Integrating Dynamic Simulation Modeling To Assess Pathophysiology Of Arthritis

Maham Fatima, Haroon Ur Rashid Kayani, Fatma Hussain, Hafiz Burhan Ul Haq

Abstract: Computer Simulations are useful means for the modeling of the many systems in natural sciences. Arthritis is normally the inflammation of joints. Rheumatoid and Osteoarthritis are common forms of arthritis. Different tests are used by physicians for the diagnosis, management, and treatment of arthritis. However, advanced computational modeling techniques based on Python, MATLAB, machine learning, and artificial neural networks are being used for this purpose for the last few decades. This review highlights the contribution of different algorithms used to assess diverse pathophysiological aspects of arthritis. These algorithms can improve performance automatically and have great potential to expand current biomedical knowledge about arthritis. It is capable of finding new features and correlations in datasets that mostly include laboratory analysis, medical history, gene sequences, and electronic health records.

Index Terms: Simulation modeling, Osteoarthritis, Python, Infrared thermography, Joint degeneration, MATLAB, Artificial neural networks.

1 Introduction

Computer simulation methods are used to analyze the outcomes of alternative strategies and to control the spread of infectious diseases. Simulation modeling is a powerful tool that is used to analyze the population's health impact of the disease. Infectious diseases such as Influenza, AIDS, Tuberculosis, Arthritis, etc. are studied through simulation modeling [1]. Now a day's epidemiological characteristics are analyzed by using computer simulation modeling. In past 2 decades, simulation models have been developed in health care and can be broadly defined as a device that mimics aspects of clinical care. A propagation in simulation model is evident in the domain of medical research and management of healthcare services [2]. Arthritis is normally inflammation of joints. In United States alone it is predicted that 19 million people a year were affected by arthritis between 1995 and 2020.Stifness, redness, joint pain, swelling, decrease range of movement are the symptoms of this disorder. Among different types of arthritis, osteoarthritis (OA) and rheumatoid arthritis (RA) are the most common. Osteoarthritis can affect both joints of the body (larger and smaller joints) including the knees, hands, feet, wrists, back and hip. RA is an autoimmune long lasting and enduring ailment. In general population, the prevalence of RA is estimated to be 1% globally. More than 3.8% people are affected by OA while RA prevalence is 0.24% [3]. The rate of RA is larger in females than in males [4]. For the detection of RA and OA, physical examination, medical history, and various diagnostic tests are used. Blood tests (anti-citrullinated protein antibody) can help to diagnose rheumatoid arthritis. Imaging tests such as MRI, ultrasound and X-rays are used to determine extent and location of Rheumatoid arthritis or Osteoarthritis damages [5]. Rheumatoid arthritis can be easily controlled if it is diagnosed in early stages. This disease needs more aggressive treatment when severe symptoms appear in RA patients [6]. For the detection and management of patients suffering from bone destructions, various computer-aided diagnosis systems are developed.

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2 Materials and Methods

Review of literature was done to assess the role of computational models in diagnosis, progression and management of OA and RA. Search engines such as PubMed, Google Scholar, and academic research databases like IEEE Xplore and Science Direct were used from June 2020 to December 2020. Based on data available, findings are detailed below.

3 Results and Discussion

Simulations methods stability is checked by using software packages like Matlab and Simulink, Python software. In mathematical medicine, biology of Arthritis and its development procedure are studied by using computer simulation models [7]. The main application of modeling is to analyze the onset of diseases, prophylactic, epidemiological conditions, and genesis of disease. The development of a simulation model must be based on birth rate, death rate, and migration because demographics play important role in emergence of the disease [8].

4 Python Based Integrated Model: Inhibition of Mir-140

There are five models in which the inhibition of mir-140 occurred. These models are model of mir-140 in SOX 9, in IL-1 /MMP13, in TGF Signaling, in IGF-1 Signaling and in IL-1 Pathway [9]. To assess the function of the mir-140 in osteoarthritis, these five models were interrelated to form an incorporated model. As per model, influence of microRNAs-140 is variable on an IL-1 incitement commencing an extended enhancement in a pulse-like reaction and the cartilage deterioration is affected. This model can be simply adapted and is comprehensive as experimental records become accessible to explore the function of microRNAs-140 in osteoarthritis. Also the additional microRNAs that are vital in osteoarthritis might be incorporated. In aging cartilage, this integrated model could not only clarify the mechanisms of microRNAs but also supply a useful gizmo to explore the consequence of the possible interferences to foil the deficit of the cartilage. In this model, two proteins MMP-13 and ADAM TS-5 and two fragments that are collagen 2 fragments and aggrecan fragments were used. Figure 1 represents the

inhibition and activation of MicroRNAs in OA.

5 Machine Learning Algorithms and MATLAB Based Artificial Neural Network

Rheumatoid arthritis (RA) can lead to heart diseases. Risk assessment of people with RA by traditional methods can give wrong predictions. Advanced imaging techniques expedited precise and timely heart diseases forecasts. By developing 2-dimensional images with B-mode ultrasound method of carotid arteries, specific plaque types, and related complications in atherosclerosis have been determined by numerous studies. Artificial intelligence based archetypes like machine learning and deep learning have facilitated automated risk depiction for treatment and management of RA [10]. Orange et al. [11] improved histologic scores of RA and OA synovial tissue by analyzing data on gene expression and machine learning. Consensus clustering was done with twenty histological characteristics and sub-classes of gene expression were proposed by support vector algorithms. Integration of machine learning describe three subtypes and several associated variables. Electronic health care data is given financial codes to predict diagnosis and it can lead to error. Another substitute is the application of machine learning (ML) models for accurate diagnosis of RA from healthcare data sets. Recently, Leiden and Erlangen, electronic data sets were analyzed with six different ML methods and a naïve word matching algorithm [12]. It was observed that this process give right information within minimal time and cost. Lötsch et al. [13], employed ML to ascertain parameters responsible for consistent pain in RA. Supervised ML was applied as random forests after computational analysis-based item categorization on anthropometric, clinical and patient-associated features. Accuracy of results suggested that ML can extract knowledge and RA earlier features play role in onset and extend of pain. Similarly, Reed et al. [14], developed a screening method by incorporating patient's hand images, queries, and physical examination to diagnose hand arthritis. Separate ML algorithms were developed. Algorithms predicted hand arthritis accurately. It was observed that ML process facilitates diagnosis and can be helpful in clinicsOsteoarthritis (OA) is most widely recognized ceaseless state of the joints, which can't be foreseen successfully. It is a degenerative joint malady. In United States, about two million individuals younger than forty-five years of age have knee OA [15]. Computational demonstration of joint condition permits to assess the patient-explicit movement of Osteoarthritis that may help physicians to appraise utmost reasonable period for careful mediation in OA patients. Computerized models of arthritis facilitates person-specific progress of disease, which physicians can use to recommend interventions. Musculoskeletal, regulatory, multipurpose, data-driven and gene (Finite Element) models [16]. Computational displays of joint destruction can be helpful to anticipate pathophysiology of various segments of joint and accordingly support physicians in opportune mediation (e.g., medical procedure, recovery, weight reduction). Computational models can run from the joint level musculoskeletal models, limited component models, and administrative system models. Musculoskeletal models assess entire joint stacking conditions that may prompt joint degradation; limited component model can assess tissue stacking and anticipate their loss in light of tissue stacking and quality administrative system models that may foresee outcome of chondrocytes when exposed to irregular biochemical and mechanical upgrades. Advancement in improvement of the computer simulation models has been done while considering the complex biomechanical factors engaged with arthritis [17]. Physiome markup languages based multidimensional framework was designed to study onset of arthritis at bone cartilage [18]. These algorithms are very hopeful in forecasting the deterioration of various components of the auricular ligament and the involvement of subchondral bone in diseased condition. However, the essential bottleneck in creating quiet explicit in silico model of joint deterioration is massive inconstancy in the joint geometry just as instinctive properties of relating tissues [16]. Rheumatoid arthritis is diagnosed by using MATLAB based artificial neural networks (ANN). ANN is a model that work as a brain and stores information. Like human brain, there are several decision-making and learning methods in ANN that are based on the information that is retrieved. For diagnosis of RA, artificial neural network (ANN) method is used to support medical diagnostics. Tok and Saritas [19], used Mat lab R2015b environment with back-propagation algorithm and results were compared with the perceptron algorithm for performance characteristic. The dataset used for the diagnosis of RA patients was obtained along with normal volunteers. Back-propagation process delivered 82 percentage accurate results while perceptron methodology showed 71 percent accuracy. Other simulation models are presented in table 1.

6 Tables and Figures

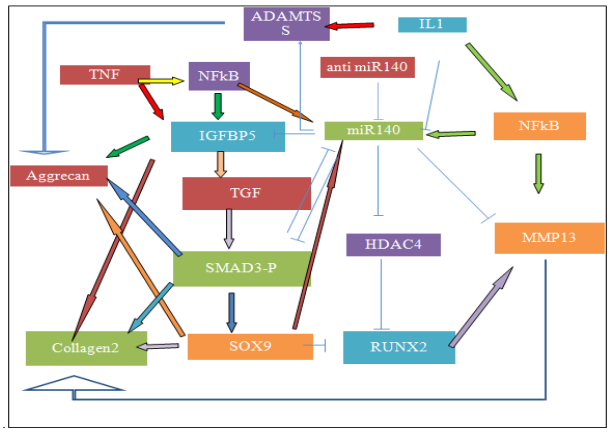

***Fig. 1**. An integrated model of the effect of mi-RNA-140 in OA*

Arrows: activation, blocked lines: inhibition

TABLE 1
DIFFERENT MODELS USED TO ANALYZE TREATMENT, DIAGNOSIS AND PROGRESSION IN ARTHRITIS

Authors	Model	Scientific work
Marques et al. [20], (2013)	MRI	To quantify tibia trabecular bone and osteoarthritis (OA), prognosis
Scott et al. [21], (2013)	Novel modeling approach	To predict age at onset and risk of RA
Wang et al. [22], (2013)	Ultrasound Elastography	To detect osteoarthritis
Miyake et al. [23], (2014)	Dynamic computer simulation of elbow CT scans	Identification of impinging osteophytes
Stender et al. [24], (2017)	Poroelastic finite element models	Determine effects of variations in permeability with osteoarthritis
Inai et al. [25], (2018)	MATLAB simulation models	Association between movement time, hip moment impulse in sagittal plane through sit-to-stand movement
Norgeot et al. [26], (2019)	A longitudinal deep learning model	To estimate clinical results in arthritis
Sajjadinia et al.[27], (2019)	Finite element model	osteoarthritis degeneration estimation
Ahmed et al. [28], (2020)	Random Forest	Monitoring medical wireless sensors, detection of knee osteoarthritis.
Gornale et al. [29], (2020)	Computer assisted automated analysis, Digital knee image X-ray	Early diagnosis of osteoarthritis
Mononen et al. [30], (2018)	Four knee joint models	Recreation of proteoglycan damage, collagen deterioration in arthritis patients
Abedin et al. [31], (2019)	Predictive model using patient assessment data	Medication use, predictions about knee OA severity

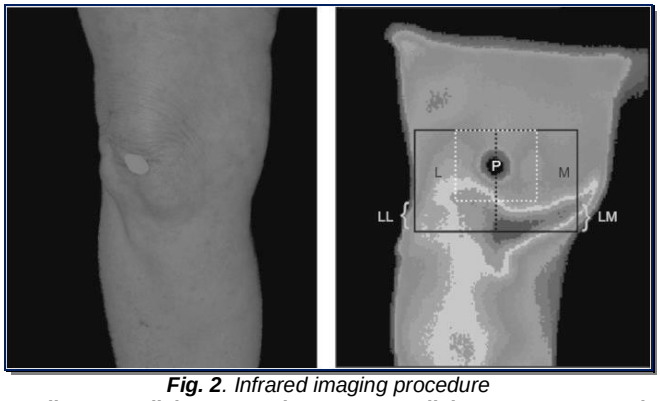

Fig. 2*. Infrared imaging procedure*
Patellar-P; Medial-M; Lateral-L; Lower Medial-LM; Lower Lateral-LL

Infra-red imaging is a reliable tool to assess inflammation, joint stiffness and tissue damage. Denoble et al. [32] monitored the skin temperature of the patellar region of knee in arthritis patients and observed that temperature was associated with OA severity as mentioned in x-ray. For the screening of knee joints, infra-red imaging procedure is shown in Figure 2.

7 CONCLUSION

It is concluded that integration of computer simulation models to extract information from data about onset and progression of arthritis and its complications is useful for the healthcare stakeholders. Each models is designed on the basis of specific clinical features of arthritis to ascertain explicit knowledge. Physicians can opt for these models to predict arthritis onset, progress and therapeutic interventions to avoid failure at any stage or side effects.

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