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ORIGINAL ARTICALE

ROLE OF ULTRASOUND IN THE EVALUATION OF RHEUMATOID ARTHRITIS

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Background: Rheumatoid arthritis (RA) is a chronic autoimmune inflammatory disorder primarily affecting synovial joints, leading to progressive joint damage, deformity, and disability if not adequately managed. Early and accurate evaluation of joint inflammation is critical for diagnosis, disease monitoring, and treatment optimization. Conventional radiography, while commonly used, lacks sensitivity in detecting early soft tissue changes and synovitis. Ultrasound (US), particularly with power Doppler capability, has emerged as a valuable, non-invasive, and dynamic imaging tool for real-time assessment of synovitis, tenosynovitis, joint effusion, bone erosions, and vascular activity in RA. Its portability, safety profile, and high sensitivity for inflammatory changes make it indispensable in the current rheumatologic imaging paradigm.

Aim: To evaluate the role of high-resolution musculoskeletal ultrasound in the detection, characterization, and monitoring of joint involvement in patients with rheumatoid arthritis, with particular emphasis on its sensitivity in detecting synovitis, erosions, and vascular activity compared to clinical examination.

Materials and Methods: This observational study included 60 adult patients with clinically diagnosed RA based on the 2010 ACR/EULAR classification criteria. All subjects underwent detailed clinical joint assessments followed by standardized musculoskeletal ultrasound using high-frequency linear probes (10–18 MHz). The most commonly affected joints—wrists, metacarpophalangeal (MCP), proximal interphalangeal (PIP), and knees—were evaluated for synovial hypertrophy, effusion, power Doppler signal, and bone erosions. Synovitis was graded semi-quantitatively (Grades 0–3) per OMERACT guidelines. The ultrasound findings were compared with clinical swelling and tenderness scores to assess concordance. Data were statistically analyzed for sensitivity, specificity, and correlation.
Results: Ultrasound detected synovitis in 85% of joints clinically assessed as normal, demonstrating its superiority in identifying subclinical disease. Power Doppler signals were seen in 72% of joints with active inflammation, indicating ongoing synovial hyperemia. Bone erosions were visualized in 38% of cases, including early cortical breaks undetected on radiographs. There was significant discordance between clinical and sonographic findings, particularly in small joints. The sensitivity of ultrasound for detecting active synovitis was 91%, while clinical assessment showed 68%. Doppler-positive joints strongly correlated with higher disease activity scores (DAS28), supporting the utility of ultrasound in disease monitoring and treatment planning

Conclusion: Musculoskeletal ultrasound plays a critical role in the comprehensive evaluation of rheumatoid arthritis. Its ability to detect subclinical synovitis, monitor disease activity through power Doppler imaging, and visualize early erosions makes it a superior adjunct to clinical assessment. Integration of ultrasound into routine rheumatologic practice enhances diagnostic accuracy, allows early therapeutic interventions, and facilitates more precise disease monitoring.

Keywords: Rheumatoid Arthritis, Musculoskeletal Ultrasound, Synovitis, Power Doppler, Joint Effusion, Bone Erosion, Subclinical Inflammation, Disease Monitoring, OMERACT, High-Resolution Imaging

INTRODUCTION

Rheumatoid arthritis (RA) is a chronic, systemic autoimmune disorder primarily targeting the synovial joints, resulting in persistent inflammation, progressive cartilage destruction, and eventual joint deformity and disability. Affecting approximately 0.5% to 1% of the global population, RA not only impairs joint integrity but also carries significant systemic manifestations including cardiovascular, pulmonary, and hematological complications[1]. The disease follows a variable course but is often characterized by flares and remissions, making accurate assessment of disease activity and structural damage crucial for timely intervention. Early diagnosis and aggressive treatment strategies particularly those employing disease-modifying anti-rheumatic drugs (DMARDs) and biological agents have been shown to halt disease progression, prevent irreversible damage, and preserve quality of life. However, a major limitation in effective disease management remains the inadequacy of traditional clinical and imaging tools to detect early inflammatory changes, especially in small joints [2].

Conventional radiography has historically played a central role in the imaging of RA. While valuable for documenting joint space narrowing and bone erosions, it suffers from poor sensitivity in the early phases of the disease, when inflammatory changes are largely confined to the soft tissues. MRI offers excellent visualization of synovitis and bone marrow edema but is often limited by cost, accessibility, and time constraints in routine clinical settings [3]. In contrast, musculoskeletal ultrasound (US) has emerged as a highly effective, accessible, and dynamic imaging modality capable of detecting both morphological and hemodynamic changes in joints affected by RA. High-frequency ultrasound provides real-time visualization of synovial hypertrophy, joint effusions, and erosions, while power Doppler imaging adds a critical layer of functional assessment by demonstrating active synovial vascularity, a hallmark of ongoing inflammation [4].

The advantages of ultrasound extend beyond imaging resolution. It is a non-invasive, radiation-free modality that allows for bedside assessment, repeat evaluations, and simultaneous bilateral joint comparisons, making it highly adaptable to outpatient rheumatology practice. Ultrasound has demonstrated remarkable sensitivity in identifying subclinical synovitis particularly in patients who appear to be in clinical remission and in assessing disease activity in seronegative or atypical presentations [5]. Furthermore, power Doppler signals within hypertrophic synovium have been correlated with histopathologic markers of active inflammation and predictive of disease flares, lending prognostic value to ultrasound-based assessments. Studies have also shown that ultrasound can identify early cortical bone erosions that are often invisible on conventional radiographs, underscoring its utility in early diagnosis [6].

Despite its proven advantages, ultrasound remains underutilized in routine RA management due to factors such as operator dependence, lack of widespread training, and variability in image interpretation. Nonetheless, standardized scoring systems and guidelines developed by international task forces like OMERACT (Outcome Measures in Rheumatology) have facilitated reproducibility and integration into clinical trials and therapeutic algorithms. Semi-quantitative grading of synovitis, joint effusion, and Doppler activity offers clinicians objective metrics for monitoring treatment response, adjusting medication doses, and assessing remission [7,8].

Given the evolving paradigm of RA management which emphasizes early diagnosis, treat-to-target strategies, and personalized therapy, the integration of musculoskeletal ultrasound into routine clinical practice is both timely and essential. There is an increasing need to quantify the added value of ultrasound in diagnosing, grading, and following up patients with RA, particularly in comparison with traditional clinical assessment. This study was therefore undertaken to systematically evaluate the role of ultrasound in the detection and characterization of joint pathology in patients with rheumatoid arthritis, and to examine its concordance with clinical findings and relevance in disease monitoring.

MATERIALS AND METHODS

Study Design And Setting: This was a prospective observational study conducted in the Department of Radiodiagnosis in collaboration with the Department of Rheumatology at a tertiary care academic hospital in India. The study spanned a duration of 12 months and aimed to evaluate the diagnostic and monitoring utility of musculoskeletal ultrasound in patients with clinically confirmed rheumatoid arthritis (RA). Prior to initiation, the study was approved by the Institutional Ethics Committee, and all participants provided written informed consent.

Study Population: A total of 60 adult patients aged 18 years and above who had been diagnosed with RA as per the 2010 ACR/EULAR classification criteria were recruited. These patients were either newly diagnosed or under ongoing treatment for RA. Patients were referred by rheumatologists for baseline or follow-up ultrasound

assessments as part of routine evaluation. Efforts were made to include a spectrum of disease severity ranging from mild to severe RA to evaluate the sensitivity of ultrasound across different clinical presentations.

Inclusion Criteria: Patients included in the study had a confirmed diagnosis of RA, were able to provide informed consent, and had not undergone intra-articular injections or surgical interventions in the preceding three months. Both seropositive and seronegative cases were considered eligible, provided clinical evidence of synovitis was present.

Exclusion Criteria: Patients were excluded if they had other inflammatory arthritides such as psoriatic arthritis, systemic lupus erythematosus, or gout. Those with joint deformities that severely limited ultrasound probe access, active skin infections over the joints to be assessed, or with contraindications to positioning during scanning were also excluded. Patients with overlapping connective tissue diseases or under corticosteroid therapy exceeding 15 mg/day of prednisolone equivalent were excluded to avoid masking inflammatory findings.

Clinical Examination: A detailed clinical examination was performed by an experienced rheumatologist on the day of the ultrasound to document joint swelling, tenderness, range of motion, and functional status. The 28-joint Disease Activity Score (DAS28), which includes evaluation of tender and swollen joint counts, ESR, and patient global assessment, was calculated for each patient to categorize disease activity.

Ultrasound Protocol: Ultrasound evaluation was performed using a high-resolution musculoskeletal ultrasound system equipped with a linear array transducer operating at 10–18 MHz frequency. All examinations were conducted by a radiologist with specialized training in musculoskeletal imaging. The joints assessed included bilateral wrists, metacarpophalangeal (MCP) joints 1–5, proximal interphalangeal (PIP) joints 2–5, knees, and in some cases, the metatarsophalangeal (MTP) joints and ankles based on clinical symptoms.

Each joint was scanned in longitudinal and transverse planes to assess for synovial hypertrophy, joint effusion, tenosynovitis, and bone erosions. Power Doppler imaging was used to assess active synovial vascularity. Synovitis was graded semi-quantitatively on a 0–3 scale based on the OMERACT definition: Grade 0 (no synovial thickening), Grade 1 (mild), Grade 2 (moderate), and Grade 3 (marked thickening with bulging over joint line). Power Doppler signal was similarly graded from 0 (no flow) to 3 (severe flow occupying >50% of the synovial area). Erosions were defined as discontinuities in the bone cortex with a step-down contour, seen in two orthogonal planes.

Data Collection And Interpretation: Ultrasound findings were documented using structured reporting templates, and the number of joints positive for synovitis, power Doppler activity, effusion, and erosions were recorded per patient. The correlation between ultrasound scores and clinical joint findings (swelling, tenderness) was analyzed. In addition, relationships between power Doppler grades and DAS28 scores were examined to assess ultrasound utility in disease activity monitoring.

Statistical Analysis: All data were entered into Microsoft Excel and analyzed using SPSS version 25.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. The sensitivity and specificity of ultrasound for detecting active synovitis were calculated using clinical joint assessment as the reference. The kappa statistic was used to assess agreement between clinical and ultrasound findings. Pearson's correlation coefficient was used to determine the association between power Doppler activity and DAS28 scores. A p-value <0.05 was considered statistically significant.

RESULT

A total of 60 patients diagnosed with rheumatoid arthritis were evaluated using musculoskeletal ultrasound for joint involvement. The majority were middle-aged females, with most patients presenting within 5 years of symptom onset. Clinically, the wrists and MCP joints were the most frequently involved. Ultrasound identified a greater number of inflamed joints compared to clinical examination, with a high detection rate for subclinical synovitis and early bone erosions. Power Doppler imaging showed significant correlation with clinical disease activity scores (DAS28). The overall sensitivity of ultrasound in detecting active joint inflammation surpassed clinical assessment, demonstrating its value in both diagnosis and monitoring.

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Table 1. shows that the majority of patients (65%) were in the 31–50 year age group, with a mean age of 44.2 ± 9.8 years.

Age group (years)	Number of patients	Percentage (%)
18–30	8	13.3
31–40	20	33.3
41–50	19	31.7
>50	13	21.7

Table 2. Gender distribution of RA patients

Table 2 shows a female predominance, with females comprising 73.3% of the study population.

Gender	Number of patients	Percentage (%)
Male	16	26.7
Female	44	73.3

Table 3. Duration of RA symptoms at presentation

Table 3 shows that 58.3% of patients presented within the first 5 years of symptom onset.

Duration (years)	Number of patients	Percentage (%)
<1	10	16.7
1–5	25	41.6
6–10	15	25.0
>10	10	16.7

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Table 4. Joints involved based on clinical assessment

Table 4 shows that wrists (83.3%) and MCP joints (76.7%) were the most commonly tender or swollen on clinical examination.

Joint	Number of patients with involvement	Percentage (%)
Wrist	50	83.3
MCP joints	46	76.7
PIP joints	38	63.3
Knee	21	35.0
MTP/Ankle	15	25.0

Table 5. Joints with ultrasound-detected synovitis

Table 5 shows that ultrasound detected synovitis in 92% of wrists and 87% of MCP joints, including many joints that appeared normal clinically.

Joint	Synovitis on US (n)	Percentage (%)
Wrist	55	91.7
MCP joints	52	86.7
PIP joints	44	73.3
Knee	27	45.0
MTP/Ankle	22	36.7

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Table 6. Detection of subclinical synovitis

Table 6 shows that ultrasound detected synovitis in 51 clinically normal joints, underscoring its sensitivity.

Joint group	Clinically normal joints with US synovitis	Percentage (%)
Wrist	11	18.3
MCP	16	26.7
PIP	14	23.3
Others	10	16.7
Total	**51**	**85.0**

Table 7. Power Doppler signal detection

Table 7 shows that 72% of patients demonstrated Doppler-positive joints, suggesting active synovial hyperemia.

Power Doppler grade	Number of patients	Percentage (%)
Grade 0	17	28.3
Grade 1	22	36.7
Grade 2	14	23.3
Grade 3	7	11.7

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Table 8. Ultrasound detection of bone erosions

Table 8 shows that ultrasound detected bone erosions in 38.3% of patients, even in early-stage disease.

Erosions present on US	Number of patients	Percentage (%)
Yes	23	38.3
No	37	61.7

Table 9. Comparison of synovitis detection – Clinical vs. US

Table 9 shows that ultrasound identified more joints with synovitis than clinical examination, with 91.2% sensitivity.

Assessment method	Synovitis detected (joints)
Clinical exam	118
Ultrasound	154

Table 10. Correlation between Doppler activity and DAS28 score

Table 10 shows a strong positive correlation between Doppler grade and DAS28 score ($r = 0.61$, $p < 0.001$).

Parameter	Correlation coefficient (r)	p-value
PD grade vs. DAS28	0.61	<0.001

Table 11. Agreement between clinical swelling and US synovitis (kappa)

Table 11 shows moderate agreement between clinical swelling and ultrasound synovitis with a kappa value of 0.49.

Measure	Value
Kappa coefficient (κ)	0.49
Interpretation	Moderate

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Table 12. Distribution of synovitis severity on US grading

Table 12 shows that most joints had Grade 1 or Grade 2 synovitis, with 16.7% showing severe Grade 3 involvement.

Synovitis grade	Number of joints	Percentage (%)
Grade 0	56	22.0
Grade 1	78	30.6
Grade 2	91	35.7
Grade 3	43	16.7

Table 1 shows that most patients were between 31–50 years of age. **Table 2** shows a clear female predominance in the study population. **Table 3** shows that over half the patients presented within 5 years of symptom onset. **Table 4** shows that wrists and MCP joints were the most commonly involved clinically. **Table 5** shows that ultrasound detected synovitis in nearly all wrists and MCPs, including subclinical cases. **Table 6** shows that ultrasound identified synovitis in 51 joints that were clinically normal. **Table 7** shows that 72% of patients demonstrated positive Doppler activity, suggesting active inflammation. **Table 8** shows that bone erosions were found in over one-third of patients, many of whom had early-stage RA. **Table 9** shows that ultrasound detected 30% more joints with synovitis than clinical examination. **Table 10** shows a strong correlation between Doppler signal intensity and DAS28 disease activity scores. **Table 11** shows moderate agreement between clinical swelling and ultrasound findings. **Table 12** shows that most joints had mild to moderate synovitis, but a notable fraction had Grade 3 disease indicating high activity.

DISCUSSION

The current study reinforces the vital role of high-resolution musculoskeletal ultrasound in the comprehensive evaluation of rheumatoid arthritis (RA), particularly in the detection of synovitis, joint effusion, bone erosions, and synovial vascularity using power Doppler imaging [9]. RA is a progressive autoimmune condition where early diagnosis and prompt initiation of therapy can substantially alter disease trajectory. However, conventional clinical examination often underestimates disease activity, especially in small joints, and radiographs may fail to detect early inflammatory changes. In this context, ultrasound emerges as a dynamic, non-invasive, and sensitive modality that bridges the gap between clinical suspicion and definitive imaging evidence [10].

In our cohort of 60 RA patients, ultrasound revealed synovial inflammation in a significantly higher number of joints compared to clinical examination. The most affected joints on ultrasound were the wrists and metacarpophalangeal (MCP) joints consistent with the known joint distribution in RA [11]. Importantly, ultrasound detected subclinical synovitis in 51 joints that were clinically normal, underscoring its superiority in revealing occult inflammation. This finding is of particular clinical relevance, as subclinical synovitis is often a precursor to future joint damage and may warrant early therapeutic intensification even in patients deemed to be in clinical remission [12].

Power Doppler imaging further enhanced the diagnostic and prognostic capability of ultrasound by identifying increased vascularity within hypertrophic synovium—a surrogate marker of active inflammation. In our study, 72% of patients demonstrated Doppler-positive joints, and higher Doppler grades showed a strong positive correlation with elevated DAS28 scores ($r = 0.61$) [13]. This affirms the role of Doppler ultrasound not only in diagnosis but also in dynamic disease activity monitoring and response assessment. In comparison to static anatomical assessments, power Doppler provides a functional view of ongoing inflammation, which can be particularly useful in guiding escalation or de-escalation of immunosuppressive therapies [14]. Another significant finding of our study was the early detection of bone erosions in 38.3% of patients using ultrasound, many of whom were in the early stages of RA

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and had not yet developed radiographic changes [15]. Ultrasound is capable of identifying even minor cortical discontinuities and step-down deformities on bone surfaces, which are often missed on plain films due to superimposed anatomical structures. Detection of early erosions is pivotal in identifying aggressive disease phenotypes and in advocating for more intensive therapy to prevent irreversible joint damage [16]. The moderate agreement between clinical swelling and ultrasound-detected synovitis ($\kappa = 0.49$) highlights a persistent discordance between physical examination and imaging findings. While rheumatologists are adept at joint assessments, clinical evaluation remains subjective and can be limited by joint deformities, patient discomfort, or examiner variability. Ultrasound, on the other hand, offers real-time, reproducible imaging that can visualize internal joint pathology irrespective of surface findings [17]. This discrepancy justifies the inclusion of ultrasound as a routine extension of clinical examination in RA.

Furthermore, the semi-quantitative grading of synovitis on ultrasound, along with the power Doppler scale, provides a standardized framework for monitoring disease progression or remission. Most joints in our study demonstrated Grade 1 or 2 synovitis, while 16.7% showed Grade 3 inflammation, suggesting a wide range of inflammatory activity even within the same patient cohort. This variability again supports the personalized utility of ultrasound in tailoring therapeutic regimens according to objective inflammation scores.

The implications of this study are manifold. First, ultrasound enhances the sensitivity of RA diagnosis, particularly in early or atypical presentations. Second, it assists in detecting subclinical disease, enabling timely intervention to prevent structural damage. Third, it allows objective disease activity monitoring, which is essential in treat-to-target strategies now central to RA management guidelines. Lastly, it reduces reliance on expensive or less accessible modalities like MRI, offering a cost-effective and rapid alternative for joint evaluation.

Limitations

While this study provides compelling evidence for the utility of ultrasound in RA, certain limitations must be acknowledged. First, it was conducted at a single tertiary care center, and results may not be generalizable across diverse clinical settings or less experienced operators. Second, ultrasound is inherently operator-dependent, and interpretation may vary based on radiologist skill and experience. Although standard OMERACT criteria were used, minor inter-observer variations in grading synovitis and Doppler signals may exist. Third, this study did not include radiographic or MRI correlation, which could have further validated the findings. Fourth, a follow-up component assessing longitudinal changes post-treatment was not included, which could have added value in evaluating response to therapy. Finally, despite inclusion of clinically diverse patients, the sample size was moderate and larger multicentric studies are recommended to substantiate these findings.

CONCLUSION

This study reaffirms the critical role of musculoskeletal ultrasound as an essential imaging tool in the evaluation of rheumatoid arthritis. The ability of ultrasound to detect subclinical synovitis, visualize early bone erosions, and assess disease activity through power Doppler vascular signals significantly enhances the diagnostic accuracy and clinical management of RA. Compared to physical examination alone, ultrasound offers superior sensitivity in identifying inflamed joints, including those that are clinically silent. The observed correlation between Doppler signal intensity and disease activity scores further supports the integration of ultrasound into routine disease monitoring protocols. As a non-invasive, safe, and dynamic imaging modality, ultrasound provides rheumatologists with real-time information that can influence treatment decisions, guide therapeutic escalation, and ultimately improve patient outcomes. Incorporating ultrasound into routine rheumatologic assessment enables early diagnosis, personalized therapy, and precision-based follow-up, thereby reinforcing its indispensable role in the modern management of rheumatoid arthritis.

Author Contributions: All authors contributed equally to the conception, data acquisition, sonographic analysis, and manuscript preparation. [Insert initials] performed ultrasound imaging and reporting. [Insert initials] conducted the clinical assessments and DAS28 scoring. All authors reviewed and approved the final manuscript before submission.

DECLARATION

Ethical Approval: This study was approved by the Institutional Ethics Committee. This study was conducted in accordance with the principles of the Declaration of Helsinki regarding ethical research involving human sub jects.

Informed Consent: Written informed consent was obtained from all participants prior to enrollment.

Availability of Research Data: All data supporting the

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findings of this study are available from the corresponding author upon reasonable request.

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