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Machine Learning, Deep Learning Assisted Clinical Data Analysis on Myocardial Infarction

Mr. R. K. Arunkumar*[1], Dr. T. A. Sangeetha[2]

[1]Ph.D Part time Research Scholar in Computer Science and Assistant Professor Department of Computer Applications, Kongu Arts and Science College (Autonomous), Erode – 638107.

[2]Associate professor and Head, Department of Computer Applications, Kongu Arts and Science College, (Autonomous), Erode – 638107.

Abstract: Myocardial Infarction remains one of the leading causes of mortality worldwide, demanding accurate and timely diagnosis for effective clinical intervention. Traditional diagnostic approaches often rely on physician expertise, electrocardiogram interpretation, biomarker evaluation, and imaging results, which may delay rapid decision-making in emergency settings. Recent advancements in Deep Learning have demonstrated significant potential in transforming disease diagnosis through automated and data-driven analysis. This study presents a Deep Learning-assisted, clinical data-driven framework for the early detection and risk assessment of myocardial infarction using patient clinical records, laboratory parameters, and physiological indicators. The framework integrates data preprocessing, feature normalization, missing value imputation, and predictive modeling to improve diagnostic reliability. Several state-of-the-art Deep Learning models are evaluated for classification performance. These models are capable of learning complex nonlinear relationships among heterogeneous clinical variables and identifying hidden patterns associated with the occurrence of myocardial infarction. This paper discusses recent 10 years existing Machine Learning, Deep Learning methods and thereby guides further enhancements and improvements to state-of-the-art techniques. This research highlights the importance of intelligent healthcare analytics and demonstrates the Machine Learning and Deep Learning-assisted clinical decision systems in myocardial infarction diagnosis.

Keywords: Deep Learning (DL), Machine Learning (ML) Myocardial Infarction (MI).

I. INTRODUCTION

Myocardial Infarction- Myocardial Infarction (MI), [1] shown in Figure 1, commonly known as a heart attack, remains one of the most critical cardiovascular emergencies and a leading cause of mortality and long-term disability worldwide. It occurs when blood flow to a portion of the heart muscle is suddenly blocked, usually due to the rupture of an atherosclerotic plaque followed by thrombus formation in the coronary arteries. The interruption of oxygen supply results in irreversible damage to cardiac tissues if timely medical intervention is not provided. According to global health reports, cardiovascular diseases account for millions of deaths annually, with MI contributing significantly to this burden. [2] The increasing prevalence of sedentary lifestyles, unhealthy dietary habits, obesity, diabetes mellitus, hypertension, smoking, stress, and aging

populations has further accelerated the incidence of MI across both developed and developing nations. [3] Early diagnosis and prompt treatment are therefore essential to reduce mortality rates, prevent complications such as heart failure and arrhythmias, and improve patient survival outcomes. However, accurate identification of MI remains challenging in many healthcare environments because symptoms may vary considerably among patients, ranging from classical chest pain and shortness of breath to atypical manifestations such as fatigue, nausea, and silent ischemic episodes. Traditional diagnostic methods rely on physician expertise, electrocardiogram (ECG) interpretation, cardiac biomarker analysis, echocardiography, and coronary angiography, which may sometimes be time-consuming, subjective, or limited by resource availability.

***Common Symptoms* –** [4] Chest pain, pressure, or tightness, Pain radiating to left arm, jaw, neck, or back , Shortness of breath, Sweating , Nausea or vomiting, Dizziness or fainting , Unusual fatigue (more common in women).

***Major Risk Factors* -** High blood pressure, High cholesterol, Diabetes, Smoking , Obesity , Physical inactivity , Family history of heart disease, Stress.

***Diagnosis* -** ECG / EKG, Cardiac troponin blood test, Echocardiogram, Coronary angiography.

***Treatment* -** Aspirin and emergency medicines, Angioplasty with stent (PCI), Thrombolytic therapy, Coronary bypass surgery (CABG), Cardiac rehabilitation.

***Prevention* -** Healthy diet, regular exercise, controlling BP/diabetes, quitting smoking, and regular health checkups greatly reduce risk.

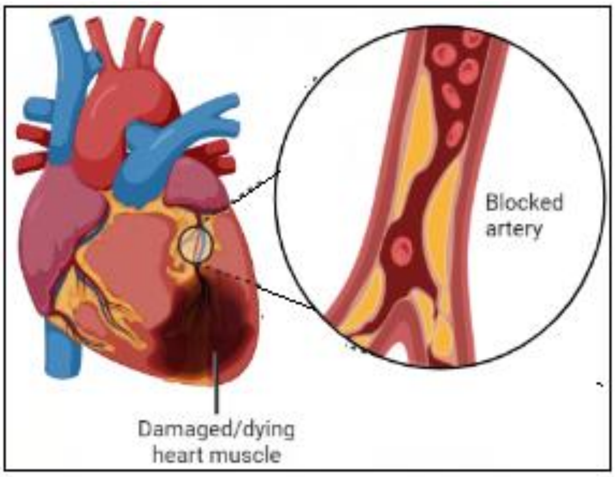

Fig 1. Myocardial Infarction

***Machine Learning* –** [5] In recent years, the rapid advancement of Artificial Intelligence (AI), particularly Machine Learning (ML) and Deep Learning (DL), has opened new opportunities for transforming cardiovascular disease diagnosis and management. Machine Learning refers to computational techniques that enable systems to learn meaningful patterns from historical data and make predictions without explicit programming. In the context of MI detection, ML algorithms can analyze large volumes of clinical data, including patient demographics, laboratory values, ECG signals, medical history, imaging results, and lifestyle factors, to identify hidden relationships associated with heart attack risk. Common ML methods such as Support Vector Machines (SVM), Random Forest (RF), Decision Trees (DT), Naïve Bayes (NB), Logistic Regression (LR), K-Nearest Neighbors (KNN), and ensemble models have demonstrated promising performance in classifying MI patients, predicting disease progression, and supporting clinical decision-making. These approaches help reduce diagnostic uncertainty, improve risk stratification, and assist physicians in prioritizing high-risk patients for urgent treatment. Furthermore, ML models can continuously improve their predictive capability as more patient data become available, making them valuable tools for personalized medicine and preventive cardiology.

***Deep Learning* –** [6] Deep Learning, a specialized subset of Machine Learning inspired by the neural structure of the human brain, has shown even greater potential in healthcare applications due to its ability to automatically learn hierarchical features from raw and unstructured data. Unlike conventional ML methods that depend heavily on handcrafted feature extraction, DL architectures such as Artificial Neural Networks (ANN), Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), Long Short-Term Memory (LSTM) networks, Autoencoders, and Transformer-based models can directly process complex medical data with high dimensionality. In myocardial infarction diagnosis, deep learning has been extensively applied to

ECG signal classification, cardiac image analysis, electronic health record mining, and multimodal data fusion. CNN models can accurately detect subtle waveform abnormalities in ECG signals indicative of ischemia or infarction, while RNN and LSTM models are effective for analyzing sequential physiological data over time. Similarly, DL techniques applied to echocardiograms, CT scans, and MRI images can identify structural abnormalities and damaged myocardium with high precision. These capabilities significantly enhance diagnostic speed, reduce dependence on manual interpretation, and enable real-time monitoring systems in emergency and remote healthcare settings.

***Integration of Machine Learning & Deep Learning* –** [7] The integration of Machine Learning and Deep Learning into MI diagnosis offers several advantages over conventional approaches. First, these intelligent systems can process vast and heterogeneous datasets rapidly, facilitating early detection even in complex clinical scenarios. Second, they provide objective and reproducible predictions, thereby minimizing human bias and inter-observer variability. Third, AI-based [8] frameworks support predictive analytics by estimating future cardiac events, hospital readmission risks, and treatment responses. Fourth, with the emergence of wearable sensors and Internet of Medical Things (IoMT) devices, ML and DL models can be deployed for continuous heart monitoring, allowing proactive intervention before severe cardiac damage occurs. Despite these advantages, challenges such as data imbalance, missing clinical records, interpretability of black-box models, privacy concerns, and generalization across diverse populations still need to be addressed. Therefore, ongoing research focuses on explainable AI, [9] federated learning, hybrid optimization techniques, and robust multimodal architectures to enhance trustworthiness and real-world applicability.

In summary, Myocardial Infarction continues to pose a serious global health threat, necessitating innovative diagnostic strategies beyond traditional methods. Machine Learning and Deep Learning [10] have emerged as powerful technologies capable of revolutionizing MI prediction, detection, and prognosis through intelligent analysis of medical data. Their ability to uncover complex patterns, automate diagnosis, and support timely clinical decisions can substantially improve patient outcomes and reduce healthcare burdens. Consequently, the development of efficient AI-driven models for myocardial infarction diagnosis has become a significant research direction in modern biomedical engineering and healthcare informatics, offering a pathway toward more accurate, accessible, and personalized cardiovascular care.

The rest of this paper is organized as: section I has the introduction part of MI, ML, and DL, section II carries the explanation of existing research works, section III described the recent ML, DL methods in analyzing MI, and section IV concludes the research analysis.

II. LITERATURE REVIEW

Divneet Mandir *et al* [11] compared traditional statistical and machine learning methods along with shallow and Deep Neural Network (DNN) architectures. Hyperparameter optimization for all methods was performed using 10-fold cross-validation to ensure robust model selection. Experimental findings revealed that the Deep Neural Network combined with random undersampling achieved the best overall classification performance among the tested methods. The model obtained an Area under the Curve of 0.835 and an F1-score of 0.092, indicating acceptable discrimination capability but relatively limited precision-recall balance due to severe class imbalance.

Tanya Aghazadeh *et al* [12] used data analysis algorithms and compare their accuracy in predicting myocardial infarction. 105 medical records of myocardial infarction patients with fourteen features were used for this purpose. The features were categorized into four main groups namely demographic features, laboratory features, clinical examination features, and type of emergency operations.

Finally, random forests with an accuracy of 76% outperforms.. Also, seven features are identified as the most effective features of the ejection fraction variable.

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Fatemeh Rahimi *et al* [13] investigated the prediction of MI risk using clinical data collected from admitted patients at Rajaei Specialized Cardiovascular Hospital in Tehran. After preparing the dataset, several classification algorithms were implemented to assess their predictive capabilities. The study also evaluated the relative importance of different risk factors contributing to MI occurrence..The experimental results demonstrated that the proposed predictive framework achieved an accuracy of 75.28% for KNN indicating a moderate capability in identifying patients at risk of myocardial infarction.

Asif Newaz *et al* [14] put forth a hybrid approach sampling techniques with cost sensitive learning for diagnosing Myocardial infarction. we utilized the SMOTE algorithm for the sampling approach It reduces the number of minority class samples required and it reduces the penalty for the cost-sensitive classifier. The proposed one achieved 91.9 % accuracy and outperforms the existing. This signifies the the proposed strategy is quite effective in dealing with imbalanced classification problems.

Pin Zhang *et al* [15] develop machine learning–based early prediction models for Myocardial Infarction. The data comprised demographic characteristics, clinical investigations, laboratory tests, and disease-related events with 4 machine learning methods namely ANN, KNN, SVM, LR, and RF. The use of machine learning–based prediction models may improve patient management is found by acquiring 80.4% with ANN also the method found top five predictors of the disease.

Ying Fang *et al* [16] presented a comprehensive exploration of the research trends in the field of MI and ML over the past two decades. The analysis revealed that Deep Learning is an emerging research direction playing a crucial role in early diagnosis, risk assessment, and rehabilitation therapy.The author put the conclusions from the analysis (1) Deep learning is an emerging research direction in MI, (2) Neural networks based on deep learning frameworks are a research hotspot in MI studies, and (3) Application of deep learning is getting viral in early diagnosis of MI.

Daotong *et al* [17] introduced the first Graph Neural Network (GNN) framework designed to simultaneously predict 12 distinct post-MI complications along with in-hospital mortality. First, a density-adaptive K-Nearest Neighbor (KNN) graph construction strategy was used to capture clinically meaningful relationships. Second, the model integrated dual-branch temporal encoders such as long-short term encoders. Third, a cross-modal attention mechanism was introduced for interactive fusion of multi-scale temporal features. Notably, the model achieved an outstanding AUC of 0.8828 for in-hospital mortality prediction.

Ryosuke Muraki *et al* [18] developed an automatic method for early detection of acute Myocardial Infarction (MI) using echocardiography images with Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM). Since abnormal wall motion is difficult to distinguish manually, the model used VGG16 for feature extraction from short-axis and left ventricular long-axis views, followed by LSTM for classification. The system identified normal and infarcted myocardium with high performance, achieving 85.1% accuracy for long-axis views and 83.2% for short-axis views, showing strong clinical usefulness.

Sumayyah Hasbullah *et al* [19] proposed hybrid deep learning models for automatic Myocardial Infarction (MI) detection using ECG signals, where rapid diagnosis is critical to prevent severe heart damage. Since CNN captures spatial features but lacks temporal memory, researchers combined CNN with recurrent networks, developing CNN-LSTM and CNN-BiLSTM architectures. Using the PTB-XL dataset, the models classified ECG inputs into MI, healthy conditions, or other cardiovascular diseases. The approach relied on automatic feature extraction without handcrafted methods. Experimental results showed strong performance, achieving 89% accuracy for CNN-LSTM and 91% for CNN-BiLSTM models.

Dharmendra *et al* [20] discussed that Artificial Intelligence (AI) is transforming healthcare by improving diagnosis, treatment planning, and hospital management. AI algorithms analyze large medical datasets to detect diseases early and support clinical decisions. In radiology, pathology, dermatology, and ophthalmology, deep learning enhances image-based diagnosis. In oncology, cardiology, and neurology, AI enables personalized treatment by predicting disease progression and selecting therapies. AI also supports robotic surgery, virtual assistants, and Electronic Health Records automation. Challenges include privacy, bias, and transparency. Future advances in wearable monitoring, precision medicine, and federated learning will further improve patient care.

Haipeng Liu *et al* [21] explained Machine Learning and Deep Learning in the way that are used for Healthcare Data Processing and Analyzing for making data-driven decisions. The paper quoted more previous literatures high lighting the key findings and research gaps that in turn useful to understand and proceed further analysis. The paper covered more ML and DL algorithms in healthcare analysis with Ensemble methods.

Procheta Nag *et al* [22] put forth a Myocardial Infarction prediction system with clinical data using data mining techniques. decision tree and random forest are used to analyze heart attack dataset. Total 301 data that explains 180 AMI patients and 121 general people data along with 25 attributes mostly related to chest pain was used and found the highest accuracy is 87%.

Fazliddin Makhmudov *et al* [23] proposed a multitask deep learning model that predicts both infarction complications and causes of mortality simultaneously. Using data from 1,700 patients with 111 features, the model achieved strong predictive performance and the results indicate its usefulness for personalized cardiac care and clinical decision support, with future validation needed in practice by achieving 91.3% accuracy for XGBoost method.

Nagaraj *et al* [24] focused on identifying normal, abnormal heart patient in heart disease dataset with 15 attributes. Decision tree with Information gain was used for classification purpose, this approach help physicians recognize patterns linked to cardiovascular conditions. Early detection through such methods can reduce delays in diagnosis, enabling timely medical intervention and preventive measures.

Payrovnaziri *et al* [25] introduced a improved method for earlier prediction models by combining structured clinical information with text-based features extracted from discharge summaries. The use of both data types enhanced the performance of deep learning models compared with structured data alone. The proposed system achieved an average accuracy of 92.89% and an F-measure of 0.928, monstrating the value of integrated healthcare data for reliable prognosis.

III. RECENT ML, DL METHODS ON MYOCARDIAL INFARCTION ANALYSIS

Deep Neural Network (DNN) – It has multiple hidden layers between the input and output layers. These layers help the model learn complex patterns from large amounts of data. Each neuron processes information and passes it to the next layer using weighted connections. DNNs are widely used in Artificial Intelligence for tasks such as image recognition, speech recognition, natural language processing, and medical diagnosis. Their depth allows them to automatically extract features and achieve high accuracy compared to traditional machine learning methods.

Random Forest (RF) - A popular Machine Learning algorithm used for classification and regression tasks. It works by creating many Decision Trees during training and combining their outputs to improve accuracy and reduce overfitting. For classification, it selects the majority vote from all trees, while for regression, it averages the predictions. Random Forest is widely used because it handles large datasets well, works with missing values, and provides good prediction performance.

K- Nearest Neighbor (KNN) - A simple and widely used Machine Learning algorithm used for classification and regression. It works by finding the K closest data points to a new input based on distance measures such as Euclidean distance. For classification, the new data point is assigned to the class most common among its nearest neighbors. For regression, it predicts the average value of the neighbors. KNN is easy to implement, effective for small datasets, and commonly used in pattern recognition and recommendation systems.

Class Sampling *with* ***Cost-Sensitive Learning*** - Techniques used in Machine Learning to handle imbalanced datasets, where one class has many more samples than another. Class Sampling Factors adjust the training data

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by oversampling the minority class or undersampling the majority class. This helps the model learn both classes more fairly and improves prediction for rare events. Cost-Sensitive Learning assigns different misclassification costs to classes. Errors on the minority or more important class are given higher penalties, so the model focuses more on correctly predicting those cases.

***Artificial Neural Network (ANN)* -** A computational model inspired by the human brain, used in Machine Learning and Artificial Intelligence. It consists of interconnected neurons arranged in input, hidden, and output layers. Each neuron receives data, processes it using weights and activation functions, and passes the result to the next layer. ANNs learn patterns from data through training and are widely used for classification, prediction, image recognition, speech processing, and medical diagnosis.

Graph Neural Network (GNN) - A type of Neural Network designed to work with graph-structured data, where information is represented as nodes and edges. It learns by aggregating features from neighboring nodes and updating node representations. GNNs are widely used in Machine Learning for applications such as social network analysis, recommendation systems, fraud detection, traffic prediction, and molecular property prediction. They are powerful because they capture relationships and dependencies between connected data points.

CNN with LSTM - A hybrid deep learning model that combines Convolutional Neural Network and Long Short-Term Memory. CNN is used to automatically extract important spatial features from input data such as images or signals, while LSTM is used to learn temporal or sequential patterns over time. It captures both spatial and time-dependent information effectively.

***CNN with BiLSTM* -** A hybrid deep learning model that combines Convolutional Neural Network and Bidirectional Long Short-Term Memory. CNN extracts important local and spatial features from data such as images, text, or signals. BiLSTM processes sequences in both forward and backward directions, capturing past and future dependencies for better context understanding. It learns both feature patterns and bidirectional temporal relationships.

***XGBoost* –**Extreme Gradient Boosting is an advanced Machine Learning algorithm based on boosted Decision Trees. It builds multiple trees sequentially, where each new tree corrects the errors made by previous trees, known for its high accuracy, fast processing speed, and ability to handle missing data and large datasets. It includes regularization techniques that reduce overfitting and improve model performance.

Decision Tree - A supervised Machine Learning algorithm used for classification and regression tasks. It works by splitting data into branches based on feature values, forming a tree-like structure of decisions. Each internal node represents a condition, each branch represents an outcome, and each leaf node gives the final prediction or class label. Decision Trees are easy to understand, simple to visualize, and useful for decision-making problems. They are widely applied in medical diagnosis, customer analysis, and risk prediction.

Table 1. Summary of ML and DL Methods on Myocardial Infarction Analysis

Author	**Methods**	**Performance in Accuracy**
Divneet Mandir *et al* [1]	DNN	83%
Tanya Aghazadeh *et al* [2]	RF	76%
Fatemeh Rahimi *et al* [3]	KNN	75.2%
Asif Newaz *et al* [4]	Sampling + Cost sensitive learning	91.9%
Pin Zhang *et al* [5]	ANN	80.4%
Daotong *et al* [7]	GNN	88%

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Ryosuke Muraki *et al* [8]	CNN+ LSTM	85.1%
Sumayyah Hasbullah *et al* [9]	CNN+ BiLSTM	91%
Procheta Nag *et al* [14]	Decision Tree	87%
Fazliddin Makhmudov *et al* [17]	XGBoost	91.3%

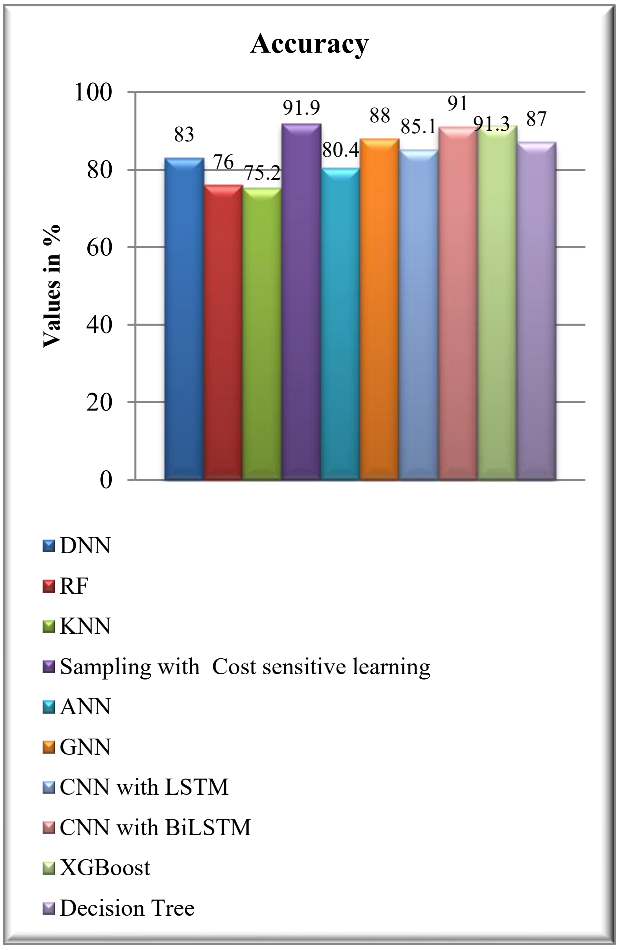

Fig 2. Performance of ML, DL on Myocardial Infarction Analysis

Table 1 and Figure 2, shows the Accuracy percentage of various state-of –the art methods ML, DL used in recent years for analyzing Myocardial Infarction. Individual and hybrid method is listed. Each method obtains different accuracy percentage and the performance highly differs, that is based on the dataset variables and method complications. Among them, the hybrid method achieve high accuracy.

IV. CONCLUSION

This research paper analyzes the ML and DL methods used in analyzing Myocardial Infarction in recent years. The methods are explained and listed as summary in Table. The performance is compared via charts and noted that mostly the hybrid method gives high accuracy than the standalone methods. However, the hybrid one has its complications too.

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