ORIGINAL RESEARCH

Submitted: 18.10.2022; Accepted: 8.11.2022; Published online: 25.12.2022

Analysis And Comparison Of Ventricular Cardiac Arrhythmia Classification Using Potassium Channel Parameters With ANN And KNN Classifier

Mahanya G.B., Nithyaselvakumari S

Department of BioMedical Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamilnadu, India, pincode: 602105

ABSTRACT

Aim: The Motive of this research is to analyze, compare ventricular Cardiac Arrhythmia (CA) classification using potassium channel (k^+) parameters with Artificial Neural Network (ANN) and K-Nearest Neighbor (KNN) classifiers. **Materials and Methods:** D Noble Model For Human Ventricular Tissue (DNFHVT) is used for our classification. The DNFHVT is a mathematical model of action potential focusing on major ionic currents like K^+,Na^+ and Ca^{+}. Size of the sample was calculated by keeping threshold 0.05, G Power 80%, confidence interval 95% and enrolment ratio as 1. Number of samples considered is 20. These data are imported to KNN and ANN classifiers to find better accuracy among them. The accuracy of novel ANN and KNN classifiers for 20 samples is obtained by alternating the cross fold validation. These results will be imported to Statistical Package for the Social Science (SPSS) software to identify the overall accuracy for each classifier. **Results:** The results are obtained from SPSS for novel ANN and KNN classifiers. ANN shows accuracy of 13.14% with standard deviation (1.6800) and Standard error mean (0.3757). Similarly KNN produces an accuracy value of 7.19% with standard deviation (1.6902) and Standard error mean (0.377). **Conclusion:** As of the results, it clearly shows that ANN has better accuracy for classification than KNN.

Keywords

Ventricular Cardiac Arrhythmia, Potassium Ion, Potassium Channel, Novel ANN and KNN Classifiers, Action Potential, Bradycardia, Tachycardia.

Imprint

Mahanya G.B., Nithyaselvakumari S. Analysis And Comparison Of Ventricular Cardiac Arrhythmia Classification Using Potassium Channel Parameters With ANN And KNN Classifier. Cardiometry; Special issue No. 25; December 2022; p. 926-933; DOI: 10.18137/cardiometry.2022.25.926933; Available from: http://www.cardiometry.net/issues/no25-december-2022/potassium-channel-parameters

INTRODUCTION

Dysfunction in the heart's electrical activity leads to some differences in the heartbeat like too fast or too slow. Generally these types of changes in the heart are called Cardiac Arrhythmias (CA). This mostly occurs at the ventricle myocardium (Skogestad and Aronsen 2018) CA wave disturbances are being the major reasons for mortality and morbidity all over the world. CA occurring at the ventricle leads to sudden cardiac death which has registered about 300,000 deaths, because of the ions concentration levels variations and channel failure (Lehmann et al. 2016). Potassium (K^+) channel dysfunction can cause life – threatening Ventricular Cardiac Arrhythmia conditions. Prescribed drugs for dysfunction K^+ channel can produce greater risk to the patients, whose type of CA is not identified correctly (Smits et al. 2008). At least 4 major potassium channels like $I_{tol,}I_{kr},I_{ks\ and}\ I_{k1}$ contribute more for the repolarization process which has different density, voltage and time dependent properties. Addition to this even cl^- channels and currents generated by the ion pumps and exchangers cause a lot of effect in AP (Moss 2005; Näbauer 1998). Any abnormality and excitability in the myocardial cells will produce ectopic beats. K^+ controls the process of repolarization of the cardiac Action Potential (AP). Any increase or decrease in K^+ channel will lead to CA (Ravens and Cerbai 2008). It is obvious that channel modeling in K^+ is very important in repolarization abnormalities. Some of these changes incorporate QT syndrome (Rahm et al. 2018). QT syndrome occurs in mutations of 5 ion channels genes (Na^+ and K^+). In 1969 it was identified K^+ channel is important in cardiac AP plateaus. When cardiac potassium current is either rising or decreasing, it changes the repolarisation in AP which causes Long QT syndrome (LQTS). Mostly identified when there is a prolongation in the QT interval (Moss 2005). Our team has extensive knowledge and research experience that has translate into high quality publications (Chellapa et al. 2020; Lavanya, Kannan, and Arivalagan 2021; Raj R, D, and S 2020; Shilpa-Jain et al. 2021; S, R, and P 2021; Ramadoss, Padmanaban, and Subramanian 2022; Wu et al. 2020; Kalidoss, Umapathy, and Rani Thirunavukkarasu 2021; Kaja et al. 2020; Antink et al. 2020; Paul et al. 2020; Malaikolundhan et al. 2020)

Studies related to ventricular Cardiac Arrhythmia and potassium channel many studies have undergone during the year 2016 – 2021 (≅ 57,700 as per google scholar data) in which ScienceDirect have published 230 articles and Pubmed have published 150 articles till the current year (2021). Potassium channels have a key role in cardiac AP control. Genes, loss of function during the mutation with voltage gated potassium channel causes QT syndrome, familial atrial fibrillation and Anderson – Tawil syndrome. And nowadays in many studies it is observed that potassium ATP implements Brugada Syndrome (BS) and early repolarization syndrome (Crotti, Insolia, and Schwartz 2011). The synchronizing closing and opening of ion channels like Ca^+, $Na^+$and K^+. Is responsible for the AP, Na^+ and Ca^+ responsible for inward depolarising and potassium ion is responsible for outward depolarising. Dysfunction in the mutation of K^+ channel is expected to result in Cardiac Action Potential Duration (APD) which leads to disease like BS and Short QT Syndrome (SQTS) (Giudicessi and Ackerman 2012). Human heart produces ≅ 1,00,000 contraction everyday. There are 10 different potassium channels where some of them are responsible for early repolarization and others responsible for delayed repolarization and even others can be open all the time for cardiac cycle. There are 3 different polarizing currents called I_{kr},$I_{ks\ and}$ I_{k1} mainly responsible for the repolarization process. They have many overlapping functions which complicate the process which are also called repolarization reserves (Schmitt, Grunnet, and Olesen 2014). K^+ channels are integrated membrane proteins that transport the K^+ ions across the membranes. This shapes the AP and regulated electrical activity of the brain and heart. Long QT Syndrome (LQTS) is a family of cardiac rhythm disorders because of QT elongation and abnormalities in T waves. SQTS is a rare but very dangerous heart disease which is characterized by the fast cardiac repolarization (<350 ms). Patients will have QT intervals, tall and upright T waves, shortened atrial and ventricular refractory periods (Burg and Attali 2021).

Since it is hard to explore the human cardiovascular system continuously to get human experimental data information and examination forecast (CA). In the case of animal studies, CA investigation is conceivable. We can't depend on animal data information because there are numerous varieties in the AP qualities when contrasted with people AP. The elective method to examine such CA is through computational methodology.

MATERIALS AND METHODS

Research is carried out in the Digital Signal Processing laboratory in the department of Biomedical Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences. The research analysis is carried out in a single group with different potassium parameter conditions. Sample size was calculated by keeping threshold 0.05, G Power 80%, confidence interval 95% and enrolment ratio as 1. Number of samples considered is 25 for each analysis. This paper's dataset was obtained by computer simulation method. It contains about 25 samples each which is labeled as Normal, Bradycardia and Tachycardia. The parameters used to identify the accuracy are Voltage,Current and Activation Gate of the channels ((Dierckx et al. 2019).

The values for the potassium channels are obtained by alternating the values from normal (5.4mM). Initially the Normal value is obtained later the values for 50% decrease (2.7mM) and 100% increase (10.8mM) is obtained. This is done for the Extracellular potassium Channel. It is observed that there is an increase in AP distance (APD) when the value is decreased to 50% which means the number of heart beats per minute decreases which leads to bradycardia. When the value is increased 100% the APD reduces, the number of heart beats increases per minute which leads to tachycardia (Dierckx et al. 2019). Based on this the dataset is tabulated in Microsoft Excel sheet and imported to the classification learner. Model type is selected as KNN and ANN

$$C_m\,(dV/dt) = -\,(I_{ion} + I_{stim}) \qquad (1)$$

C_m is the Membrane Capacitance (μF), dv/dt is Membrane Potential (mV), I_{ion} is total ionic current (pA), I_{stim} is stimulation current (pA) as given in Equation (1).

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \qquad (2)$$

Equation (2) is to find the accuracy using the confusion matrix obtained from the classifiers individually. Using SPSS software finally we are calculating the group statistics and independent t test data containing the standard deviation, mean and standard error mean.

Artificial Neural Network

ANN is a classifier inspired from the sophisticated functions of the human brain where billions of interconnected neurons process the information parallely. ANN includes applications in various fields like computing, science, medicine, engineering, environment, agriculture, climate etc. In recent days ANN is becoming a more popular and helpful model for clustering, classification and pattern recognition. ANN are very effective and efficient in providing high level capacity in handling complex problems (Abiodun et al. 2018). In our research ANN is used to classify the data to normal, tachycardia and bradycardia from 25 samples.

K-Nearest Neighbor

KNN is known as one of the most well – known supervised learning algorithms for pattern classification, it is the oldest and simplest classifier. KNN uses the Nearest Neighbour (NN) rule for the classification of data. Advantages like simplicity, effectiveness and competitive classification performance. It finds the closest point to "K" which is a query and assigns its class label to the query ("Website," n.d.; Chua and Tan 2009). In our research KNN is used to classify the 25 samples into normal, tachycardia and bradycardia.

Statistical Analysis

For the statistical approach, the computational tool used is IBM SPSS Statistics 28.0.0.0. Independent sample t test was performed to test the samples to identify the accuracy, mean and standard deviation and also to compare two novel ANN and KNN classifiers. The values named as group 1 and 2 are imported to the SPSS software. The output is represented in tables and graphs and the results conclude ANN produces better accuracy compared to KNN. ANN has accuracy of 13.14% with standard deviation (1.6800) and Standard error mean (0.3757). KNN produces an accuracy value of 7.19% with standard deviation (1.6902) and Standard error mean (0.377) ((Dierckx et al. 2019).

RESULTS

Figure 1 (a) Represents the normal AP of a good cardiac health in which the APD distance is normal when the K^+ channel is fixed to its normal value (5.4mM).

Figure 1 (b) Represent the abnormal ECG pattern and AP when the K^+ channel value is increased by 100% the APD is reduced when compared to normal APD which increases the number of beats per minute which leads to tachycardia.

Figure 2 Represents the confusion matrix of ANN classifiers when training the sample data. Which represents the True Negative, True Positive, False Positive and False Negative in 3*3 matrix.

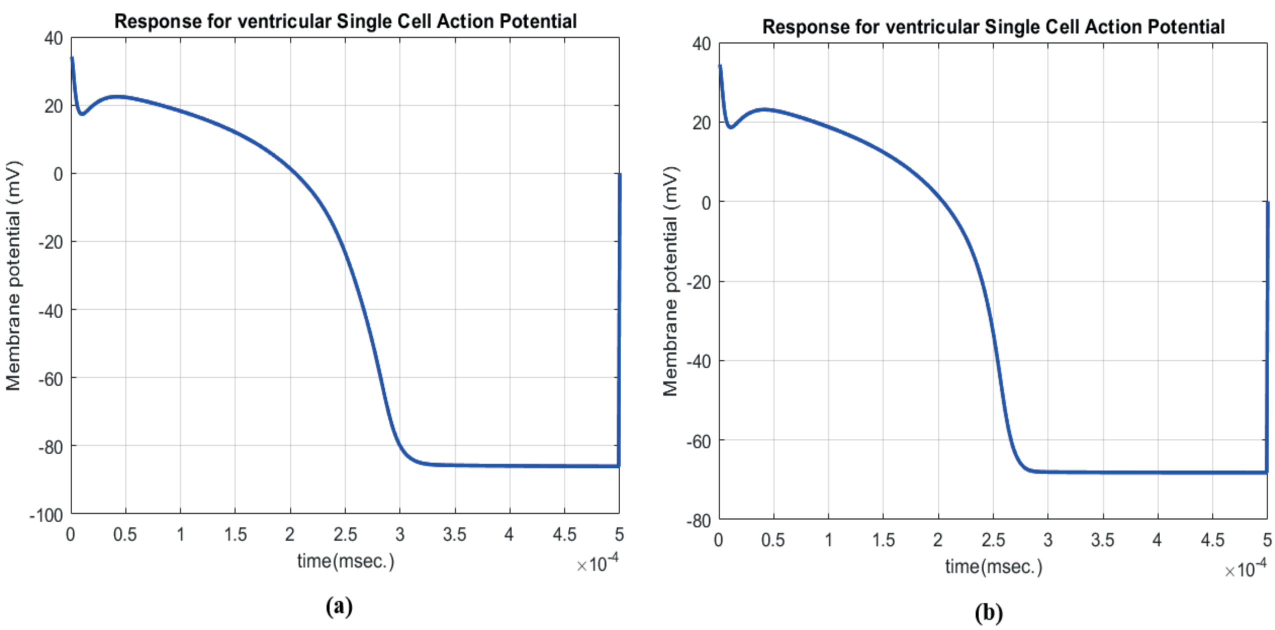

Fig. 1. (a) Normal ECG pattern when the Potassium channel value is normal (5.4mM). (b) Abnormal ECG pattern when the Potassium channel value is increased by 100% (10.8mM)

Figure 3 Represents the confusion matrix of KNN classifiers when training the sample data. Which represents the True Negative, True Positive, False Positive and False Negative in 3*3 matrix.

Figure 4 Shows the graphical representation of the accuracy of two groups obtained from SPSS software. X-axis represents the groups (KNN and ANN) and Y-axis represents the accuracy (%) KNN shows accuracy of 7.19% and ANN shows 13.14%.

Table 1 represents the accuracy of novel ANN and KNN classifiers obtained for 20 samples of potassium channel.

Table 2 represents the group statistics of the two groups ANN and KNN, their standard deviation, mean and standard error mean.

Table 3 represents the independent t test data obtained from the SPSS software which compares ANN and KNN to check if the data is different.

DISCUSSION

Figure 1 (a) represents the normal AP pattern of normal cardiac health when the value of K^+ channel is set to 5.4mM and the APD will be at 3 x 10^{-4} m/sec. Figure 1 (b) represents the abnormal AP pattern when the value of K^+ channel is increased by 100% to 10.8mM, there will be a slight abnormal decrease in APD (2.7 x 10^{-4} m/sec). K^+ channel which is present in the cell membrane controls the movement of K^+ to and fro into the cells, plays an important role in excitable and

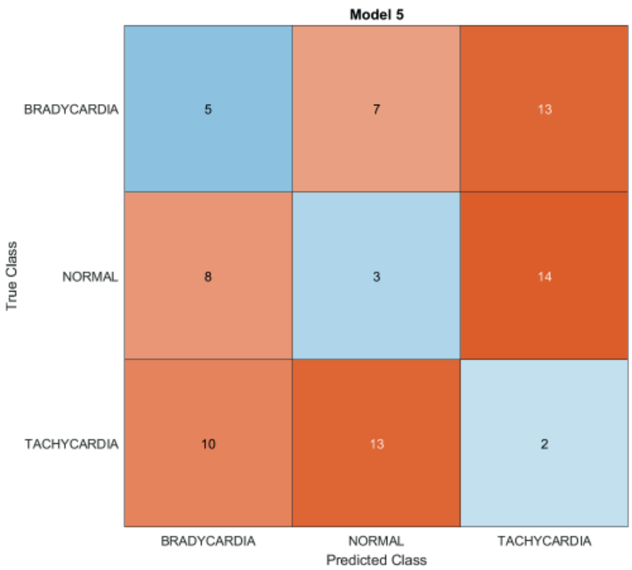

Fig. 2. Confusion Matrix of Artificial Neural Network (ANN) classifier

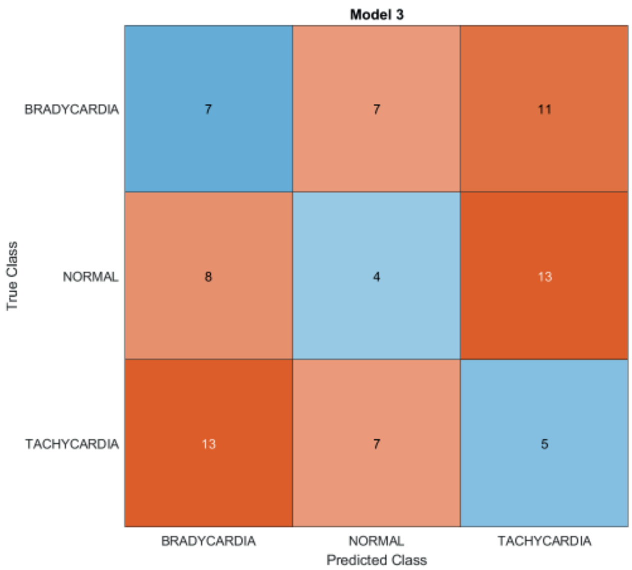

Fig. 3. Confusion Matrix of K-Nearest Neighbor (KNN) classifier

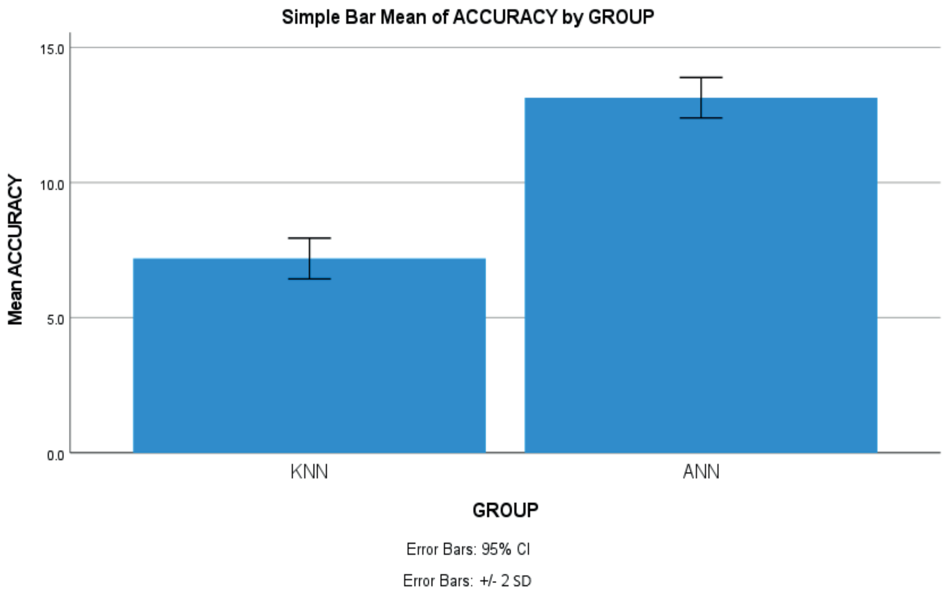

Fig. 4. Mean accuracy rate of accuracy rate of the two groups Artificial Neural Network (ANN) and K-Nearest Neighbor (KNN). X axis: Artificial Neural Network (ANN) and K-Nearest Neighbor (KNN); Y axis: Mean accuracy rate SD+-2.

Table 1

Accuracy obtained for potassium channels by Artificial Neural Network (ANN) and K-Nearest Neighbor (KNN). 20 sample data were loaded in SPSS for analysis.

S.No	ACCURACY OBTAINED THROUGH ANN FOR POTASSIUM CHANNEL	ACCURACY OBTAINED THROUGH KNN FOR POTASSIUM CHANNEL
1	5.3	13.3
2	6.7	13.3
3	9.3	14.7
4	5.3	10.7
5	6.7	9.3
6	6.7	10.7
7	6.7	9.3
8	5.3	10.7
9	5.3	9.3
10	9.3	10.7
11	5.3	16
12	9.3	14.7
13	9.3	13.3
14	6.7	13.3
15	5.3	10.7
16	6.7	14.3
17	6.7	14.3
18	9.3	14.3
19	9.3	13.3
20	9.3	13.3

Table 2

Group statistics of the accuracy rate of the two groups Artificial Neural Network (ANN) and K-Nearest Neighbor (KNN), their mean, standard deviation and standard error Mean. Accuracy Rate of ANN Algorithm is 13.14% and KNN classifier has an accuracy rate of 7.19%

GROUP STATISTICS

	Group	N	Mean	Std. Deviation	Std. Error Mean
Accuracy	KNN	20	7.190	1.6902	0.3779
	ANN	20	13.140	1.6800	0.3757

non excitable cells. K^+ channel has 3 stages: resting,activation and inactivation, during resting the channel will be closed and opened during activation and then to the non-conduction states (Kuang, Purhonen, and Hebert 2015). The decrease in APD will increase the heart rate per minute which may lead to Tachycardia (>100 beats per minute).

Figure 2 represents the confusion matrix obtained from the ANN classifiers represented in 3x3 matrix shows the predicted and actual classifier where 3 represents the number of different classes namely normal, tachycardia and bradycardia. Where x-axis lists the predicted class and y-axis lists the ANN class predictions (true class). It has entries as True Positive (TP),, False Positive (FP), True Negative (TN), False Negative (FN) (Kuang, Purhonen, and Hebert 2015; Visa et al. 2011). Figure 3 represents the confusion matrix obtained from the KNN classifier represented in the 3x3 matrix. KNN is the most simple and most used method for classification of data. It is a case-based learning method keeping all data for classification (Kulkarni, Chong, and Batarseh 2020; Guo et al. 2003). It is the most widely used method for classification problems. It represents the actual and predicted value counts. It contains entities such as TP,TN, FP and FN. The most important metrics used during large sets of classification problems is accuracy (%) (Kulkarni, Chong, and Batarseh 2020). Figure 4 represents the graphical representation of accuracy obtained from SPSS software which indicates ANN produces better accuracy than KNN x-axis plot consisting of the group (ANN and KNN), y-axis consists of the accuracy (%). SPSS software is a good software to do statistical analysis of any type of datasets. It can be used to perform analysis and data entry to create tables and graphs. Also capable of handling very large amounts of data and to perform any type of analysis. In our research

Table 3
Independent Sample t test which compares the two independent groups (KNN and ANN). Datas are statistically insignificant (p=0.414)

Independent Sample Test										
		Levene's Test for Equality of variances		T-test for Equality of Means						
		F	Sig.	t	df	Sig (2.tailed)	Mean diff	Std. diff error	5%confidence interval of the difference	
									Lower	Upper
ACCURACY	Equal variances assumed	.682	.414	-11.166	38	<.001	-5.9500	.5329	-7.0288	-4.8712
	Equal variances not assumed			-11.166	37.999	<.001	-5.9500	.5329	-7.0288	-4.8712

SPSS is used to identify the accuracy,mean and standard deviation. It also has many other applications like analysis, interpretation, presentation and organization of the data. SPSS is a package of analytical process, data collection, reporting and deployment (Nagaiah and Ayyanar 2016). Table 1 represents the accuracy obtained through ANN and KNN classifiers for potassium channels. Table 2 represents the group statistics which are tabulated as group (KNN and ANN), number of samples (N), standard deviation, mean, and standard error mean all these are compared for their accuracy (%). SPSS software conducts all forms of statistical analysis which converts the quantitative data into qualitative analysis. It helps in arranging the data by using computational analysis which reduces the technical error (Nagaiah and Ayyanar 2016). Table 3 represents the independent sample t test performs the Levene's test for equality of variance and t – test for equality of variance and compass the accuracy whether equal variance assumed or equal variance not assumed. This sample test is done when the two groups are independent. It is a widely used experimental design in medical experiments to identify the difference in physiological index with different diseases which in our case is normal,tachycardia and bradycardia (Liang, Fu, and Wang 2019).

The disservice of our outcome is however ANN creates better precision of 13.14% it is still less exact contrasted with numerous different classifiers like gaussian and polynomial classifiers which produces higher exactness than ANN and KNN.

Future Works will incorporate investigating more potassium ion channels and its commitment to the heart normal function and precision rate of numerous different classifiers will be looked at and learned. Also, a lot more real-life samples can be gathered and examined to apply it, in actuality.

CONCLUSION

The conclusion exhibits that the ANN classifier has the highest values. The Accuracy Rate of ANN Algorithm is 13.14% and KNN classifier has an accuracy rate of 7.19%. The Precision and Recall of ANN Algorithm is efficient when compared with KNN for potassium ions.

DECLARATIONS

Conflict of Interests

No conflict of interest in this manuscript.

Authors Contributions

Author GBM was involved in literature survey in mathematical models, Euler integration matlab code development, Arrhythmia analysis and manuscript writing. Author SN involved in conceptualization, data validation and critical review of manuscript.

Acknowledgment

The authors would like to express their gratitude towards Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences (Formerly known as Saveetha University) for providing the necessary infrastructure to carry out this work successfully.

Funding:

We thank the following organizations for providing financial support that enabled us to complete the study.

1. Venus Electronics, Tamil Nadu, India.
2. Saveetha University
3. Saveetha Institute of Medical and Technical Sciences
4. Saveetha School of Engineering

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