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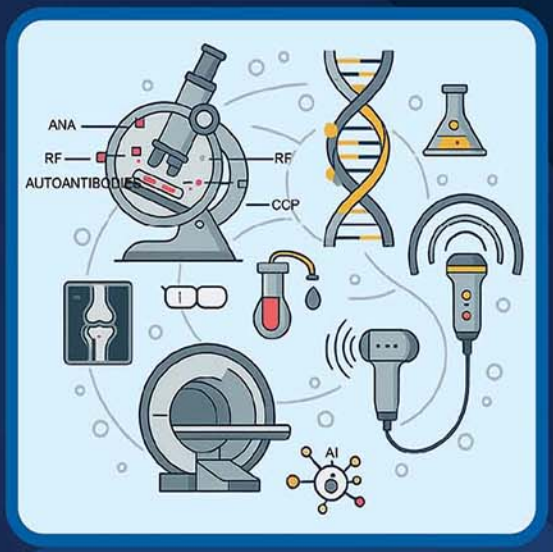

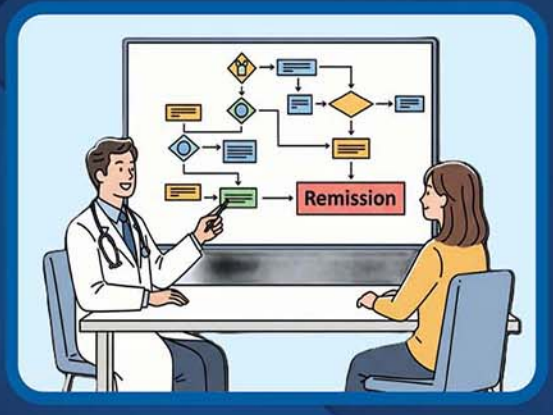

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CHAPTER 17

Artificial Intelligence in Rheumatology: Where are We?

Keerthi Talari

ABSTRACT

Artificial intelligence (AI) is reshaping the field of rheumatology, offering innovative tools to enhance clinical care, research, and personalized medicine. AI encompasses machine learning (ML), deep learning (DL), natural language processing (NLP), multimodal systems, and large language models (LLMs), all of which enable data-driven decision-making.

In the clinical setting, AI supports each step of the care continuum—from triaging referrals and capturing clinical details to electronic health record (EHR) to interpreting investigations and predicting treatment response. Tools such as Augmedix, MedLM, and several others are streamlining documentation, while wearable devices are enabling real-time monitoring of disease activity. In research, AI facilitates automated data extraction, clustering of phenotypes, identification of novel biomarkers, and generation of synthetic control arms. NLP and LLMs are transforming literature review, cohort selection, and hypothesis generation.

Despite its promise, AI integration raises several ethical concerns including data privacy, bias, model explainability, prediction errors, accountability, and the phenomenon of LLM "hallucinations." Internationally, regulatory frameworks such as the EU AI Act and reporting guidelines such as CONSORT-AI, CANGARU, and MI-CLAIM are being adopted to ensure transparency and reproducibility.

Looking ahead, innovations such as federated learning, explainable AI, and multimodal LLMs will deepen AI's role in clinical reasoning. For AI to achieve its full potential in rheumatology, inclusive data, interdisciplinary collaboration, and proper regulations are essential.

Keywords: AI, machine learning, clinical, applications, uses, ethics.

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INTRODUCTION

Artificial intelligence (AI) is no longer a futuristic concept—it is now a powerful tool transforming healthcare, including rheumatology. Defined as the simulation of human intelligence by machines, AI encompasses a wide range of subfields including machine learning (ML), deep learning (DL), natural language processing (NLP), and multimodal AI. ML is a subset of AI where algorithms learn patterns from data without being explicitly programmed.[1] Deep learning is an advanced form of ML that uses structures called neural networks—somewhat inspired by the human brain. These networks can process huge amounts of complex data to make predictions. NLP is another branch of AI that helps machines understand and interpret human language—especially useful for reading and summarizing clinical notes, referral letters, or patient-reported symptoms. Multimodal AI refers to combining multiple types of data—such as clinical notes, laboratory results, imaging scans, and genetic profiles—into a single predictive model.

This is particularly useful in rheumatology, where disease patterns are complex and span across various data types. Large language models (LLMs) such as generative pretrained transformers (GPT) are advanced NLP systems trained on massive text datasets. These models can understand clinical context, summarize articles, draft discharge summaries, and even assist in answering diagnostic questions.

Rheumatic diseases are among the most complex and heterogeneous in medicine, often characterized by overlapping symptoms, varied serological markers, and a fluctuating disease course. These complexities make diagnosis, classification, and individualized treatment particularly challenging. AI has the potential to bridge these gaps by assisting in multiple facets of rheumatology. It can enhance disease subclassification by identifying hidden phenotypes that are not captured by current criteria, helping refine diagnoses and stratify patients for research and treatment. Prognostic models built using AI can forecast flares, treatment failure, or organ damage. In clinical imaging, AI algorithms have demonstrated the ability to grade radiographs, detect joint erosions, and interpret musculoskeletal ultrasound or MRI scans with speed and consistency. Personalized treatment approaches can also be enabled by AI tools that predict which patients are likely to respond to specific biologics or DMARDs.[2]

In research, AI is revolutionizing how we interpret large-scale omics datasets, identify novel biomarkers, and design smarter, more adaptive clinical trials. It also helps generate synthetic control arms and optimize patient selection.[1] In patient care, AI is becoming increasingly integrated into routine workflows—supporting clinical decision-making, helping triage referrals, and extracting critical insights from electronic health records (EHRs).[3] It can assist in creating discharge summaries, generating automated progress notes, and collating diverse data from multiple sources into coherent care plans. Overall, AI is steadily becoming a cornerstone of precision rheumatology—guiding both the science and the art of delivering better, individualized care.

CLINICAL APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN RHEUMATOLOGY

Artificial intelligence is being increasingly integrated across all stages of the clinical workflow in rheumatology—from referral and triage to diagnosis, treatment planning, and long-term monitoring. These technologies are helping streamline patient care, improve diagnostic accuracy, and support personalized treatment approaches **(Table 1)**.

Referral and Triage

One of the earliest points of patient entry into the rheumatology care pathway is through referrals, often made by primary care practitioners or physicians or other

TABLE 1: Clinical applications of AI in rheumatology.

Stage	AI application	Technology
Referral and triage	Prioritization using initial assessment	ML + NLP
History and EHR	Autodocumentation, summarization	LLMs
Diagnosis	Subclassification, flare prediction	ML, clustering
Imaging	Interpretation of X-ray, US, and MRI	Deep learning
Treatment planning	Predict response to DMARDs/biologics	Supervised ML
Monitoring	Symptom trends via wearable and mobile apps	AI + wearables

(AI: artificial intelligence; LLM: large language model; ML: machine learning; NLP: natural language processing; US: ultrasound)

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specialists based on symptoms such as joint pain, prolonged fever, fatigue, or rash. This can lead to substantial delays in identifying patients who require urgent rheumatologic assessment. AI, particularly through NLP and ML, has shown the potential to enhance referral triage.

A recent study by Maarseveen et al. demonstrated that an AI-based model analyzing GP referral letters could effectively prioritize patients likely to have rheumatoid arthritis (RA), osteoarthritis, or fibromyalgia. This model achieved area under the curve (AUC) values of 0.78 for RA and 0.81 for fibromyalgia, surpassing the performance of standard manual triage methods.[3] Such tools can be embedded within electronic referral systems to flag high-risk patients for earlier appointments, thereby reducing diagnostic delays and improving outcomes.

History Taking and Electronic Health Record Integration

Rheumatology consultations often involve complex histories covering symptom onset, joint involvement, systemic features, flares, medication use, and prior investigations. AI-powered tools are being developed to assist in capturing this information efficiently. NLP systems can analyze unstructured clinical notes to extract key information such as symptom duration, autoantibody results, and prior imaging findings.

Moreover, AI can assist in maintaining EHRs by generating structured documentation from dictated or typed clinical narratives. LLMs such as GPT-4 and Med-PaLM are now being adapted for summarizing outpatient visits, preparing clinical letters, and autopopulating forms with relevant information.[4,5] One real-world example is Augmedix, a platform that uses Google's healthcare-focused MedLM model to transform clinician–patient conversations into structured notes followed by automated documentation directly into the EHR with minimal effort from the clinician.[6]

Diagnostic Support

The diagnosis of rheumatic diseases is inherently complex, often requiring a combination of clinical examination, serological markers, histopathologic and imaging findings. AI models are being trained on large datasets to aid in this process by recognizing patterns that may not be evident to human clinicians.

In RA, AI-based tools have been used to differentiate seropositive and seronegative cases, and to predict disease severity and early progression using EHR data.[7] In systemic lupus erythematosus (SLE), ML models have helped identify distinct phenotypes based on autoantibody clustering, which correlate with disease manifestations and prognosis.[8] Such tools can enhance early and accurate classification of patients, especially those with incomplete or overlapping features.

Additionally, AI is being applied in Sjögren's syndrome to improve disease subtyping and to predict the risk of lymphoma using integrated data from genetic, clinical, and serologic markers.[9]

Diagnostics Interpretation

Interpretation of investigation reports is another area where AI is making significant contributions. Deep learning models have been used to interpret musculoskeletal radiographs, scoring joint space narrowing and erosions in RA patients with high consistency. AI-based grading of hand and knee radiographs has shown comparable or superior accuracy to trained radiologists in detecting osteoarthritic changes.[1]

In ultrasound, AI is being explored to automate the assessment of synovitis or tenosynovitis by quantifying Doppler signal intensity and joint effusion. Early models show promise in reducing interobserver variability and supporting less experienced clinicians.[10]

Furthermore, AI is being applied in digital pathology to analyze synovial biopsy samples or salivary gland tissue in Sjögren's syndrome. Models trained on digitized histological

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slides can aid in grading inflammation and fibrosis, which has implications for diagnosis, research, and personalized therapy.[11]

Treatment Planning and Personalization

Artificial intelligence systems are increasingly being used to predict patient response to various therapies, allowing for more personalized treatment plans. Supervised ML models can integrate baseline clinical features, biomarkers, and prior treatment history to predict which patients are more likely to respond to specific disease-modifying antirheumatic drugs (DMARDs) or biologics.

A recent review reported that ML models have achieved AUCs between 0.63 and 0.92 for predicting treatment response in RA and spondyloarthritis, suggesting their growing reliability in decision support.[12] Reinforcement learning models, which continuously update recommendations based on real-time patient data, are also being explored to optimize tapering or escalation strategies over time.[3]

Such models, once validated and embedded into clinical workflows, could reduce trial-and-error prescribing and improve long-term outcomes by initiating the most effective therapy earlier.

Monitoring and Follow-up

Once treatment is initiated, AI tools can assist in monitoring disease activity, treatment adherence, and flare prediction. Mobile health applications and wearable devices allow patients to report symptoms, pain scores, and functional metrics in real time. AI algorithms can analyze this longitudinal data to identify early signs of disease worsening or remission.[2]

In RA, the weaRAble-PRO trial demonstrated the feasibility of using Apple watches and smartphones to detect RA disease activity. AI models trained on these data streams accurately distinguished RA from healthy controls and predicted disease severity scores with high correlation.[13]

Artificial intelligence can also help monitor drug safety by scanning EHRs and laboratory results for early warning signs of adverse effects—such as rising liver enzymes or cytopenias—and alerting providers to intervene before complications occur.

ARTIFICIAL INTELLIGENCE IN RESEARCH

Artificial intelligence is revolutionizing research by enabling the analysis of complex datasets, automating data extraction from clinical records, and uncovering novel disease subgroups. Traditional clinical research has been constrained by small sample sizes, manual data entry, and variable interpretation of clinical variables. AI-based techniques, particularly ML, offer scalable solutions for addressing these challenges.

In rheumatology, supervised ML algorithms such as support vector machines (SVMs), decision trees, and random forests have been used to predict disease outcomes, treatment response, and flare risk. Unsupervised ML techniques such as k-means clustering and hierarchical clustering are particularly useful in discovering hidden subgroups within diseases as discussed in SLE earlier.[8]

Natural language processing and LLMs are also transforming rheumatology research. NLP techniques allow extraction of structured data from unstructured clinical notes, enabling large-scale retrospective studies. For instance, a Spanish study used NLP on over 60 million EHRs with unstructured data to characterize RA with interstitial lung disease.[14] More recently, LLMs such as GPT-4 are being explored for summarizing literature, generating hypotheses, and assisting in the preparation of scientific manuscripts. The development of rheumatology-specific LLMs could further enhance domain-specific applications such as identifying rare adverse events or improving cohort selection.[15]

These tools are reshaping the way researchers approach disease classification, treatment stratification, and biomarker

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discovery. With the growth of real-world data registries and open-source datasets, AI will continue to play a central role in accelerating discovery and translation into practice.

ETHICAL CONSIDERATIONS AND REGULATORY LANDSCAPE

The integration of AI into rheumatology brings forward a range of ethical challenges.[16] The key concerns are:

- *Data privacy and security*: AI systems in rheumatology often process longitudinal and sensitive health data, including genetic information and autoimmune histories. A breach in data would mean compromising security of patient data and loss of patient trust.
- *Bias and fairness:* Bias in AI training datasets can lead to underrepresentation of certain populations, thereby producing discriminatory outcomes. This is especially problematic in rheumatology where disease presentation may vary across ethnicities and even with in an ethnicity there could be varied presentations. This affects the validity of a model.
- *Transparency and explainability:* Many AI systems—particularly deep learning models—are considered "black boxes," making their decision-making processes difficult to interpret. Lack of explainability can hinder clinical trust of both patients and rheumatologists, and appropriate use of the model is hindered.
- *Prediction errors:* False positives or negatives in flare prediction or diagnosis can lead to overtreatment or missed interventions. Without adequate validation, such errors pose risks to patient safety.
- *Human oversight and accountability:* Overreliance on AI may undermine clinical judgment. Ensuring that clinicians retain responsibility and authority over AI-generated insights is essential to ethical use.
- *Liability and lifecycle monitoring:* Defining liability in the event of AI-related errors is complex. Developers, clinicians, and institutions must all share responsibility. Proper regulations regarding AI use in patient care is needed.
- *"Hallucination":* A phenomenon in LLMs, where models generate plausible-sounding but incorrect information. This can lead to misdiagnosis or inappropriate recommendations.[15]

The AI adoption in rheumatology must align with ethical imperatives. Safeguards around data privacy, equity, transparency, and clinical accountability are crucial.[16]

Globally, regulatory frameworks are evolving to address the ethical use of AI in healthcare. The European Union's AI Act, set to be enforced in 2026, is the first comprehensive legislation of its kind, classifying AI systems based on risk and imposing stringent requirements for high-risk applications, including those in medicine. These include mandates for transparency, human oversight, postmarket surveillance, and rigorous performance testing.[17] Journals increasingly require AI usage disclosures, and several tailored reporting frameworks have been developed—such as CONSORT-AI for clinical trials using AI, and CANGARU and MI-CLAIM GEN for AI using generative models respectively.[18-20] These standards aim to improve reproducibility, interpretability, and accountability in AI research. India must also establish clear guidelines to address algorithmic accountability, data governance, and equitable access to AI tools in clinical care.

FUTURE APPLICATIONS

Several innovations in AI applications are poised to transform the integration of AI in rheumatology **(Fig. 1)**. Federated learning is one such advancement, allowing AI models to learn from decentralized data across multiple institutions without sharing sensitive patient information. This approach improves generalizability and protects privacy, especially relevant in collaborative registries and multicenter research networks.[21]

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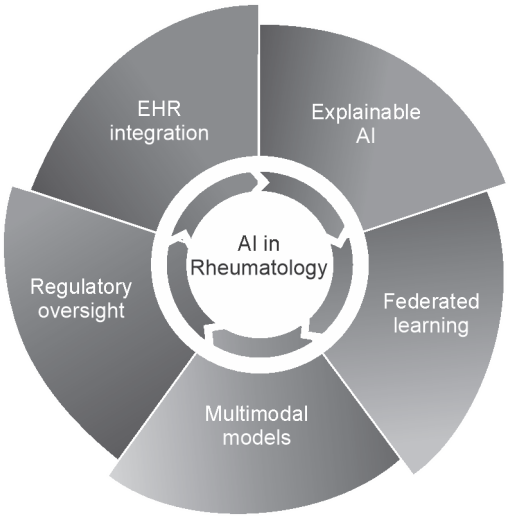

FIG. 1: Future ecosystem for responsible and scalable AI in rheumatology.
(AI: artificial intelligence; EHR: electronic health record)

Another emerging focus is explainable AI (XAI)—a set of methods that make AI decision-making processes more transparent and interpretable. Tools such as SHAP (SHapley Additive exPlanations) and LIME (Local Interpretable Model-Agnostic Explanations) can provide clinicians with insights into why a particular AI model recommended a diagnosis or treatment path, thus building trust and facilitating clinical adoption. These models are already being applied in Alzheimer's disease.[22]

Large language models will likely play an increasing role in clinical reasoning, integrating multimodal inputs—such as imaging, laboratory reports, pathology, and clinical notes—into cohesive interpretations that augment physician decision-making. Future EHR systems may include embedded AI assistants that synthesize complex patient data in real time. Future developments should emphasize collaboration, inclusivity, and validation of AI tools across diverse populations.

CONCLUSION

Artificial intelligence has rapidly emerged as a transformative force in rheumatology, influencing clinical care, research, and education. From streamlining referral pathways and enhancing diagnostic precision to predicting treatment outcomes and supporting personalized care, AI applications are expanding across the care continuum. In research, ML and LLMs are accelerating discovery and unlocking new insights from complex datasets.

However, the integration of AI into rheumatology must be approached with caution and accountability. Ethical, regulatory, and technical frameworks must evolve alongside innovation to ensure patient safety, equity, and transparency. With appropriate oversight and collaboration among clinicians, data scientists, policy makers, and patients, AI has the potential to not only augment human intelligence but also elevate the standard of rheumatologic care.

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