Abstract

Ventricular Tachyarrhythmia, also known as Ventricular Tachycardia, is a heart condition in which three or more consecutive beats are at a rate of more than 100 beats per minute. If gone unnoticed, this condition can result in a greater risk of cardiac arrest. Ventricular Tachycardia results in an estimated 300,000 deaths in the United States [1]. Ventricular Arrhythmias, such as Ventricular Tachycardia, are estimated to cause 75% to 80% of sudden cardiac death in the United States [2]. As such, being able to develop a system that accurately predicts the onset of Ventricular Tachycardia is of particular interest, as many lives can be saved. With the recent rise and development of Artificial Intelligence (AI) systems, our study focused on the implementation of such systems to help assist in predicting the onset of Ventricular Tachycardia. We developed a 3-minute warning system and trained this system using Extreme Gradient Boosting (XGB). This is an optimized gradient boosting algorithm that is known for its high performance. XGB combines decision trees as well as gradient boosting and tends to generally outperform other algorithms such as RF and SVM in a wide variety of scenarios. Using XGB, we are getting better results [3] versus other papers who developed a 5 minute and 10 second warning system using RF and SVM algorithms [4]. The implications for such a warning system are profound; besides saving thousands of lives each year, doctors can use the data gathered from the warning system to further understand the causes and cures of Ventricular Tachycardia.

Introduction

Ventricular Tachyarrhythmia, or simply V-Tach, is a heart condition wherein the heart rate extends beyond 100 bmp. These fast-paced beatings, or tachycardias, originate for the lower ventricle of the heart. The symptoms for V-Tach include racing heartbeat (palpitations) that is 100 or more beats per minute, shortness of breath due to lack of oxygen, dizziness and even lack of consciousness, and chest pains that usually go away within 30 seconds. If the chest pain lasts longer than 30 seconds, it can usually lead to a cardiac arrest and possibly even death [5]. Ventricular Tachycardia is one of the most debilitating diseases with a death rate of over 300,000 per year in just the United States, of which 34,000 people fall under the category of senior citizens alone [9]. While multiple kinds of cardiac arrests are responsible for deaths of these hundreds of thousands of people, V-Tach remains the cause of 75% to 80% of cases of sudden cardiac arrests, most likely followed by the death of the patient [10].

Implantable-Cardioverter Defibrillator, or ICD, is a device implantable inside the body that can perform defibrillation, cardioversion and control the pacing of the heart. It can detect and terminate life-threatening ventricular tachyarrhythmia by recognizing irregular heartbeat and subsequently providing electric shocks to the heart to bring the heartbeat back to a normal pace [4]. For the researched data, the ICD's sampling rate was 128 Hz and it also was capable of storing data for the last 2048 R-R intervals and intracardiac electrograms that immediately preceded the occurrences of the shocks [3]. However, although highly helpful, ICD shocks are extremely painful and tremendously affect the patient's quality of life and their emotional and mental wellbeing. These shocks may also be applied unreasonably and incorrectly in scenarios where a shock was not really necessary, such as a faster heartbeat that may occur for a small interval of time due to a high energy-consuming activity [6]. As a hypothetical instance, consider an old person in a sudden panic, walking from their room to the kitchen at a brisk pace to quickly turn off the gas stove. In such a case, a simple brisk walk for the old person, along with the sudden panic and anxiety, may result in a heartbeat that is higher than 100 bpm and could signal the ICD to provide an electric shock to the old person, even though it does not seem to be required. So although the heart rate of this old person might have come back to the regular pace itself eventually, the person would still have to suffer a severe unsolicited pain, and in the process, might even accidentally hurt themselves from something around the kitchen. Inappropriate ICD shocking can be caused due a variety of reasons such as lead fracture, electromagnetic interference, set screw malposition, etc. [7]. These unnecessary electric shocks become especially problematic when the patient is in a risky position where such a shock can be life-threatening regardless [3]. For example, a painful ICD shock to a patient—who may be driving a vehicle, climbing up or down a flight of stairs or a ladder, in possession of

an infant, etc.—might distract them from their current activity, resulting in an accident that might be injurious, and possibly even deadly, not only to themselves but to those around them as well.

The utilization of Machine Learning and Artificial Intelligence in the field of healthcare and medicine has increased significantly within the past few years [3]. In health, AI enabled decision support systems, when implemented correctly, can aid in enhancing patient safety by improving error detection, patient stratification and drug management. In recent years, one additional area that has become a very important use case for artificial intelligence in healthcare roughly is that of risk prediction to improve the patient safety outcomes. While ICD collects and stores data about the occurrences of previous shocks, AI's capabilities leveraging machine learning can be used to observe and identify the frequency of these occurrences and therefore predict future possibilities of potential life-threatening events such as in the case of V-Tach, thereby acting as an early warning system that can help reduce the risks associated with the unpredictability of such events and furthermore by improving the patient's quality of life and of those around them [8].

HRV, short for Heart Rate Variability, is the data that illustrates the variations in heart rate of a patient. HRV provides indexes that contain information about the cardiac electrophysiology and autonomic regulation such as respirator, baroreflex and circadian fluctuations, which are usually signs of a positive and healthy response [1]. Higher HRV usually indicates a better cardiovascular fitness and resilience to stress, whereas on the other hand a lower HRV often points to increased risks of cardiovascular diseases and mortality post myocardial infarction [2]. While HRV signals used with Machine Learning do help in predicting occurrence of Sudden Cardiac Death, most of these studies have been done on healthier patients and therefore it is hard to conclude the difference between the practicality of predicting SCD in healthier patients and that of patients with cardiac diseases [3].

In this paper, our focus was to study the ICD data, which was collected from the patients in three months intervals throughout the trial [3], to predict the heart rate variability and develop a warning system that would notify the patient and their chosen delegates 3 minutes before, and 10 seconds before the occurrence of a ventricular tachyarrhythmia with the idea that the earlier the warning signal, the better. Two kinds of heart rhythms were analyzed—Regular and Pre V-Tach—and different features were extracted. The features utilized in this research are Principal Component Analysis, Mean N-N Interval, Hjorth Complexity and Mobility, Detrended Fluctuation Analysis, and Frequency Domain Analysis. The research paper also compares between three kinds of algorithms, namely Random Forest, Support Vector Machine and Extreme Gradient Boosting. Random Forest, or RF, is an ensemble that combines multiple decision trees to make predictions. Support Vector Machine, or SVM, is a powerful ML algorithm for classifying small-to-medium-sized datasets. It constructs an optimal hyperplane to separate classes, making it effective for both linear and non-linear data. Extreme Gradient Boosting, or XGB, is a highly optimized algorithm that combines decision trees and gradient boosting and outperforms RF and SVM in most of the cases. Using these features and machine learning models, and Area Under the Curve (AUC), Sensitivity and Specificity as the evaluation metrics, the study of the research project was justified by judging the performance of the model.

Related Works

Early detection of Ventricular Tachyarrhythmia is an area explored by numerous researchers. Machine Learning, as also mentioned by Tauben Averbuch et al, is the major contributor for predictions of V-Tach. By extracting important information from the raw data provided, ML models can acquire useful information related to risk prediction through their advanced computational techniques.

References

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