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Use of artificial intelligence in rheumatoid arthritis

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Abstract:

Early diagnosis of rheumatoid arthritis (RA) is essential in preventing irreversible joint damage, disease progression, reducing symptoms, and improving long-term outcomes for patients. Artificial intelligence (AI) including machine learning (ML) and deep learning (DL) have the potential of helping medical professionals in detecting RA at an early stage and therefore helping in disease management and timely intervention. However, more research is required to confirm dependabillity of AI in RA. Despite the promising results achieved by AI models they are not fully ready to be used in clinical practice. Future investigations are required to create reliable algorithms.

Objective:

The objective of this research is to determine the potential use of AI in diagnosing RA and improving long-term outcomes for patients.

Keywords:

Rheumatoid arthritis, Artificial intelligence, deep learning, machine learning

Introduction:

Rheumatoid arthritis (RA) is one of the most commonly spread autoimmune diseases in the world with an estimate of 17.6 million cases as of 2020 [1]. RA is a chronic autoimmune disease with inflammation and unclear etymology affecting many joints including hands, feet, pulmonary fibrosis etc. [2,3]. It most commonly starts in the small joints of the body impacting everyday life. RA affects any gender at any age but is 2-3 times more likely to occur in women between the age 60-70 [1]. The disease affects mortality, disability, chronic pain, joint disfunction and deformation and causes premature death [4]. Over the years advancements have been made when it comes to treating RA. However, improvements can be made when it comes to an early diagnosis, treatment and effective management of RA. Diagnosis of RA lacks gold standard tests or well-established criteria [5], it involves thorough clinical, laboratory and imagining findings. Blood tests are done in order to look for rheumatoid factor (RF) and anti-citrullinated protein antibodies (ACPAs). The existence of these antibodies can help with diagnosing RA. However, lack of these antibodies does not rule out the possibility of having RA [6]. The most commonly used criteria when it comes to RA diagnosis and classification are the 2010 American College of Rheumatology/European League Against Rheumatism (ACR/EULAR) classification system [7]. Prompt intervention is crucial for slowing down disease progression and minimizing permanent joint damage. Challenges include difficulties in selecting appropriate medications, poor adherence to treatment, and variability in patients' responses to drugs [3]. First-line treatments typically involve non-steroidal anti-inflammatory drugs (NSAIDs) and corticosteroids, followed by disease-modifying anti-rheumatic drugs (DMARDs). Methotrexate (MTX) is generally the preferred initial DMARD, though it can be replaced or supplemented with other therapies if necessary [8]. There is a need for personalized medicine approaches and biomarkers to predict the effectiveness of treatments. Additionally, RA is a chronic condition that requires ongoing management to control symptoms, prevent joint damage, and enhance the quality of life. However, low adherence to treatment, insufficient follow-up visits, and inadequate management of chronic conditions contribute to a high rate of disease relapse. Therefore, significant efforts in early diagnosis, timely intervention, predicting disease progression, and managing the condition are vital to improving long-term outcomes for RA patients [3].

Artificial intelligence (AI) is described as machine's ability to copy human behavior and intelligence such as reasoning, deep learning and reasoning [9]. Machine learning is one of the subgroups of AI. It is a powerful analytic device that relies on using advanced algorithms to process medical data and help physicians in various settings [10]. The use of AI/ML can be used in complex situations such as drug development, personalized treatment, medical images, randomized controlled trials (RCTs) and many more [10][11]. Deep learning is a subset of ML which combines multiple ML processes with each other [12]. DL is a more potent tool that is based on artificial neural networks (ANNs). It can address various tasks without the need for human intervention [13]. Over the years DL experienced big development and is expected to undergo constant evolution [14]. The use of AI in rheumatology has not been as big as in other fields. More studies are needed in developing and implementing AI methods in diagnosing and treating RA [3].

Methods:

We conducted an online search using PubMed in April 2025 using the following keywords: “rheumatoid arthritis" AND ("artificial intelligence" OR "machine learning" OR "machine intelligence" OR "deep learning"). The study selection was limited to full-text studies published between 2020 to 2025 and the aim was related to the diagnosis, intervention, and management of RA. We aim to provide a review of recent studies connected to the use of AI in RA. We will focus on showing the potential role of AI in diagnosis, treatment and management of RA.

Discussion:

Use of AI in the diagnosing of RA

Early diagnosis of RA helps with preventing structural damage that leads to disability [15]. Therefore, it is important to diagnose patients as early as possible to give them better treatment and outcomes. However, early diagnosis of RA can be difficult because of the non-specific symptoms that are present at the beginning of RA, such as joint pain [16]. Another problem comes from the fact that RA can present itself differently depending on patient to patient and as of now there is no specific test for RA. Diagnosis includes clinical evaluations, imaging test and laboratory tests (rheumatoid factor (RF) and anti-cyclic citrullinated peptide (anti-CCP) antibodies, erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP) [17]. However, RF and ACPA have suboptimal sensitivity, while ESR and CRP have limited specificity. The lack of an optimal biomarker with high sensitivity and specificity requires the development of new biomarker panels for early identification of RA [18][19].

A lot of research using machine learning has been conducted to aid in the diagnosis of rheumatoid arthritis to help clinicians make more accurate and faster diagnostic decisions.

Artificial intelligence algorithms such as naive Bayes, convolutional neural network (CNN), logistic regression, and support vector machine (SVM) or deep learning can analyze imaging data to detect subtle changes in joints that may indicate early RA. CT, MRI and X-rays are commonly used to monitor changes in joints and progression of RA [20][21]. Bai et al. [22] developed a method using X-ray hand images for detecting finger joint involvement in RA by training artificial neural network (ANN) and they achieved 91,8% accuracy.

Another method for helping with early diagnosis of RA could be analysis of omics (i.e., genomics, transcriptomics, proteomics, metabolomics, lipidomics, glycomics, or metagenomic) using AI. Using machine learning in the analysis allows for simultaneous assessment of the association of numerous biomolecules with RA [23].

Liu and colleagues assessed gene expression profiles of peripheral blood cells and identified 52 differentially expressed genes in patients with RA. Further protein–protein analysis identified nine hub genes with crucial roles in the development of RA, which are fundamental in immune regulation, namely CFL1, COTL1, ACTG1, PFN1, LCP1, LCK, HLA-E, FYN, and HLA-DRA. The logistic regression and random forest models showed an AUC ≥ 0.97 for the panel of these nine messenger RNAs (mRNAs) in distinguishing RA from healthy samples [24]. In one other investigation of gene expression profile, Pratt et al. showed that a 12-gene transcriptional pattern in peripheral blood cluster of differentiation (CD) 4 + T cells could predict the development of RA in patients with undifferentiated arthritis during a median follow-up of 28 months [25]. Other diagnostic models have been developed using omics data derived from serum, particularly inflammatory and oxidative stress markers. Analysis of circulatory levels of 38 cytokines using an artificial neural network (ANN) resulted in a model with a sensitivity and specificity of 100% in differentiating patients with RA from controls and patients with osteoarthritis (OA). Heard et al used a single decision tree to identify cytokines that had the greatest impact on the model's outcome. These cytokines included CD40L, transforming growth factor (TGF)-α, epidermal growth factor (EGF), interferon (IFN)-γ, eotaxin, macrophage inflammatory protein (MIP)-1β, tumor necrosis factor (TNF)-α, IL-1α, granulocyte colony-stimulating factor (G-CSF), fractalkine, growth-regulating oncogene (GRO), and vascular endothelial growth factor (VEGF). The levels of cytokines such as eotaxin, G-CSF, IL-1α, TGF-α, and TNF-α did not show statistically significant differences between groups using classical statistical methods. This result emphasizes the need to use machine learning algorithms as a complement to conventional statistical analyses to develop optimal diagnostic panels [26].

Biomarkers used for diagnosis of RA do not have high sensitivity. With the advancement of AI, DL and ML studies have been done to show the potential use of AI in the early diagnosis, treatment, and development in RA through inflammatory changes seen in MRI [27] [28].

Shlereth et al. [27] used a 3D residual network (ResNet-3D) to automatically segment bone erosion, synovitis and edema in the group of 60 RA patients who were undergoing a 48-week treatment with baricitinib. The assessment was done by using RAMRIS score and pre- and post-contrast T1W and T2W coronal MRI sequences. By the end of the treatment, the reduction of RAMRIS score was observed, decreasing from 20,6 at week 0 to 18,3 at week 48. Mc Ardle et al [29] created a random forest model that showed a good performance in differentiating between patients with RA and psoriatic arthritis by evaluating serum protein biomarkers. The model achieved an area under the curve (AUC) of 0.85 in the subsequent validation phase. The researchers created a matching learning feature selection pipeline, which identified new biomarkers for RA in over 2000 blood samples from RA patients [30].

Overall, by using AI in the diagnostic process, clinicians may be able to identify RA earlier, which can prevent progression of the disease. However, further research is needed to validate the reliability and accuracy of AI in diagnosing RA.

Use of AI in disease management of RA

Proper management of RA is a crucial task to prevent poor outcomes such as joint damage, increased disease activity, and disability. Patients should be treated with personalized and effective treatments for the best outcomes. However, low compliance with follow up appointments and lack of disease management are common problems with RA treatment [31]. AI has shown potential in overcoming these barriers. One way to improve management in RA is by monitoring the disease including notification for medications, scheduling follow-ups. Gossec et al. [32] used data form wearable trackers to predict flare sensitivity, and a connected monitoring interface developed by Pers et al. Lowered the number of physical visits [33].

Point care ultrasound (POCUS) is frequently used in monitoring disease activity in RA. Images are a great source of data for AI models. Access to large amounts of data has enabled the development of deep learning models for image recognition and analysis [34]. Fiorentino et al. used CNNs to accurately identify the cartilage interface (margins) within the metacarpal joints and to make accurate thickness measurements. Their model proved to be very accurate, with a mean absolute difference (*ADF*) comparable to the intra-observer variability of skilled clinicians in the study [35].

Irreversible joint damage is one of the markers of disease progression and is monitored with radiographs. Combinations of joint space narrowing and erosion are typically used to quantify radiographic changes in RA. However, these systems can be hard to implement [36]. Hirano et al. [37] developed a deep learning model to identify and assess joint damage on hand radiographs. They achieved this in two steps; they first used a ML model to detect the small finger joints (MCP, PIP etc.) and then used a deep learning model (CNN) to score joint destruction (utilizing the Sharp/van der Heijde method).

Conclusion:

Artificial intelligence has the potential to detect RA earlier, facilitate early intervention, and better disease management. Further investigations are required to develop reliable algorithms.

Disclosure:

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