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The Uses of Artificial Intelligence in Rheumatology

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Abstract **Review Article**

Artificial intelligence refers to computers performing tasks typically linked to human intelligence, such as recognizing speech, understanding language, identifying objects, and translating between languages. These tasks often involve learning, allowing algorithms to adjust to the data they receive. The integration of AI in medicine, particularly, clinical practice such as rheumatology has revolutionized medical practice in terms of precision in diagnosis, and accuracy in treatment. The main objective of this study was to review the updates of the literature regarding the use of AI in rheumatology. The researcher reviewed the main research engines to collect cited literature. The results of this study confirmed the importance of the integration of AI into medicine to offer precision in diagnosis, cost-effectiveness, and therapeutic accuracy.

Keywords: Artificial Intelligence, rheumatology, diagnosis, precision, accuracy.

1. Introduction to Rheumatology and Artificial Intelligence (AI)

1.1 Artificial Intelligence Overview

Artificial intelligence (AI) refers to computers performing tasks typically linked to human intelligence, such as recognizing speech, understanding language, identifying objects, and translating between languages (García *et al.*, 2019). These tasks often involve learning, allowing algorithms to adjust to the data they receive (Mahesh, 2020). In the field of medicine, for example, the vast repositories of patient care data provide valuable resources for developing new algorithms, given their reliability and extensive data, which surpasses human capacity for interpretation (Abbaoui *et al.*, 2024).

1.2 Introduction to Rheumatology

Rheumatology is an independent, highly specialized branch of medical science that has been developed for the study, diagnostics, and treatment of chronic, long-term systemic diseases (Mannstadt and Mehta, 2024). The essence of these diseases is the abnormal behavior of connective tissue, and they are included in the connective tissue diseases group (CTD) (Zamora *et al.*, 2024).

The reasons for the development of rheumatology are the social necessity of resolving health problems as quickly and thoroughly as possible, and the scientific necessity of filling gaps in knowledge and addressing the uncertainty of unpredictable problems arising from complex structures with uncertain outcomes and their aggressive treatment (Radu and Bungau, 2021).

2. Definition and Scope of Rheumatology

Furthermore, in these many diseases and conditions, disorders like chronicity, relapses, and multiple symptoms are commonly seen, therefore it has been one of the clinical areas deeply associated with our physical discomfort (Choutka *et al.*, 2022). The fields of clinical rheumatology are made up of adult diseases such as rheumatoid arthritis, osteoarthritis, ankylosing spondylitis, hypocellular or hypercellular bone marrow problems, amyloidosis, and so on, pediatric diseases such as juvenile idiopathic arthritis, hypoplasia of the bone marrow, mucopolysaccharidoses, dermatomyositis, periodic fever syndrome, and so on, soft tissue diseases such as bursitis, tendonitis, synovitis, carpal tunnel syndrome, and so on, metabolic and endocrine system diseases such as osteoporosis, avascular necrosis of the femoral head, hyperparathyroidism, hypophyseal function disorder, and so on, other systemic diseases such as systemic lupus erythematosus, systemic scleroderma, dermatomyositis, mixed connective tissue disease, Sjogren syndrome, vasculitis, amyloidosis, and so on. Arthritis, which comprises various types of joint

diseases, is a common symptom of most rheumatologic diagnoses (Han *et al.*, 2016).

3. Introduction to Artificial Intelligence and Machine Learning

Because the development of AI systems is a very complex and multidisciplinary task (since a comprehensive AI system, much like the human brain, must have perception, attention, memory, imagination, and learning abilities), there is still no consensus regarding a unique and complete implementation to date (Markauskaite *et al.*, 2022). That is, in other words, current AI solutions can be tailored to solve specific tasks while other, equally important, tasks still require the intervention of human expertise (Capraro *et al.*, 2024). One sub-field of AI that has seen several very important developments in the last few years is the development of machine learning algorithms, which we will simply call learning algorithms. This comprises the use of certain classes of algorithms to make inferences and predictions given data (Feuerriegel *et al.*, 2024).

The creation of computers capable of performing tasks that typically require human intelligence was one of the biggest challenges of computer science since its conception. In other words, the idea of AI encompasses the development of algorithms that allow a machine to be able to solve a complex task that would otherwise need human intelligence to be either solved automatically (which is the goal of AI) or semi-automatically (i.e., with little human assistance) (Wang *et al.*, 2024). The first conceptualization of what we now refer to as AI appeared almost at the same time as the creation of the modern computer, and since then many contributions and research efforts have been made to develop AI solutions that can help experts in their daily tasks (Ashrafi and Javadi, 2024). These solutions are used in a rather broad set of scientific and societal domains, and the tasks that are currently solved by AI systems range from simple calculations to more complex reasoning problems (Ashrafi and Javadi, 2024).

4. Current Challenges in Rheumatology Diagnosis and Treatment

The major clinical challenges in the management of patients with rheumatoid arthritis (RA) are making a timely diagnosis, excluding other conditions that can present with similar symptoms, starting effective therapy, and reaching clinical remission while preventing relapses and managing established or still unrecognized comorbidities, such as fragility fractures (Raslan *et al.*, 2024). Early treatment has become increasingly important because a significant proportion of patients do not respond well to conventional synthetic disease-modifying antirheumatic drugs and require biologic drugs or targeted synthetics (Kjørholt *et al.*, 2024). Unfortunately, there are no validated instruments to predict which patients will have a good or bad response to treatment, so most guidelines suggest starting with a bDMARD in poor prognosis patients despite the substantial economic burden they represent to the healthcare system (Novella-Navarro *et al.*, 2020,).

4.1. Complexity of Rheumatic Diseases

The complexity of rheumatic diseases (RD) is associated with a broad spectrum of different diseases with an impact that goes beyond the musculoskeletal system. These conditions can affect any age, including early life, have different clinical presentations with periods of remissions and flares, and can have a significant impact on the patient's quality of life and life expectancy (Bullock *et al.*, 2018). Therefore, it is necessary to approach them with a multidisciplinary team. A complementary Oriental Medicine approach emerges as an important way of acting, due to the typical involvement of many organs and systems (Zeng and Jia, 2024). In some cases, like osteoarthritis or gout, used as examples, clinical manifestations are not exclusive and other diseases might have a similar clinical presentation (Sudoł-Szopińska *et al.*, 2024). The association with serologic analysis and radiological cortical, trabecular bone, and 3D cylindrical parameters provide sound results in their applications (Trincă *et al.*, 2021).

4.2. Limited Access to Rheumatologists

Alternative medical assessment methods should be made affordable without the need for professional services in the field of rheumatology, using applied artificial intelligence techniques (Al-Maini *et al.*, 2023). In the early diagnosis as well as the treatment stages of the disease, the importance of early diagnosis of RA can also be great because the patients cannot get an early appointment from the sparse number of rheumatologists available (Lespasio *et al.*, 2018). Neural networks are one of the most common strategies used for forecasting issues in medical diagnosis. They can be applied to both linear and nonlinear datasets (Kufel *et al.*, 2023). Neural network architecture, the number of hidden cells, activation function, the contact of network equations, diversity, and mode of real data are some of the critical neural network modeling techniques. According to a critical neural network configuration, there is no universally recognized method (Montesinos López *et al.*, 2022).

The first barrier any patient faces when seeking medical attention is physician accessibility. The major musculoskeletal issue for the general adult population is back pain, with a high risk of developing into chronic pain (El-Tallawy *et al.*, 2021). Because society is aging, degenerative diseases such as pseudarthrosis, temporary auto-fusion, shared psychotic disorder, spinal stenosis, and ossification of the yellow ligament are shaping the future and are extremely pronounced (Emami *et al.*, 2018). The sole treatment for such problems is conducted by rheumatology professionals. There is a severe shortage of rheumatologists able to take care of this ever-growing demand. Although the proportion of

rheumatologists among practicing physicians did not change significantly, the interest in rheumatology as a medical specialty and the approaching rheumatology workforce in the United States continued to decrease (Puchner *et al.,* 2020). In recognizing the limited availability of professional services, robotic surgery is the only technology for integrating advanced technologies into the clinical care of patient populations (Reddy *et al.,* 2023).

5. Applications of AI in Rheumatology

AI may be helpful in primary and secondary diagnosis and treatment management in cases that present diagnostic challenges like RA. Automatic data processing recognizes biomarkers or diseases and provides a predicted score, which also aids the doctor in assessing a patient's severity and finding sooner which anti-inflammatory drug most accurately suits the person. Such data is beneficial for monitoring the progress of subjects participating in specific treatment or drug-test studies, furthermore, having a favorable impact on patient pharmacotherapy. Data on monitoring disease development and the anti-inflammatory treatment chosen to improve the patient's experience can be useful in assisting an analysis of the patient's experience pattern (Krishnan *et al.,* 2023). AI may assist radiologists in imaging-based disease detection and diagnosis, reducing the rate of false positive errors with other techniques. Rheumatology is a field that could benefit from an encouraging result among several AI-engineered data systems; therefore, AI's future in the world of rheumatology can be revolutionary (Najjar, 203).

It has been increasingly necessary to apply AI in the field of rheumatology in recent years. It can also help doctors make more accurate diagnoses and prognoses, facilitating decision-making. AI's competitiveness is starting to speak for itself, and shortly, no doctor will be dispensable, so that both can grow in knowledge, making the doctors' work increasingly ergonomic and safe. Disease-specific AI models, including Rheumatoid Arthritis (RA), provide valuable diagnostic and therapeutic resources (Dudek *et al.,* 2024). It is very difficult to make a diagnosis through a pattern in imaging exams. The use of AI techniques for the analysis of these data can be beneficial. The output of the segmentation is typically a binary image in the same format as the original image, where the number of pixels that are classified as padding corresponds to the numerator and denominator of the Jaccard index (Pinto-Coelho, 2023).

5.1. Automated Diagnosis and Classification of Rheumatic Diseases

The available rheumatology literature on ANCA-associated vasculitis (AAV) reveals the use of alignment models in retrospective cohorts to generate diagnosis prediction models using clinical data. Nevertheless, these reports are limited to relatively low numbers of hospitalized patients. It is noteworthy that not only do the studies described avoid the so-called algorithm-based syndrome, but also the model input consists of relatively simple clinical or laboratory data. The development of a cutting-edge rheumatic disease classifier using only three z-transformed laboratory results: C-reactive protein level, erythrocyte sedimentation rate, and serum albumin levels. In contrast, the genomics of variety in inflammatory disease studies linked various types of polymyalgia rheumatica to differences in immune cell-associated gene expression (Chen *et al.,* 2023). The use of dimensionality reduction methods in the genomics of variety in inflammatory disease studies to understand the complexity underlying immune response in the synovium of rheumatoid arthritis patients or to disentangle the complexity of different clinical forms of ANCA-associated vasculitis is only an example of the many uses of machine learning in this field (Tay *et al.,* 2019).

For almost twenty years, machine learning classification techniques have been used to mine rheumatic disease datasets, aiming to extract the best from clinical profiles in diseases like polymyalgia rheumatica, systemic lupus erythematosus, or giant cell arteritis. As digitized clinical data becomes increasingly accessible to researchers, the number of potential machine-learning applications in precision medicine increases (McMaster *et al.,* 2022). These advances will, in turn, lead to improvements in the diagnosis and classification of complex syndromes such as ANCA-associated vasculitis and systemic sclerosis. For decades, the development of algorithms for decision support using clinical data has outperformed human practitioners. The seminal 1980 PRODIGY program by Miller and colleagues is still good evidence of the impact of deep computational knowledge extraction from clinical data. The utilization and selection of complementary machine learning algorithms to mine data and infer models have been successfully used to diagnose complex diseases (Clark *et al.,* 2023).

5.2. Personalized Treatment Plans

The output data is usually qualitative rather than quantitative, and it can be used to design diagnostic, decision support, or therapeutic models. These models require the use of an inductive inference engine, such as decision trees, probabilistic networks, fuzzy logic, and rough sets. These engines process the details of each case to provide advice in the form of interpretation rules. These rules are both general, applying to similar patients, and specific, based on the patient and their disease (Nopour *et al.,* 2021). The input data consists of the patient's response to the treatments used, while the outcomes are used to select the best therapeutic option for the individual patient at a specific time in their life.

Currently, personalized treatment plans are already being used in clinical practice for patients with rheumatic diseases. The main goal is to improve the

long-term prognosis and make the best use of available resources for each patient (Bywall *et al.,* 2023).

6. Benefits and Limitations of AI in Rheumatology

Other factors include regulatory requirements for the use of AI in Rheumatology such as ethical considerations, programs, teams, and organizational structure, etc. Datasets used in the development of various AI techniques can be quite disparate, as just borrowing the information from primary locations does not typically build AI algorithms that generalize (D'Antonoli, 2020). For example, the use of electronic health records (EHRs) does not capture the patient populations who may not encounter healthcare through traditional channels. In some cases, the rich information in EHRs might be used primarily as a training set, while the initial information is obtained from other sources, such as the collection of patient-reported outcomes (Tsai *et al.,* 2020).

AI is an emerging transformative technology today. Healthcare is one of the fields poised to gain tremendously, and Rheumatology has much to gain by incorporating these techniques as well. The future of patient care and Rheumatology is dependent on the use of data, information systems, and advanced analytics for the quintuple aim. We will be discussing the different AI techniques along with their applications and limitations, and how they might evolve in the Rheumatology field (Bajwa *et al.,* 2021). AI consists of several different techniques such as machine learning, which includes supervised, unsupervised, and reinforcement learning. Within supervised learning, several models are used such as Naïve Bayes, linear, polynomial, logistic regression, etc., along with non-parametric techniques such as decision trees, random forest, support vector machines, k-nearest neighbor, neural networks, and boosting techniques (Sarker, 2021).

6.1. Improved Diagnostic Accuracy and Efficiency

AI and machine learning methods can comb through patient data and deliver from a vast array of sources. Electronic health records, radiographs, magnetic resonance imaging, laboratory tests, and tissue or serological biomarkers could provide a lot of information when it comes to diagnosing patients efficiently and accurately (Krishnan *et al.,* 2023). When AI and machine learning algorithms are compared to traditional clinical reasoning, it is evident that they outperform traditional statistical models without a lot of thought or emotion. The consistency and efficiency are what make clinical diagnoses faster and maybe more accurate. This increased efficiency allows the provider to have more time to spend with patients instead of data collection and entry. Once data is delivered from the source, these automated algorithms can analyze, organize, and assess data in the same manner as a trained specialist without the training time, career trajectory, or free-thinking abilities of a human provider (Karalis, 2024).

The consistent algorithms, in turn, could reduce cycles of care across the spectrum of health care, from more rapid, stable management of patients with chronic diseases to reducing unnecessary antibiotic prescribing. When this is translated to Rheumatology, the field will be forever changed (Mohamed *et al.,* 2024).

AI and machine learning methods can comb through patient data from a vast array of sources such as labs, imaging, and electronic health records. When this is compared to traditional clinical reasoning, it is evident that these automated algorithms can outperform traditional statistical models with ease (Karalis, 2024). Consistency and efficiency are what make clinical diagnoses more accurate. This increased efficiency allows the provider to have more time to spend with patients instead of data collection and entry. These accurate, efficient data mining techniques that AI and machine learning provide could pinpoint high-risk groups in the population in time to prevent serious illness or death (Bečulić *et al.,* 2024).

6.2 The Use of AI in Magnetic Resonance Imaging Analysis for Rheumatology

The fundamental physical principles of magnetism and radiofrequency (RF) waves, as well as the computer-related technical features of signal acquisition and processing, are reviewed to allow efficient improvement of MR imaging techniques and the proper understanding of the appearance of pathological findings on MR images. An overview of the anatomy of the normal joints of the musculature system allows a better understanding of the complexity of potential pathological findings, highlighting the information of MR images (Nicoara *et al.,* 2023).

Knowledge of biochemistry is required for a conditioned understanding of potential pathological findings in inflammatory joint diseases. The pathogenesis of joint involvement is usually dynamic, involving a series of sequential inflammatory events that take place on vascularized tissue in their initial phase. Eventually, these processes involve adjacent hypovascularized structures, such as articular cartilage and bony structures. Accordingly, the sequence of potential pathological findings on MR images seems to follow the sequence of the progressive pathological events, being dependent on the actual location of the joint involvement at the moment of the MR examination (Weaver *et al.,* 2022).

Progressive potential pathological findings involving the cartilage-bone-synovium-hypertrophic bone-pannus-subligamentous bone-iliopsoas tendon, and other structures are presented, together with their pathogenesis, and with the expected behaviors of these findings on MR images, depending on the MRI technique used (i.e., on TR, TE, and other factors) (Turan *et al.,* 2017).

Particular attention is paid to potential finding artifacts. An overview of the normal and pathological vascularization of the joints is provided, together with significant MR angiography aspects, to approach the topic of vascularized joint involvement in Magnetic resonance imaging of rheumatological diseases (Blum *et al.*, 2021).

The characteristics of the viscous synovial fluid are described, together with the phantoms and techniques developed to explore them in vivo, to offer a better understanding of the biomechanical implications of arthritis on the interaction of the cartilage-bone complex with nutrients, as well as of the potential development of alloplastic steels (Tamer *et al.*, 2013).

6.2.1 Applications of Artificial Intelligence in MRI Analysis for Rheumatologic Conditions

Innovation has become necessary due to the great demand for improvement in rheumatology practice, whether in treatment, diagnosis, or finding new biomarkers, as well as better cost-effectiveness, preservation of resources, and support in clinical environments as day-to-day patient care becomes more and more complex. Artificial Intelligence has made a positive impact on various paths of innovation (Benavent *et al.*, 2024).

It has been proposed that a convolutional neural network (CNN) algorithm for image processing of MRI scans with knee osteoarthritis by enhancing images using a set of filters, allowing better evaluation of synovial membranes and periaqueductal gray grenses (Subhas *et al.*, 2020).

6.3 Ethical and Regulatory Considerations

The challenge of harnessing AI for the benefit of patients, companies, and health systems must be addressed urgently at every level of the stakeholder's communities, to which we should add the regulatory constraints in considering the right balance between benefits and risks. There is no doubt that AI can dramatically shift the paradigms towards personalized medicine, allowing the development of innovative drugs to predict the response to treatments and by the generalization of the patient-reported outcome measures throughout the complete patient journey (Yelne *et al.*, 2023). In parallel, innovative HR or professional organizations should necessarily follow. Considering the huge potential benefit of these new developments, it will be critical to collaborate and to create the ground for the development and approval of these disruptive innovations (Henderikx and Stoffers, 2023).

AI is increasingly being used and tested in the domain of drug development, but its use in identifying biomarkers to predict response to treatment is once again in its infancy. The development, validation, and clinical implementation of these AI-based tools for predicting responses require particular attention to avoid biases and a lack of generalizability (Vora *et al.*, 2023).

The general challenge of harnessing AI tools for the benefit of patients, companies, and health systems must be addressed urgently at every level of stakeholders, to which we should add regulatory constraints in considering the right balance between benefits and risks. Meanwhile, AI can be increasingly used in randomized clinical trials, for instance by modeling patients' inclusion criteria and creating virtual populations, which would allow real-life confirmatory trials before valorizing actual real-life data. Although a clear vision is needed, a pragmatic and feasible approach should not be jeopardized when solutions present a level of certainty that would otherwise discourage any attempt at innovation (Mennella *et al.*, 2024).

CONCLUSIONS

The use of AI in rheumatology, particularly clinical practice has been recognized as a revolutionary aspect in recent medicine. AI helps in achieving a precise and accurate diagnosis. Analyzing large medical data using AI systems can recognize examples and associations, a matter that exceeds observations made by humans, which, in turn, gives more accurate interventions**.** Furthermore, AI reduces the cost associated with health services.

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