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Effect of DMARDs (Methotrexate) on Rheumatoid Arthritis using MRI-Informed CNN

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***Abstract*—Rheumatoid arthritis (RA) in elderly people causes joint discomfort, swelling, and bone degradation, limiting their mobility and lifestyle. Disease-modifying antirheumatic medications (DMARDs) like methotrexate (MTX) are extremely experimental and cause discomfort, nausea, and inflammation. RA diagnosis research has had little impact on treatment. To improve treatment and recovery, patients must determine DMARD side effects based on their symptoms and information. Convolutional neural networks (CNNs) trained on magnetic resonance imaging (MRI) scans may identify joint patterns and predict treatment outcomes. This research investigates whether MRI-informed CNN can improve DMARD clinical trials for RA. A CNN will be trained on MRI scans of RA patients who received MTX. The CNN will classify images by inflammation and damage and compare them to patient outcomes. MRI-informed CNN may be used to assess DMARD efficacy in RA treatment. This work may lead to more accurate and efficient clinical trial procedures for RA medication efficacy evaluation.**

***Index Terms*—Magnetic resonance imaging (MRI), Rheumatoid arthritis (RA), Convolutional neural network (CNN)**

I. Introduction

Scientific communities can utilize machines with high levels of accuracy and efficiency to diagnose patients, replacing the inadequacies of humans in a precise field of disease treatment and prediction. Optimizing machine learning models further enhances the likelihood of its undoubtedly positive effects on the medical field, even suggesting new applications. One of the foremost diseases afflicting the elderly population is rheumatoid arthritis (RA), which causes painful swelling and diminishes patients' quality of life. Though treatments are readily available, they introduce the risk of even greater pain to their users through numerous side effects. Analyzing treatments' effects on patients based on their conditions avoids detrimental collateral risks.

II. Research Question

The research question for this paper is as follows: How can magnetic resonance image classifications by trained Convolutional Neural Networks (CNN) advance clinical trials of disease-modifying antirheumatic drug's effectiveness in rheumatoid arthritis treatment?

III. Literature Review

Though primary evidence of similar diseases has been found in prehistoric animals, the first human reference to arthritis was found to be in 4500 BC [10]. This description drew many parallels to what we know today as rheumatoid arthritis, an autoimmune and inflammatory disease that affects joints associated with continual usage [3]. First making a distinction between osteoarthritis and rheumatic gout, A.B. Garrod titled this disease rheumatoid arthritis and paved the way for further examination into the field [7]. As it inflames the linings of joints, the disease causes painful swelling for its nearly 1.3 million victims and prompts other health developments, such as general pain, fatigue, and even bone erosion [15]. Yearly, approximately 200,000 more afflicted people in the U.S. are stripped of their autonomy as their conditions worsen [21]. Moreover, RA has a serious socioeconomic impact on patients' lives, reducing their health-related quality of life more than other similar chronic diseases [17]. The prevailing treatments of RA are disease-modifying antirheumatic drugs (DMARDs), aimed to reduce inflammation and other underlying conditions [16]. Disease-modifying antirheumatic drugs (DMARDs) are a group of medications commonly used in people with rheumatoid arthritis. Some of these drugs are also used in treating other conditions such as ankylosing spondylitis, psoriatic arthritis, and systemic lupus erythematosus. One such DMARD is known as methotrexate (MTX), consumed as a pill in scheduled doses over months; it is recognized by the FDA and proven to cause symptomatic improvement in patients with a high efficacy rate [2]. One-third of patients, after a year of treatment, see no active radiographic progression, as seen in [20], and even see reductions in symptoms. Though advances have been made to quantify the effectiveness of DMARDs, patients can risk sustaining their dangerous side effects through prolonged usage [6]. The necessity of novel analysis methods is at an all-time high; to best reduce the implications of experimental drugs, predictions on the effectiveness of DMARD usage should be considered when prescribing solutions for patients. Information regarding preliminary drug results can be found in magnetic resonance imaging (MRI) scans of the affected areas. MRI enables medical professionals to visualize a patient's inner organs and tissues using a large scanner

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[12]. In regards to RA, bone erosion can easily be spotted and distinguished among other tissues to varying degrees but it has been difficult to assess the impact of DMARDs without their implementation on patients. MRI scans can be sorted into databases, where they are preprocessed and resized to optimize results from an analytical neural network. Specifically, a convolutional neural network is a class of artificial neural networks; it can gain proficiency with the training of analyzing images with predetermined layers and biases to produce binary conclusions and accuracy reports [11]. Particularly, the CNN consists of multiple convolutional and pooling layers (see Figure 1), where high-level details are converted into numbers for patterns to be analyzed and the input is filtered to reduce complexity, respectively [14]. Then, the fully connected layer is where images are classified based on the patterns detected and inputted; filters on successive layers increase in complexity [1].

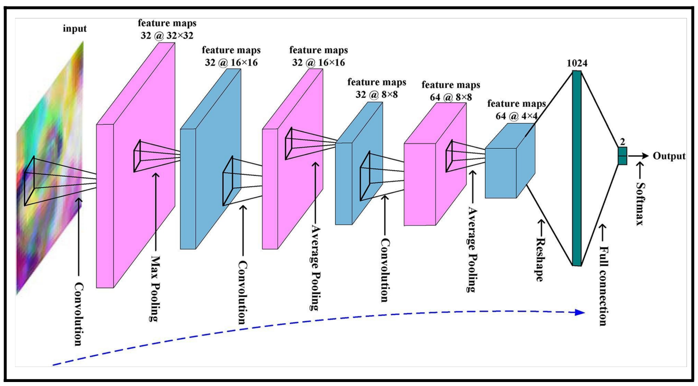

Fig. 1. Architecture of a CNN model (Lin 2018)

Predominantly, CNNs are used for real-world applications such as face detection, image analysis, and pattern recognition, but can be best put to use in a medical context [19]. Researching medical applications of this powerful computational tool using MRI scans can ease the dangerous side effects of patients prescribed with experimental DMARDS–predictions can be made to determine the optimal course of action for each patient.

IV. Experimental Design

A. Objectives

The experiments aim to utilize CNNs to analyze and predict alterations in RA patients being treated with MTX. Experimental methods have been synthesized from other successful studies in similar fields to improve efficiency.

B. Methods

1) Participatory Information: Data will be collected from the output of a trained CNN to predict the effectiveness of MTX on the conditions of patients, observed through an MRI scan, to determine the ideal course of medication (type, frequency, etc [see Figure 2]). Participatory groups, given their medical and informational consent, will consist of a control and experimental; in the control, approximately 25 participants will have RA and remain untreated. In the experimental group, 50 patients will have RA with half treated with MTX and the other half with a placebo. These groups are substantial in providing high-accuracy results for the CNN while being representative of populations across the globe, particularly from ages 30-50 [3].

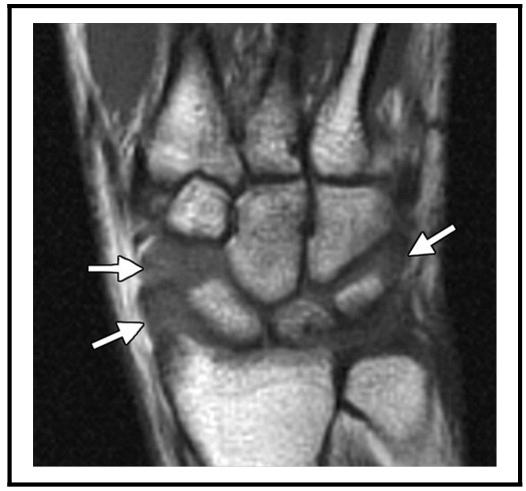

Fig. 2. Architecture of a CNN model (Lin 2018)

V. CNN Application

The algorithm will be implemented in Python, using the TensorFlow and Keras libraries, importing calculation and file modules for organization [22]. To optimize the data for the ideal CNN input conditions, it must be preprocessed through resizing, normalizing, and scanning functions [5]. Building the training and validation datasets will be done to organize the input and allow the network to show its optimal effectiveness. The control group and the untreated experimental samples' scans will be input into the neural network for it to train, refining itself with a correction algorithm. This algorithm will be dependent on comparisons with data from healthy patients, provided by MRI bone databases [13]. Based on expected data size, read-in, and computer processing time, these images will be stored in a picture archiving and communication system (PACS), where radiology images are frequently stored with relevant metadata [18]. Based on the model's accuracy, there can be key takeaways for the future of CNNs in RA treatments.

VI. Results

If the precision is over the 95% threshold, it can be classified as a reliable predictor (see Figure 3). Comparing the model's predictions for whether DMARD implementation will be useful on experimental patients to their actual results will open the door for new specifications in this field, such as precise recommendations for medication dosage and types, personalized for each patient to ensure optimal recovery. In the sample data above, it can be noticed that Algorithm 3 seems to have the highest accuracy as a result of an increased number

	Algorithm 1	Algorithm 2	Algorithm 3
Number of Samples	200	250	300
Learning Rate	0.05	0.1	0.25
Training Time (s)	143	112	96
Mean Squared Error	0.01	0.005	0.002
Accuracy %	68.235	86.713	96.458

Fig. 3. Sample Result Table Based on CNN

of samples. This trend holds true in real CNN-based studies and correlates to the Mean Squared Error results. Additionally, the inclusion of multiple algorithms can optimize accuracy and training time processes. Reaching the aforementioned precision threshold, the CNN outlined by Algorithm 3 can be reliably used, with the assistance of doctors to provide reassurance.

VII. Limitations

However, limitations, such as the sampling method or predetermined biases of the CNN, in the experimental design may lead to moderate inaccuracies in the conclusions. Symptom onset for individuals is a highly variable factor that could result in false negatives and incorrect predictions, making it ill-suited for real-life applications. Yet, these drawbacks can be answered with the use of non-RA patient data in the CNN training process; this higher level of complexity enables it to make accurate predictions with certainty [9].

VIII. Analysis

The data will be analyzed by standards of averages, accuracy, outliers, and general progress compared to similar neural networks. The CNN's predictions for whether DMARDs will be effective, contingent on certain patterns of bone erosion, will be compared to how DMARD usage appeared on the patient's conditions and general health. A benefit analysis will be conducted to see whether the sustained use of CNNs can substantiate the pressures of required high-accuracy input parameters.

IX. Hypothesis

Similar to other neural networks, the results of the CNN will slowly become more and more accurate to reach above the outlined threshold. Valuable takeaways can uncover multiple paths of medication any given patient is best suited for. It is probable that, with more optimized training algorithms, this CNN will be able to determine likely DMARD effectiveness for patients with precision and speed.

X. Conclusion

The further and extensive use of analytical techniques, such as neural networks, can enable breakthroughs and advancements in the medical field. In regards to rheumatoid arthritis, experimental medication is provided for patients to remedy some of its symptoms. However, this comes at a heavy price, as even the most common DMARDs, such as MTX, have side effects that include but are not limited to nausea, fatigue, headaches, unusual bleeding, and general body pain [4]. To best understand these effects before they happen, an MRI-informed CNN will be used as a predictor. With ample input data, the neural network can learn by adjusting biases and weights as information passes through convolutional and pooling layers to optimize important image details, such as a major area of bone erosion commonly associated with RA. Once the machine has a confidence level of 95% or higher, it can be preliminarily used in experimental settings with user data to begin its real-world applications. For many years, patients have struggled with the side effects of medication, which shouldn't be the reality of modern medicine. Convolutional neural networks can pave the way for image classification and should be used to determine how RA patients will react to treatments and create further recommendations accordingly.

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