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An Innovative Approach for the Prediction of Future Arrhythmia through T-wave Alternans on Surface Electrocardiogram (ECG)

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ABSTRACT

Objective: To explore the techniques for predicting risk-causing arrhythmia in cardiac patients.
Study Design: Prospective longitudinal Study.
Place and Duration of Study: Armed Forces Institute of Cardiology, Rawalpindi Pakistan, and Government College University, Faisalabad Pakistan, from Jul to Oct 2017.
Methodology: The Electrocardiograms of 24-hour Holter monitoring were collected from the Electrophysiology Department. Electrocardiogram data was collected in the portable document format that was further transformed into Image format for computational analysis. Administrative data were analysed in multiple episodes of cardiac arrhythmogenesis. Data were classified by using a Convolutional Neural Network (CNN) based on computing the results of selected T-waves in three consecutive peaks within each cardiac cycle of patients.
Results: One hundred twenty-six patients diagnosed with arrhythmia were selected. The mean episode of premature ventricular contractions in participants was 21.5±30. The mean duration of significant ECG episodes was 3.33±9.65 (seconds). The accuracy and precision rate of the classifier was about 81% for the overall significance of data that exhibited the risk of causing future life-threatening arrhythmia.
Conclusion: This study introduces an innovative approach based on clinical paradigms that may help prevent the upcoming cardiac arrhythmogenesis events.

Keywords: Arrhythmia, Electrocardiogram, Python, MATLAB, T-wave.

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INTRODUCTION

Computational approaches are being practised in the prediction and diagnosis of Cardiac arrhythmia. Several categories are well defined in the division of cardiac arrhythmias, including the most significant are Premature Ventricular Contractions (PVCs), Atrial Fibrillation (AF), Premature Atrial Contractions (PACs), Ventricular Tachycardia & T-wave Alternans (TWA).[1,2]

T-wave reflects the phenomenon of repolarisation of ventricular heterogeneity in the ECG, including its duration and amplitude, to diagnose the pathologies and assess the malignant arrhythmias.[3,4] Several methods have been suggested for the analysis of TWA.[5] This study was based on real ECG signal values that the paper ECG transformed in the soft form of 24-hour Holter monitoring data. Basic steps included in this approach were designed by using the Digital Image Processing (DIP) technique, periodic distance vertical direction (PDVD),[6] considering significant features in the morphological changes of the T-wave used. It also provides the classification of the included arrhythmia(s) subjects.[7,8]

Furthermore, this classification predicts the extent of future arrhythmia in patients with no episode of electrophysiological changes. The graphical representation of the electrocardiogram reports generally describes the computerised values, which explain the visible aspects of the T-wave changes in a single RR.[9,10] In this study, we applied deep learning using convolutional neural networks (CNN) to classify the arrhythmia using Python programming language 3.9 version. Deep learning is an innovative approach to analysing medical imaging data more conveniently and efficiently. This study aimed to consider the significant morphological changes of T-waves in patients with classical Arrhythmia episodes.

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METHODOLOGY

The prospective longitudinal study was conducted at the Armed Forces Institute of Cardiology (AFIC), Rawalpindi, Pakistan and Government College University, Faisalabad, Pakistan, from July to October 2017 after Institutional Ethical Review Board approval (AFIC-IERB-SOP-15).The WHO sample size calculator was used with anticipated population proportion at approximately 22.87%.[11]

Inclusion Criteria: ECGs of patients with significant arrhythmia episodes showing on 24-hour Holter monitor recording were included.

Exclusion Criteria: None.

The patients predominantly showed the symptoms of arrhythmia selected in this study. All patients were referred for 24-hour Holter monitor recording by the consultant Electrophysiologist of the respective department. ECG data of 126 cardiac patients having clinical symptoms of abnormal heartbeat retrieved from 24-hour Holter monitoring machine EC-12H having bipolar channels 1,2,3,12. The targeted population consisted of four classes: IHD, PVC, BD, and control.

Python programming language was used to analyse the ECG imaging data. Installing Python with the appropriate version with image processing libraries or functions was necessary. The whole data comprised on ECG images were then inputted into the model for training and prediction was performed using Convolutional Neural Network (CNN).[12,13]

A basic understanding of ECG feature extraction was considered to achieve the best matching training results by the classifier, and then characteristics for the prediction of future arrhythmia were applied. The T-wave amplitude was measured using the Matplotlib library of Python programming language. Training and testing were performed to predict future arrhythmia through each set of ECGs based on the morphology of T-waves. CNN classifiers were used to analyse categorically each ECG signal digitised values of significant T-waves that were recognised for the given population size of the cardiac patients. The classification was performed using two dimensions (2D) CNN.[14]

All analysis were performed on an Intel core i7 8300 CPU, and multiple epoch numbers were embedded to run the training of ECG data. Batch sizes were focused on finding the highest accuracy in the implemented model. Data augmentation was performed for better results in PVC and IHD ECG images. Quantitative variables were expressed as Mean ± SD and qua-litative variables were expressed as frequency and percentages.

RESULTS

One hundred twenty-six patients diagnosed with arrhythmia were selected. The ECG dataset of patients was divided into samples for training and testing. The mean episode of PVCs in participants was 21.5± 30 (percentage of ratio from 126 patients). The mean duration of significant ECG episodes was 3.33±9.65 (seconds). A high-frequency range was observed in the class of IHD 48(61.8%) compared to PVCs 26(28.76%). The dataset was divided for training and testing purposes, with 88(70%) for training and 38(30%) for testing. These are the standard distributions of data practising in machine learning 24. No comparison with age and sex was included in the selected population. Paper ECG images were used for the analysis in this study, as shown in Figure.

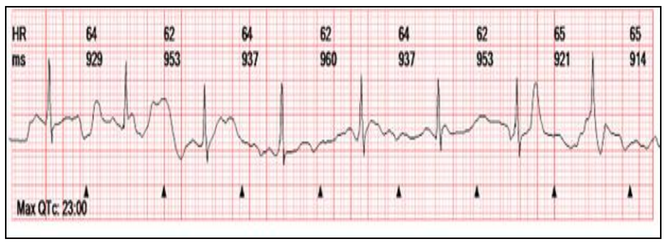

Figure: ECG showing T-waves Morphology on Holter ECG with QRS Complex Depression

The ST-segment elevation observed in 40 patients (50.4%), and ST-segment depression observed in patients having cardiac ischemic episodes were 20(25.2). Long and short QT intervals were excluded from the signal processing analysis. The selected ST-segment values were used to classify ischemic heart disease in 36 patients (45.36%). PVCs were observed in the ECG of 30 patients (37.8%). The study variables comprise each class of arrhythmia with the number of patients. Table illustrates the rank of each class's accuracy of classification results. T-wave peaks next to PVCs were high in the group of IHD with acute MI patients (0.2-0.35%) difference.

Table: Frequency results of trained CNN model for classification of arrhythmia

Classes	Precision	Recall	F1-Score	Accuracy	n
Ischemic Heart Disease	63%	50%	56%	82%	48
Control	75%	95%	50%	53%	40
Bradycardia	40%	84%	44%	61%	12
PVC	71%	82%	82%	82%	26

DISCUSSION

Following the extent of varying amplitude variations from beat to beat in T-waves, various studies showed the results using different classifiers.[13,14] The risk of getting arrhythmia in patients having clinical episodes of IHD has been recognised as more conducive as compared to other ventricular contractions. The disparity was encountered while comparing the data used in previous studies.[15] The classification algorithm used in this study to predict the arrhythmia is 2D CNN, which is traditionally applied for 2D ECG image classification. The approach based on deep learning for the arrhythmia classification was presented, and the evaluation was performed using the MIT-BIH arrhythmia database. Another study presented with ECG signal classification through 1-D convolutional neural network (CNN).[16]

The automatic classification of arrhythmia is a challenging problem for several reasons, including dissimilarity in morphological characteristics, and the most significant wave involved in this challenge is T-wave morphology. Heart rate variability is also another challenging hurdle for the classification.

According to the well-known methods to determine future arrhythmic consequences, the Holter monitoring recordings are more considered in computational measures.[17] The clinical findings that comprised the ventricular premature beat (VPB) usually detected from normal people's ECG data and symptoms may be skipped for trial studies. The extraction of ECG signals is quite hard, and most of the time, feature extraction is performed using a combination of characteristic points.[18,19]

The potential limitations of the study include follow-up of patients who were diagnosed with specific types of arrhythmia. Moreover, adverse effects such as sudden cardiac arrest and VT are not included in the study. This study suggested that larger-scale data analysis of cardiac patients is required for the Electrophysiologists and medical researchers in clinical perspectives for the future outcomes of cardiac arrhythmia by using artificial intelligence and deep learning computational approaches.

CONCLUSION

This innovative approach described the precision rate for the future aspect of causing cardiac arrhythmia in the population with no history of T-wave alternans. The proposed methodology can be considered for clinical diagnosis that may help electrophysiologists and medical researchers examine the heart rate in patients even with low differences in amplitude variation of T-wave.

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Authors Contribution

Following authors have made substantial contributions to the manuscript as under:

AF, IR & SF: Data acquisition, data analysis, data interpretation, critical review, approval of the final version to be published.

AH, NM & AS: Study design, drafting the manuscript, concept, approval of the final version to be published.

AH, GA & MUM: Critical review, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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