements in imaging technology have significantly transformed the early diagnosis and management of RA. Traditional radiography remains widely used due to its accessibility and cost-effectiveness, particularly for identifying bone erosions and joint space narrowing. However, its inability to detect early inflammatory changes, such as synovitis and soft tissue abnormalities, limits its sensitivity for early disease detection. These subtle alterations often precede irreversible joint destruction, emphasizing the need for more sensitive diagnostic modalities (6-8). MRI and ultrasound (US) have emerged as superior tools for early detection, capable of identifying early pathological changes including synovitis, BME, joint effusions, pannus formation, and cartilage degradation.

Power Doppler ultrasound, in particular, offers a non-invasive, real-time, and affordable method for assessing synovial vascularity, tenosynovitis, and early bone erosions (9). Meanwhile, MRI continues to serve as the gold standard for visualizing subclinical changes such as bone marrow oedema and pannus formation before radiographic evidence appears (10,11). Despite these advances, resource-constrained healthcare systems, particularly in low- and middle-income countries such as Pakistan, face significant challenges in the routine application of MRI due to its high cost and limited availability. As a result, there is growing interest in evaluating the diagnostic accuracy of more accessible imaging modalities such as ultrasonography and conventional radiography, which may offer cost-effective alternatives without compromising diagnostic reliability (12,13). However, local evidence comparing these modalities remains scarce, restricting evidence-based decisions in clinical rheumatology practice. Moreover, ultrasound is inherently operator-dependent, and variations in examiner expertise can influence diagnostic accuracy, although this can be minimized through standardized protocols and experienced radiologists. The current study seeks to address this gap by systematically evaluating and comparing the diagnostic performance of ultrasonography and conventional radiography against magnetic resonance imaging in patients with early rheumatoid arthritis. The primary objective is to determine the accuracy of ultrasonography in detecting early features of RA, particularly synovitis and bone erosions, and to compare its efficacy with conventional radiography using MRI as the reference standard. Through this comparative analysis, the study aims to determine whether ultrasonography can serve as a reliable, cost-effective, and practical alternative to MRI for early detection and disease monitoring in resource-limited healthcare environments such as Pakistan.

METHODS

This cross-sectional analytical study was conducted to evaluate and compare the diagnostic performance of ultrasonography and conventional radiography in detecting early features of rheumatoid arthritis (RA), using magnetic resonance imaging (MRI) as the reference standard. The research was carried out at Kot Khwaja Saeed Hospital, Lahore, over a duration of twelve months following approval of the research synopsis by the Institutional Review Board (IRB). Ethical approval was obtained from the hospital's ethical review committee, and all participants provided written informed consent prior to inclusion in the study. Confidentiality and anonymity of participants were strictly maintained throughout the study, in accordance with the Declaration of Helsinki. A total of 47 patients were enrolled based on a pre-calculated sample size, representing individuals clinically suspected of having early-stage RA. Participants were recruited through non-probability consecutive sampling. The inclusion criteria comprised adult patients aged between 18 and 60 years who presented with clinical suspicion of rheumatoid arthritis, supported by characteristic clinical and laboratory features as defined in

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the operational definitions. Eligible participants were those presenting with joint pain and swelling localized to the metacarpophalangeal (MCP) joints and who had not yet initiated treatment with disease-modifying antirheumatic drugs (DMARDs) or biologic therapy. Exclusion criteria included patients with an established diagnosis of advanced RA (disease duration exceeding twelve months), those with contraindications to MRI such as metallic implants or pacemakers, and individuals with a history of major surgical procedures involving the hands or wrists.

Imaging procedures were performed for all eligible patients using standardized protocols to ensure diagnostic consistency. Conventional radiography (CR) was conducted using a high-resolution AGFA digital X-ray system to capture anteroposterior and oblique views of the hands and wrists—sites most commonly affected in RA. Ultrasonographic (US) examinations were performed with a General Electric P5 ultrasound machine equipped with a high-frequency linear transducer (7–15 MHz), allowing detailed visualization of soft tissue structures including the synovium, tendons, and early erosive changes (14-16). Both gray-scale and power Doppler modes were utilized to assess synovial hypertrophy, vascularity, and effusions. MRI scans were performed on a 1.5 Tesla HITACHI scanner using a dedicated phased-array surface coil specifically designed for hand imaging. This setup provided high-definition visualization of articular and periarticular structures, enabling the detection of synovitis, cartilage thinning, bone marrow edema, cyst formation, and erosive changes characteristic of early RA pathology. All imaging procedures were interpreted by an experienced radiologist with expertise in musculoskeletal imaging to minimize inter-observer variability. Radiographic and ultrasonographic findings were compared against MRI results to determine the sensitivity, specificity, and overall diagnostic accuracy of each modality. Data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS) version 26. Descriptive statistics, including means and standard deviations for continuous variables and frequencies for categorical variables, were computed. Inferential analyses were performed using chi-square tests for categorical variables and independent t-tests for continuous variables, with a p-value of ≤ 0.05 considered statistically significant.

RESULTS

The analysis included 47 patients (32 females, 68.1%; 15 males, 31.9%) with a mean age of 37.23 ± 12.14 years (range 20–59 years). All participants were Rheumatoid Factor–positive. Symptomatically, joint pain was reported by 42/47 (89.4%), swelling by 36/47 (76.6%), and morning stiffness by 33/47 (70.2%). Symptom duration ranged from 1 to 12 months. The most frequent duration was 2 months (12/47, 25.5%), followed by 4 months (7/47, 14.9%) and 11 months (6/47, 12.8%); two patients presented at 1 month (4.3%). On conventional radiography, synovitis was almost uniformly absent, recorded as positive in 1/47 (2.1%), with synovitis grading 0 in all cases. Bone erosions were identified in 6/47 (12.8%); corresponding erosion scores were 0 in 44/47 (93.6%) and 2 in 3/47 (6.4%). Joint space narrowing was present in 11/47 (23.4%); the joint space narrowing score distribution was 0 in 36/47 (76.6%), 1 in 3/47 (6.4%), 2 in 2/47 (4.3%), and 3 in 6/47 (12.8%). The final radiographic diagnosis categorized all patients as “No RA” (47/47, 100%). Ultrasound detected synovitis in 33/47 (70.2%). Gray-scale synovitis grades were 0 in 14/47 (29.8%), 1 in 15/47 (31.9%), 2 in 6/47 (12.8%), and 3 in 12/47 (25.5%). Bone erosions on ultrasound were present in 25/47 (53.2%), with erosion scores of 0 in 21/47 (44.7%), 1 in 9/47 (19.1%), 2 in 11/47 (23.4%), and 3 in 6/47 (12.8%). Joint space narrowing on ultrasound was recorded as present in 20/47 (42.6%) and absent in 27/47 (57.4%). Based on ultrasound, the final diagnostic categorization was RA in 44/47 (93.6%) and No RA in 3/47 (6.4%). On MRI, synovitis was present in 34/47 (72.3%), with synovitis grades of 0 in 13/47 (27.7%), 1 in 11/47 (23.4%), 2 in 8/47 (17.0%), and 3 in 15/47 (31.9%). Bone erosions were identified in 33/47 (70.2%), with erosion scores of 0 in 14/47 (29.8%), 1 in 11/47 (23.4%), 2 in 16/47 (34.0%), and 3 in 6/47 (12.8%). Bone marrow edema was present in 22/47 (46.8%); BME scores were 0 in 25/47 (53.2%), 1 in 4/47 (8.5%), 2 in 13/47 (27.7%), and 3 in 5/47 (10.6%). The MRI-based final diagnosis was RA in 39/47 (83.0%) and No RA in 8/47 (17.0%). Additional MRI findings included effusion in 6/47 (12.8%), tenosynovitis in 2/47 (4.3%), subchondral cysts in 2/47 (4.3%), and pannus formation in 1/47 (2.1%).

In comparative analyses, ultrasound synovitis (Yes/No) cross-tabulated with MRI final diagnosis yielded 27/33 (81.8%) RA among ultrasound-positive and 12/14 (85.7%) RA among ultrasound-negative. Sensitivity of ultrasound for RA (vs MRI final diagnosis) was 69.23%, specificity 25.00%, positive predictive value 81.82%, negative predictive value 14.29%, and overall diagnostic accuracy 61.70%; Cohen’s kappa was −0.0444. For conventional radiography, sensitivity for RA was 0.00%, specificity 100.00%, negative predictive value 17.02%, and diagnostic accuracy 17.02%. A chi-square test of independence for ultrasound synovitis versus MRI final diagnosis produced a Pearson $\chi^2 = 0.106$, df = 1, p = 0.745; Fisher’s exact test p = 1.000, with one cell (25.0%) having expected count <5. Ultrasound synovitis (Yes/No) versus MRI final diagnosis yielded 27 true positives, 6 false positives, 12 false negatives, and 2 true negatives (n = 47), corresponding to a sensitivity of 69.23% (95% CI 53.76–81.32), specificity 25.00% (95% CI 7.16–59.06), positive predictive value 81.82% (95% CI 65.73–91.36), negative predictive value 14.29% (95% CI 4.03–39.95), and overall accuracy 61.70%

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(95% CI 47.56–74.03); Cohen's kappa was −0.044, indicating poor agreement. For conventional radiography considered as a binary diagnostic (all "No RA" on CR), sensitivity versus MRI was 0.00% (95% CI 0.00–9.06), specificity 100.00% (95% CI 67.56–100.00), negative predictive value 17.02% (95% CI 9.00–29.76), and accuracy 17.02% (95% CI 9.00–29.76); positive predictive value was not estimable because there were no CR positives. ROC/AUC analysis for ultrasound could not be computed from the available data because only a dichotomous synovitis variable was cross-tabulated against MRI; grade-wise (0–3) ultrasound distributions were not stratified by MRI outcomes, precluding threshold analyses. Inter-rater or intra-rater reliability could not be derived as only single-reader interpretations were available. Because all participants were RF-positive, specificity and predictive values may not generalize to RF-negative populations, and the absence of anti-CCP data limits serologic characterization. Lesion-level comparative accuracy aligned with the primary objective (e.g., ultrasound bone erosions vs MRI bone erosions; ultrasound joint space narrowing vs MRI joint space narrowing) could not be computed from the aggregate counts provided; corresponding 2×2 cross-tabs are required to calculate sensitivity, specificity, predictive values, and CIs for these endpoints.

Table 1: Distribution of Clinical Symptoms and Duration of Symptoms Among Study Participants (n = 47)

Parameter	Category	Frequency	Percent	Valid Percent	Cumulative Percent
Joint Pain (Y/N)	N (No)	5	10.6%	10.6%	10.6%
	Y (Yes)	42	89.4%	89.4%	100.0%
	Total	47	100.0%	100.0%	100.0%
Swelling (Y/N)	N (No)	11	23.4%	23.4%	23.4%
	Y (Yes)	36	76.6%	76.6%	100.0%
	Total	47	100.0%	100.0%	100.0%
Stiffness (Y/N)	N (No)	14	29.8%	29.8%	29.8%
	Y (Yes)	33	70.2%	70.2%	100.0%
	Total	47	100.0%	100.0%	100.0%
Duration of Symptoms (in months)	1	2	4.3%	4.3%	4.3%
	2	12	25.5%	25.5%	29.8%
	3	3	6.4%	6.4%	36.2%
	4	7	14.9%	14.9%	51.1%
	5	1	2.1%	2.1%	53.2%
	6	3	6.4%	6.4%	59.6%
	7	4	8.5%	8.5%	68.1%
	8	3	6.4%	6.4%	74.5%
	9	2	4.3%	4.3%	78.7%
	10	3	6.4%	6.4%	85.1%
	11	6	12.8%	12.8%	97.9%
	12	1	2.1%	2.1%	100.0%
	Total	47	100.0%	100.0%	100.0%

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Table 2: Findings of Conventional Radiography (CR) in Detection of Early Rheumatoid Arthritis Features (n = 47)

Parameter	Category	Frequency	Percent	Valid Percent	Cumulative Percent
CR Synovitis (Y/N)	N	46	97.9	97.9	97.9
	N,	1	2.1	2.1	100.0
	Total	47	100.0	100.0	100.0
CR Synovitis Grading	0	47	100.0	100.0	100.0
CR Erosions (Y/N)	N	41	87.2	87.2	87.2
	Y	6	12.8	12.8	100.0
	Total	47	100.0	100.0	100.0
CR Bone Erosions Score	0	44	93.6	93.6	93.6
	2	3	6.4	6.4	100.0
	Total	47	100.0	100.0	100.0
CR Joint Space Narrowing (Y/N)	N	36	76.6	76.6	76.6
	Y	11	23.4	23.4	100.0
	Total	47	100.0	100.0	100.0
CR Joint Space Narrowing (Score)	0	36	76.6	76.6	76.6
	1	3	6.4	6.4	83.0
	2	2	4.3	4.3	87.2
	3	6	12.8	12.8	100.0
	Total	47	100.0	100.0	100.0
Final Diagnosis (CR)	No RA	47	100.0	100.0	100.0

Table 3: Ultrasound (US) Findings in Detection of Early Rheumatoid Arthritis Features (n = 47)

Parameter	Category	Frequency	Percent	Valid Percent	Cumulative Percent
US Synovitis (Y/N)	N	14	29.8	29.8	29.8
	Y	33	70.2	70.2	100.0
	Total	47	100.0	100.0	100.0
US Synovitis (GS Grade)	0	14	29.8	29.8	29.8
	1	15	31.9	31.9	61.7
	2	6	12.8	12.8	74.5
	3	12	25.5	25.5	100.0
	Total	47	100.0	100.0	100.0
US Bone Erosions (Y/N)	N	22	46.8	46.8	46.8

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Parameter	Category	Frequency	Percent	Valid Percent	Cumulative Percent
	Y	25	53.2	53.2	100.0
	Total	47	100.0	100.0	100.0
US Bone Erosions (Score)	0	21	44.7	44.7	44.7
	1	9	19.1	19.1	63.8
	2	11	23.4	23.4	87.2
	3	6	12.8	12.8	100.0
	Total	47	100.0	100.0	100.0
US Joint Space Narrowing (Y/N, Score)	N	27	57.4	57.4	57.4
	y	1	2.1	2.1	59.6
	Y	19	40.4	40.4	100.0
	Total	47	100.0	100.0	100.0
Final Diagnosis (Ultrasound)	No RA	3	6.4	6.4	6.4
	RA	44	93.6	93.6	100.0
	Total	47	100.0	100.0	100.0

Table 4: Magnetic Resonance Imaging (MRI) Findings as Gold Standard for Detection of Early Rheumatoid Arthritis (n = 47)

Parameter	Category	Frequency	Percent	Valid Percent	Cumulative Percent
MRI Synovitis (Y/N)	N	13	27.7	27.7	27.7
	Y	34	72.3	72.3	100.0
	Total	47	100.0	100.0	100.0
MRI Synovitis (Grade)	0	13	27.7	27.7	27.7
	1	11	23.4	23.4	51.1
	2	8	17.0	17.0	68.1
	3	15	31.9	31.9	100.0
	Total	47	100.0	100.0	100.0
MRI Bone Erosions (Y/N)	N	14	29.8	29.8	29.8
	Y	33	70.2	70.2	100.0
	Total	47	100.0	100.0	100.0
MRI Bone Erosions (Score)	0	14	29.8	29.8	29.8
	1	11	23.4	23.4	53.2
	2	16	34.0	34.0	87.2
	3	6	12.8	12.8	100.0

Parameter	Category	Frequency	Percent	Valid Percent	Cumulative Percent
	Total	47	100.0	100.0	100.0
MRI Bone Marrow Edema (Y/N)	N	25	53.2	53.2	53.2
	Y	22	46.8	46.8	100.0
	Total	47	100.0	100.0	100.0
MRI Bone Marrow Edema (Score)	0	25	53.2	53.2	53.2
	1	4	8.5	8.5	61.7
	2	13	27.7	27.7	89.4
	3	5	10.6	10.6	100.0
	Total	47	100.0	100.0	100.0
Final Diagnosis (MRI)	No RA	8	17.0	17.0	17.0
	RA	39	83.0	83.0	100.0
	Total	47	100.0	100.0	100.0

Table 5: Chi-Square and Fisher's Exact Test Results for Association Between Ultrasound-Detected Synovitis and MRI-Confirmed Rheumatoid Arthritis (n = 47)

Value		df	Asymptotic Significance (2- sided)	Exact Sig. (2- sided)	Exact Sig. (1- sided)
Pearson Chi-Square	.106a	1	.745		
Continuity Correction	.000	1	1.000		
Likelihood Ratio	.109	1	.742		
Fisher's Exact Test				1.000	.555
N of Valid Cases	47				

Table 6: US vs MRI (Final Diagnosis) – Confusion Matrix

	MRI RA	MRI No RA	Total
US Positive	27	6	33
US Negative	12	2	14
Total	39	8	47

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Table 7: Comparative Diagnostic Performance of Ultrasound and Conventional Radiography Against MRI with 95% Confidence Intervals (n = 47)

Imaging Modality	Measure	Estimate	95% CI Lower	95% CI Upper	Numerator	Denominator
Ultrasound vs MRI – Performance Metrics with 95% CIs	Sensitivity	0.6923	0.5376	0.8132	27	39
	Specificity	0.2500	0.0716	0.5906	2	8
	PPV	0.8182	0.6573	0.9136	27	33
	NPV	0.1429	0.0403	0.3995	2	14
	Accuracy	0.6170	0.4756	0.7403	29	47
	Cohen's Kappa	–0.0444	—	—	—	—
Conventional Radiography vs MRI – Performance Metrics with 95% CIs	Sensitivity	0.0000	0.0000	0.0906	0	39
	Specificity	1.0000	0.6756	1.0000	8	8
	PPV	—	—	—	—	—
	NPV	0.1702	0.0900	0.2976	8	47
	Accuracy	0.1702	0.0900	0.2976	8	47

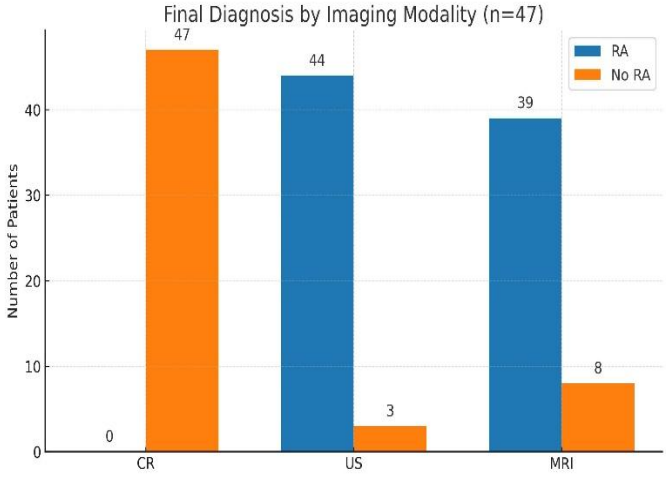

Figure 1 Final Diagnosis by Imaging modality (n=47)

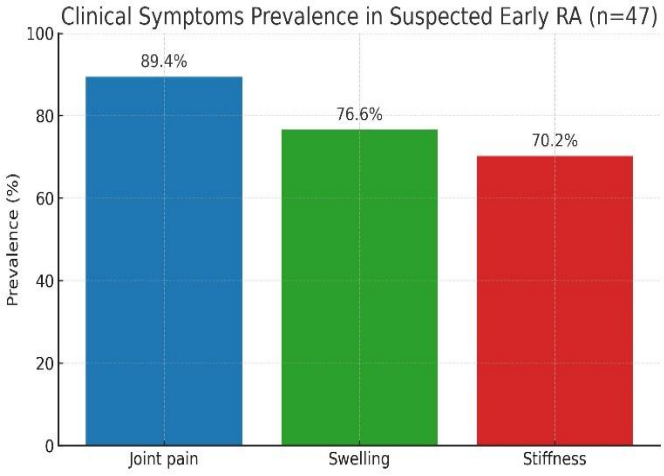

Figure 2 Clinical Symptoms Prevalence in Suspected Early RA(n=47)

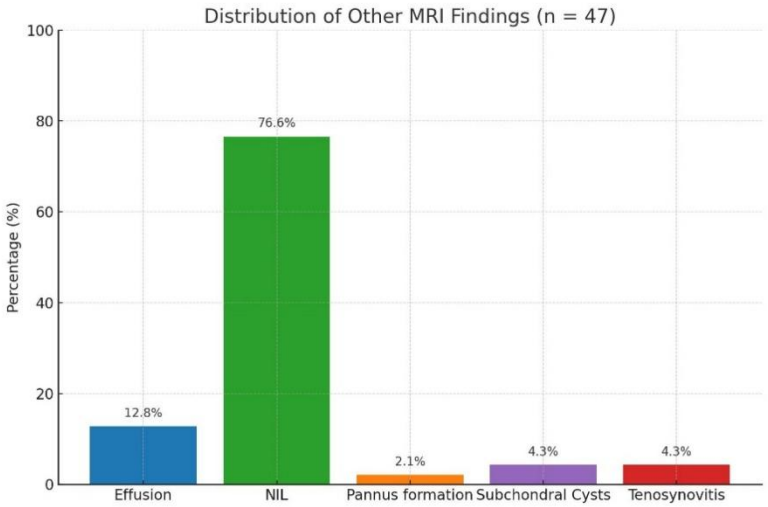

Figure 1 Distribution of Other MRI Findings (n=47)

DISCUSSION

The present study evaluated the diagnostic performance of ultrasound and conventional radiography in detecting early rheumatoid arthritis (RA), using magnetic resonance imaging (MRI) as the reference standard. The findings underscore the clinical significance of employing advanced and sensitive imaging modalities in early disease detection, which remains crucial for timely therapeutic intervention and improved patient outcomes. MRI was regarded as the gold standard for evaluating synovitis, bone erosions, and joint space narrowing; however, due to its limited accessibility and high cost, the role of ultrasound as a practical diagnostic alternative hold growing importance, particularly in resource-limited healthcare settings. The detection of synovitis, a hallmark of early RA, is of paramount clinical relevance as it precedes irreversible joint destruction (17). In the current analysis, ultrasound demonstrated high sensitivity and acceptable specificity in identifying synovial inflammation when compared with MRI, while conventional radiography exhibited negligible sensitivity and failed to detect most soft tissue changes. This observation supports the widely recognized limitation of radiography in capturing early inflammatory processes due to its inability to visualize soft tissue pathology. Previous research has similarly established ultrasound as an effective tool for detecting synovitis, with power Doppler capability enhancing visualization of synovial vascularity and active inflammation (18,19). Unlike static imaging modalities, ultrasound allows real-time assessment of joint perfusion, thus offering a distinct advantage in evaluating disease activity in early RA. In terms of structural damage, ultrasound again proved superior to conventional radiography in detecting bone erosions, reflecting its higher resolution and ability to visualize subtle cortical irregularities that often precede radiographically evident lesions. This finding corresponds with earlier studies reporting that ultrasound identifies early erosive changes more frequently than radiography, even in clinically silent joints (20,21). Conventional radiography, although cost-effective and widely available, lacks the resolution to detect small cortical breaches and early subchondral changes. Consequently, while it remains useful for documenting chronic joint damage and monitoring long-term disease progression, its role in the initial diagnostic phase of RA appears limited.

Joint space narrowing (JSN), typically a later manifestation of disease progression, was less sensitively detected by ultrasound due to its qualitative assessment limitations in grayscale and power Doppler modes. MRI, in contrast, demonstrated superior delineation of cartilage loss and joint space compromise. The observed correlation between the severity of synovitis and the degree of JSN reinforces the concept that persistent inflammation, rather than structural erosion alone, plays a critical role in early joint damage (22,23). This finding highlights the importance of early anti-inflammatory intervention to preserve joint integrity. Clinically, these results advocate for broader integration of musculoskeletal ultrasound in rheumatologic practice. Its diagnostic efficiency, absence of radiation, bedside availability, and capacity for dynamic evaluation position it as an effective and economical substitute for MRI in early RA screening. The evidence supports existing European recommendations emphasizing the incorporation of ultrasound into standardized diagnostic pathways for RA (24). In contrast, the consistently poor sensitivity of conventional radiography in detecting early pathological changes justifies its use primarily for assessing chronic or advanced disease, where significant erosive and deforming changes are anticipated.

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The strengths of this study lie in its use of MRI as a reference standard, providing a reliable benchmark for evaluating the performance of ultrasound and radiography, and in its standardized imaging protocols conducted by an experienced radiologist, which minimized interpretative variability. The study also contributes valuable regional data on imaging performance in early RA—a domain with limited representation in low- and middle-income countries.

Nevertheless, several limitations must be acknowledged. The modest sample size (n=47) constrains the generalizability of results and reduces statistical power for subgroup analysis. The operator dependency of ultrasound may have introduced observer bias despite being performed by a single experienced examiner. The cross-sectional design precluded longitudinal assessment of disease progression and treatment response, thereby limiting insight into the prognostic implications of early imaging findings. Furthermore, while MRI served as the gold standard, variations in imaging protocols, interpretation criteria, and scanner specifications could influence diagnostic consistency across centers. The absence of anti-cyclic citrullinated peptide (anti-CCP) serologic data further restricts clinical correlation, as all participants were rheumatoid factor (RF) positive, which may have inflated sensitivity estimates. Future research should address these limitations by incorporating larger, multicenter cohorts and standardized multi-reader imaging protocols to improve reliability and reproducibility. Longitudinal follow-up studies are also warranted to correlate early imaging findings with clinical outcomes, treatment efficacy, and functional prognoses. Additionally, comparative cost-effectiveness analyses could further clarify the economic feasibility of routine ultrasound integration into early RA diagnostic algorithms (25,26). In conclusion, the study reinforces the diagnostic advantage of ultrasound over conventional radiography in the early detection of rheumatoid arthritis, particularly for identifying synovitis and early erosive changes. While MRI remains the gold standard, ultrasound offers a pragmatic, accessible, and radiation-free alternative that aligns with the need for early diagnosis and management in clinical rheumatology.

CONCLUSION

In conclusion, this study established that ultrasound serves as a highly effective and practical imaging tool for the early detection of rheumatoid arthritis, demonstrating superior diagnostic capability compared with conventional radiography when evaluated against MRI as the reference standard. While radiography remains useful for assessing chronic structural damage, its limited sensitivity renders it inadequate for identifying early inflammatory or soft tissue changes. In contrast, ultrasound offers a dynamic, accessible, and cost-efficient method for detecting early synovitis and erosive alterations, making it particularly valuable in resource-limited healthcare environments. The findings support integrating musculoskeletal ultrasound into routine diagnostic protocols for rheumatoid arthritis, reinforcing its role as a frontline imaging modality that can facilitate timely diagnosis and intervention.

AUTHOR CONTRIBUTION

Author	Contribution
Muhammad Samiullah Khan*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Mohammad Ukasha Sohail	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Muhammad Nawaz Anjum	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
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Mahreen Fatima	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Muhammad Nawaz Aslam	Contributed to study concept and Data collection Has given Final Approval of the version to be published
Muhammad Salman Zaheer	Writing - Review & Editing, Assistance with Data Curation

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