© 2016 IJSRSET | Volume 2 | Issue 4 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

A Comparative Study on Performance Parameters for Cardiovascular Disease using Various Imaging Techniques

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ABSTRACT

Heart disease is one of the most leading issues of death. Hence to predict this disease in advance, early detection and diagnosis is required. This plays a major role in disease severity identification, predicts the outcome of disease and helps to improve the patient management. Though there are several cardiac imaging modalities used for this purpose, less-invasive imaging modalities like coronary CT angiography, cardiac magnetic resonance imaging, cardiac radionuclide imaging such as SPECT and PET modalities are widely used for assessment of heart diseases. This study works on applications of above mentioned imaging modalities in assessing various heart diseases and provides comparison among them.
Keywords : Less invasive imaging modalities, Cardiac Magnetic Resonance Imaging (CMRI), coronary CT angiography, Coronary Artery Disease (CAD).

I. INTRODUCTION

Heart disease is a disorder or abnormal condition that affects heart and blood vessels. There are different types of heart disease includes Atherosclerosis, Cardiac arrhythmia, Congenital heart defect, Heart valve disorder, coronary artery disease, Myocarditis and Pericarditis. Among these, coronary artery disease (CAD) is the most common heart disease which causes sudden cardiac death. So there is a need for screening, prediction and treatment approaches for this type of heart disease. Primary less-invasive modalities like Echocardiography, cardiac magnetic resonance (CMR) and cardiac computed tomography (CCT) are used for cardiac imaging.

In coronary artery disease (CAD), plaque grows within the walls of the coronary arteries that restrict the flow of blood to the heart tissues. Proper management and cardiac testing is crucial for successful recovery of the patient. The main aim of cardiac testing includes:

(1) To identify or exclude various forms of heart disease as a reason for a person's symptoms
(2) To establish the risk of developing heart disease such as myocardial infarction
(3) To decide on the need for additional medical therapies and procedures

There are various imaging techniques for CAD. Among them, Cardiac MRI and multi-slice computed tomography are the most recent addition to the cardiac imaging technique.

Echocardiography is a test that shows moving pictures of the heart with sound waves. This is used to detect congenital heart defect. It shows the problems in heart's valves, a blood clot.

Computed tomography (CT) uses X-rays to make pictures of the heart. This is used to determine deposition of calcium in coronary arteries of heart disease patient. This is also known as calcium-score screening heart scan. After CT scanning process, following information is obtained.

(1) The number and density of calcified coronary plaques in the coronary arteries
(2) Calcium score

When this CT combined with multi-slice CT gives high resolution and high speed imaging of the coronary artery.

CT scans expose patients to more radiation than normal x-rays.

Cardiac MRI gives better results on wall-motion analysis, myocardial tissue morphology, rest and stress first-pass myocardial perfusion and ventricular systolic function. It is also used to find the location and thickness of myocardial scars. MRI is capable of imaging coronary arteries and determining stenoses without catheterization of contrast material. Moreover, this imaging technique avoids ionizing radiation and usage of iodinated contrast agent. MRI also applied on assessment of myocardial ischemia and viability, cardiomyopathies, myocarditis, iron overload, vascular diseases and congenital heart disease. This technique proceeds as follows:

(1) estimates the anatomy and function of the heart chamber
(2) diagnoses a variety of cardiovascular disorders
(3) estimates the effects of coronary artery disease
(4) plans a patient's treatment for cardiovascular disorders
(5) monitors the progression of certain disorders over time
(6) estimates the effects of surgical changes

This study describes various imaging techniques in heart disease prediction and shows their merits and demerits.

II. METHODS AND MATERIAL

1. Literature Survey

Matjaz Kukar (1999) diagnosed ischemic heart disease with machine learning methods. The four diagnostic levels consists evaluation of signs and symptoms of the disease and ECG (electrocardiogram) at rest, sequential ECG testing during the controlled exercise, myocardial scintigraphy, and finally coronary angiography (which is considered as reference method). Machine learning methods may enable objective interpretation of all available results for the same patient and in this may increase the diagnostic accuracy of each step. Machine learning algorithms are used for classification (classifiers) are typically designed to minimize the errors (incorrect classification) made.

Dragan Gamberger et al (2003) presented an approach to active mining of patient records to recognize patients at high risk for coronary heart disease (CHD). This approach proposes active expert involvement, from following steps of the knowledge discovery process: data gathering, cleaning and transformation, subgroup discovery, statistical characterization of induced subgroups, their interpretation, and the evaluation of results. The analysis results proved that, the proposed methodology has high potential on screening and diagnosing patient groups at risk for CHD.

Heon Gyu Lee et al (2008) proposed Data Mining Approach for Coronary Heart Disease Prediction using HRV Features and Carotid Arterial Wall Thickness. It is a unique methodology which develops the various features such as heart rate variability (HRV) and carotid arterial wall thickness are helpful in diagnosing cardiovascular disease. A suitable prediction model is also proposed to enhance the reliability of medical examinations and treatments for cardiovascular disease.
Sellappan Palaniappan & Rafiah Awang (2008) developed an Intelligent Heart Disease Prediction System (IHDPS) using data mining techniques. Data mining techniques includes Decision Trees, Naïve Bayes and Neural Network are used for predicting heart disease in high accuracy. Using medical profiles such as age, sex, blood pressure and blood sugar are used to predict the likelihood of patient getting a heart disease.

Resul Das et al (2009) proposed a neural network ensemble method for efficiently diagnosing the heart disease. This method works on SAS based software which supports the data mining process. It includes heart database component for recognizing healthy persons and patients, Data partition component to divide input database into train and validation data sets, Variable selection component to reduce number of inputs. Neural networks block component was used to classify the feature space and Ensemble component was used to create new models by combining the posterior probabilities (for class targets) or the predicted values (for interval targets) from multiple predecessor models. The new model is then used to score new data. This method results in better classification accuracy, sensitivity and specificity.

Shaikh Abdul Hannan et al (2010) proposed an expert system to diagnose Heart Disease by using Support Vector Machine (SVM) and Feed forward Backpropagation Technique (FFBP). Initially, author collects information about the patients. Then the collected information is trained by using SVM and FFBP and gives robust results after testing. However, it provides minimum medical prescription result for heart disease patient and also it need additional technique to increase speed and performance of the back propagation algorithm, weight initialization, use of momentum, adaptive learning rate.

Dragana Lakic et al (2010) developed a Multimarker Approach for the prediction of Coronary Artery Disease. Here, author used a multimarker approach to explore discriminative abilities of several lipid, inflammatory, and oxidative stress/antioxidative defense markers as CAD predictors and predicts the CAD in patients.

P.K. Anooj (2012) proposed a clinical decision support system (CDSS) for predicting the heart disease. The author developed weighted fuzzy rule-based CDSS in two phases. First, weighted fuzzy rules are generated by using attribute selection and attribute weightage method. Then data preprocessing is done to remove noise and unnecessary information from the datasets. Class labels are given to the input database for mining the frequent attribute category individually. To find the relevant attributes, deviation range is computed and based on that decision rules are constructed and these rules are scanned in the learning database to find its frequency. Finally, fuzzy rule-based decision support system generates the weighted fuzzy rules based on obtained frequency value. By this, the system can learn these rules and the risk prediction can be carried out in an efficient manner.

Jabbar et al (2012) proposed an approach to predict the heart disease effectively. This approach use Associative Classification and Hybrid Feature Subset Selection methods. In the associative classification, the mining techniques are used to discover the association between the attribute values and produce more accurate classifiers. Feature selection is a field to improve learning efficiency, prediction accuracy and reduce complexity in reduced results. This algorithm involves filter and wrapper model. The advantages of this approach are high accuracy, remove irrelevant and redundant attributes in the data set.

Roohallah Alizadehsani et al (2013) used several data mining approach for diagnosing coronary artery disease (CAD). Sequential Minimal Optimization (SMO), Naive Bayes, Bagging, and Neural Network algorithms were applied on input datasets. Then the features from datasets are extracted by using ‘weights by SVM’ in RapidMiner. At last, for recognizing the blocks in Left Anterior Descending (LAD), Left Circumflex (LCX), or Right Coronary Artery (RCA), three features namely LAD recognizer, LCX recognizer, RCA recognizer is created. For better recognizing, information gain and Gini index indicators are evaluated. This approach results in higher diagnostic accuracy.

Jesmin Nahar et al (2013) presented a rule extraction experiment on heart disease data using different rule mining algorithms (Apriori, Predictive Apriori and Tertius). Apriori algorithm is used for gender classification. But it is based on confidence only. But, Predictive Apriori algorithm uses both support and confidence. Hence, it is well suited for classification and disease identification tasks. In addition to these algorithms, association rule mining techniques are provided to detect sick individuals and healthy individuals.

Sasa Grbic et al (2013) proposed a method to estimate the volumetric model of the Aortic Valve. From the high resolution single phase CT, this method extracts the volumetric model of the aortic valve leaflets and calcium information. Additionally a multi class resolution is introduced to label the regions for TAVI planning. Graph-cuts used to construct and optimize the final markov random field. The advantage of this method is to analysis the paravalvular leakages and stroke.

Jabbar et al (2013) proposed a classification technique called Lazy Associative Classification. It classifies the new instance from the training dataset and the generalization model cannot build earlier. This classification uses information centric PCA. The advantages of this classification are high accuracy, reduce number of rules generated. The drawback of this method is high computational cost is required.

Sonawane et al (2014) presented a new prediction system called Learning vector Quantization neural network algorithm. LVQ is based on Artificial neural network is to extract unique patterns or features from complicated or imprecise data. It is used in non-linear separation problem to classify the data in large extent.

The advantage of this system is to compute the different parameters like accuracy, sensitivity, specificity, training time, testing time, error and ROC curve.

Lakshmi et al (2015) proposed an associative classification technique called Stream Associative Classification Heart Disease Prediction is used to extract hidden information from the huge dataset. In this model landmark window data model is used to predict the heart disease that considers the data from the starting time to the current time for mining. It works in two phases 1.generate the rules; 2.Pruning and arranging the rules.

Ilayaraja M & Meyyappan T (2015) proposed an Efficient Data Mining Method to predict the risk of cardiac diseases through Frequent Itemsets and also discover the risk level of cardiac disease among patients. The proposed method stores minimum support value and symptoms related to heart disease. Based on this, the proposed method generates dataset and recognizes the cardiac disease. This method avoids the generation of unnecessary dataset and discard factors that do not satisfy support value.

Hui Yang & Jonathan M. Garibaldi (2015) proposed a hybrid model for automatic identification of risk factors for heart disease. This model is the combination of machine learning methods and nature language processing (NLP) techniques. NLP techniques used here are rule-based approaches and dictionary-based keyword spotting tends to be robust to prediction. Also information extraction system is described to automatically detect the risk factors by using medical records.

Nguyen Cong Long et al (2015) proposed an interval type-2 fuzzy logic system (IT2FLS) for diagnosing heart disease. This system with rough sets based attribute reduction for diagnosing purpose. IT2FLS model comprises fuzzy c-mean clustering algorithm, parameters tuning by chaos firefly and genetic hybrid algorithms for providing high-dimensional dataset. Attribute reduction based on rough sets using chaos firefly algorithm is used to find the optimal reduction from these datasets. By combining these two methods, author minimizes computational burden and improves the system performance.

Jitendra Jonnagaddala et al (2015) presented the method to extract risk factors about heart diseases from unstructured electronic health records using clinical text mining system. An error analysis was conducted to understand the output has got from the text mining system. Cohort selection was performed to determine patients eligible for calculating Framingham risk score (FRS). Systematic assessment was carried out for finding quality of data. Finally, analysis was performed on affected patients by stratifying them according to their CAD status.

Hyeongsoo Kim et al (2016) proposed a Data Mining Approach for Cardiovascular Disease Diagnosis. This approach uses both Heart Rate Variability (HRV) and Images of Carotid Arteries (CA). Initially, multiple feature vectors from HRV and CA are invented with the help of image processing and carotid intima-media thickness measurements. Then their importance tested by Neural Networks, Support Vector Machine (SVM), Decision tree induction, Classification based on Multiple Association Rule (CMAR), and Bayesian classifier. The result shows that, multiple feature vectors obtained from CA and HRV has maximum accuracy than separate feature vectors. But sufficient data is required for reliable operation.

III. RESULTS AND DISCUSSION

Comparison Based on Performance Parameters

In the following comparison table, performance parameters used in corresponding imaging techniques are discussed.

Ref. No.	Title	Techniques used	Parameters
1	Analysing and improving the diagnosis of ischemic heart disease with machine learning	the naive Bayesian classifier, back-propagation learning of neural networks, two algorithms for induction of decision trees (Assistant-I and Assistant-R), and k-nearest neighbours method	classification accuracy - 0.80 specificity - 0.76 sensitivity - 0.82
2	Active subgroup mining: a case study in coronary heart disease risk group detection	subgroup discovery algorithm, covering algorithm	Employee set Sensitivity (TPr%): 97 false positive rate FPr (%): 18
3	A Data Mining Approach for Coronary Heart Disease Prediction using HRV Features and Carotid Arterial Wall Thickness	CMAR (Classification based on Multiple Association Rules), CPAR (Classification based on Predictive Association Rules), SVM (Support Vector Machine), Bayesian classifier, C4.5, MDA (Multiple Discriminant Analysis)	gain similarity ratio : 0.95 weight decay factor : 0.67
4	Intelligent Heart Disease Prediction System Using Data Mining Techniques	Data mining techniques- Decision Trees, Naïve Bayes and Neural Network	Chest pain type : 3 Probability : 41.057 %
5	Effective diagnosis of heart disease through neural networks ensembles	neural networks ensemble method	Sensitivity - 80.95% Specificity - 95.91%
6	A Multimarker Approach for the Prediction of Coronary Artery Disease: Cost-Effectiveness Analysis	Multimarker approach	FRS accuracy - 85.4%

7	Diagnosis and Medical Prescription of Heart Disease Using Support Vector Machine and Feedforward Backpropagation Technique	Support Vector Machine (SVM) and feedforward Backpropagation technique	Accuracy : 97%
8	Clinical decision support system: Risk level prediction of heart disease using weighted fuzzy rules	neural-network-based approach	Accuracy - 50.583%
9	Prediction of Risk Score for Heart Disease using Associative Classification and Hybrid Feature Subset Selection	Genetic algorithms for optimization, associative Classification technique	Accuracy : 77.5%
10	A data mining approach for diagnosis of coronary artery disease	Naïve Bayes, SMO, Bagging, and Neural Network algorithms	Bagging and SMO methods: Accuracy – 89% Neural Network: Accuracy – 85%
11	Advanced Intervention Planning For Transcatheter Aortic Valve Implantations (Tavi) From CT Using Volumetric Models	Robust machine learning technique	Dice score(aortic valve leaflet segmentation): DSC = 0.73 Dice score (calcification segmentation): DSC = 0.79
12	Heart Disease Prediction using Lazy Associative Classification	Lazy associative classification method, PCA dimensionality reduction technique	Accuracy : 90%
13	Association rule mining to detect factors which contribute to heart disease in males and females.	Apriori, Predictive Apriori and Tertius	Rules with confidence levels-90% Rules with accuracy levels -99% Rules with confirmation levels-79%
14	Prediction of Heart Disease Using Learning Vector Quantization Algorithm	Learning vector quantization (LVQ)	Accuracy : 85.55%
15	Efficient Data Mining Method to Predict the Risk of Heart Diseases Through Frequent Itemsets	Association rule mining algorithm	Minimum support value - 0.1
16	Coronary artery disease risk assessment from unstructured electronic health records using text mining	Text mining approach	high FRS category: mean and median - 31%

17	Fast Rule-Based Heart Disease Prediction using Associative Classification Mining	Stream Associative Classification Heart Disease Prediction (SACHDP)	SACHDP Accuracy : 96.6% Prediction Time (ms) : 108
18	A highly accurate firefly based algorithm for heart disease prediction	fuzzy c-mean clustering algorithm, genetic hybrid algorithms, chaos 28 firefly algorithm	Without attribute reductions Accuracy : 86% Sensitivity :87.1% Specificity :90% BPSORS-AR: Accuracy : 87.0 % Sensitivity :93.3% Specificity :79.2% CFARS-AR: Accuracy : 88.3% Sensitivity :84.9% Specificity :93.3%
19	A hybrid model for automatic identification of risk factors for heart disease.	nature language processing (NLP) techniques such as machine learning, rule-based methods	F-measure - 0.915
20	A Data Mining Approach for Cardiovascular Disease Diagnosis Using Heart Rate Variability and Images of Carotid Arteries	Support Vector Machine (SVM) and Classification based on Multiple Association Rule (CMAR)	Accuracy – SVM : 89.51% Accuracy - CMAR : 89.46%

IV. CONCLUSION

Various less-invasive imaging techniques for heart disease prediction were studied and their advantages and disadvantages were discussed. Among them, CT and MRI techniques are most widely used for assessing heart disease. These techniques can diagnose several heart diseases like CAD, CVD and Congenital heart defect and help patients at the risk of cardiac death. In this study, various techniques are compared based on their performance parameters.

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