# ID163_Atrial features-based prediction of sinus tachycardia using LSTM-RNN model


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## ABSTRACT

**Sinus Tachycardia (ST) reveals pathological dysfunctions and differentiates distinct arrhythmias. The progression of Atrial Fibrillation (AF) from paroxysmal to persistent is frequently associated with tachycardias. Moreover, the most effective AF detection methods suggest incorporating both atrial and R-R interval features. Therefore, the study aims to use the Long Short-Term Memory Recurrent Neural Network (LSTM-RNN) model to investigate the influence of atrial characteristics on predicting tachycardia. Electrocardiograms (ECGs) from 10 healthy volunteers 26 ± 3.4 years (4 females) were recorded for Sinus Rhythm (SR) and ST conditions along with 10 AF data. For ST, the 5-day follow-up recording was performed with each volunteer. ECG recordings were performed for a duration of 10 s. Atrial features, along with R-R interval and Heart Rate (HR), were utilized as inputs for the developed LSTM-RNN multivariate time series forecasting model. The features were statistically analyzed before training the LSTM-RNN model. The correlation is positive and significant between HR and atrial amplitude (p<0.05) in ST. The developed LSTM-RNN model has training and validation loss with mean squared error values of 0.0827 and 0.1568. Thus, the study concludes that the proposed atrial feature-based LSTM-RNN model may be suitable for predicting AF and effectively distinguishing it from other atrial arrhythmias in the future.**


## INTRODUCTION

- **Tachycardia frequently coexists with the progression of paroxysmal to persistent Atrial Fibrillation (AF) [1].**
- **AF is a prevalent cardiac arrhythmia marked by the rapid and abnormal electrical activity of the atria that can lead to a rapid ventricular response.**
- **Tachycardia is characterized by a sinus rate greater than 100 bpm and inquiries on Sinus Tachycardia (ST) demonstrate a range of issues, ranging from a persistent autonomic disorder to an underlying inflammatory or other infectious condition [2].**
- **The identification of atrial arrhythmias relies on evaluating the presence and characteristics of P-waves with their temporal changes [3].**
- **In a recent study, several atrial features have been incorporated to examine the variations in P-wave morphology during both Sinus Rhythm (SR) and ST settings, with the aim of optimal lead selection [4].**
- **Hence, implementing these atrial features along with R-R interval may increase the prediction and diagnostic accuracy of AF at its early paroxysmal condition.**
- **The main aim of this study is to use an LSTM-RNN model to predict HR under ST conditions. The proposed model is based on the concept of multivariate time series forecasting.**

## METHODOLOGY

### ➢ *Data collection*

- **ECGs were collected from 10 healthy volunteers with the age of 26 ± 3.4 years (4 females) for SR and ST conditions under a supine rest position.**
- **On focusing ST, each volunteer underwent a 5-day follow-up with 10-second ST recordings, resulting in 50 data samples for ST, with 5 samples from each volunteer.**
- **Additionally, the study included 10 AF data from the Chapman University and Shaoxing People's Hospital (CUSPH) database with a mean age of 76 ± 6.9 years [5].**

### ➢ *Feature set*

- **The feature set is made only for ST conditions as the study focuses on predicting tachycardia HR.**
- **The ECG signal was acquired and processed using the Mindray Beneheart R12 ECG machine to extract the required features.**
- **The input feature set consists of atrial features like P-wave amplitude, area, duration, duration/amplitude, area/duration, and P/QRSpp ratio, along with the R-R intervals and HR.**

### ➢ *Statistical analysis*

- **All the data underwent a Shapiro-Wilk test to assess their normal distribution.**
- **Pearson's correlation (r-value) was intended to examine the relationship between HR and atrial amplitudes.**
- **Additionally, a Two-Sample T-Test was performed to identify significant differences (p<0.05). All data were expressed in mean ± Standard Deviation (SD).**

### ➢ *LSTM-RNN architecture*

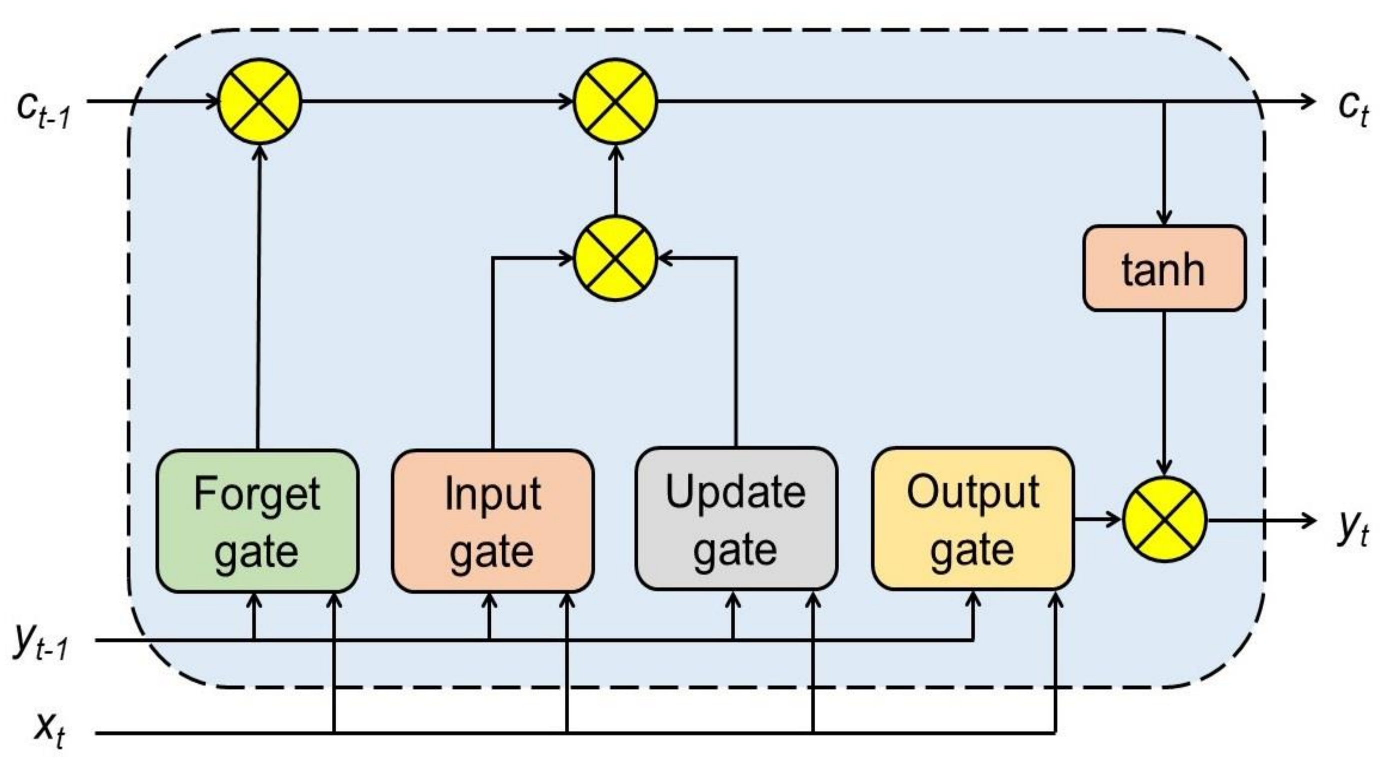



**Figure 1. Block diagram of Long Short-Term Memory Recurrent Neural Network (LSTM-RNN). Where '$x_t$' is the current state input, '$y_t$' is the output gate, '$y_{t-1}$' previous state output, '$c_t$' upgrade gate, and '$c_{t-1}$' is the previous upgrade gate.**

## RESULTS

**Table 1. Parameters of SR, ST, and AF.**

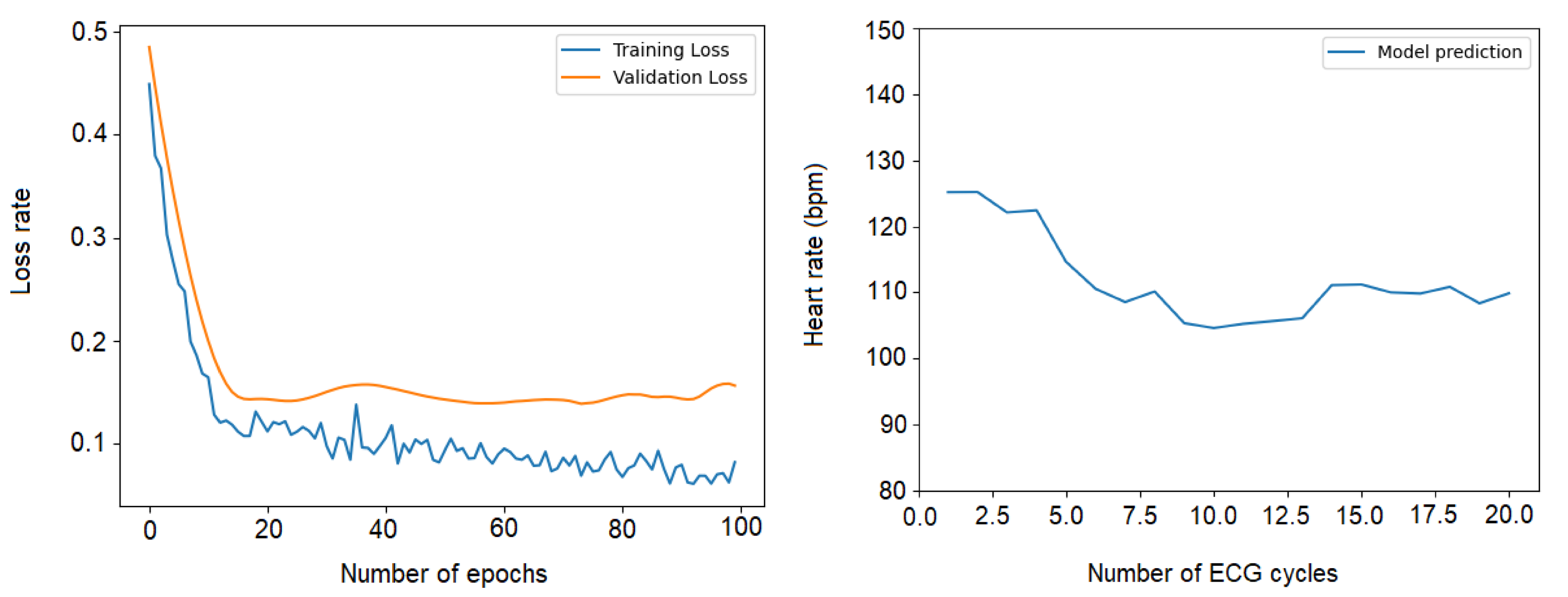
| Parameters | SR | ST* | AF* |
|---|---|---|---|
| R-R interval (ms) | 764 ± 72.7 | 527 ± 77.3 | 693 ± 193.2 |
| HR (bpm) | 79 ± 7.6 | 116 ± 17.1 | 100 ± 27.6 |
| P/f-wave amplitude (μV) | 102 ± 8.4 | 158 ± 38.7 | 37 ± 17.4 |

The values are in mean ± SD and *Two sampled T-Test with p<0.05 (SR vs ST; SR vs AF).

**Table 2. Atrial (P-wave) features and HR for SR and ST conditions.**

| Parameters | SR | ST | p-value* |
|---|---|---|---|
| HR (bpm) | 79 ± 7.6 | 116 ± 17.1 | p<0.05 |
| R-R interval (ms) | 764 ± 72.7 | 527 ± 77.3 | p<0.05 |
| amplitude (μV) | 102 ± 8.4 | 158 ± 38.7 | p<0.05 |
| duration (ms) | 97 ± 15.4 | 102 ± 17.3 | p>0.05 |
| area (μV*ms) | 5843 ± 1521 | 8940 ± 3110 | p<0.05 |
| area/duration (μV) | 60 ± 14 | 86 ± 23.3 | p<0.05 |
| $P/QRS_{pp}$ | 0.1 ± 0.05 | 0.09 ± 0.03 | p>0.05 |
| PR interval (ms/μV) | 0.9 ± 0.3 | 0.6 ± 0.1 | p<0.05 |

The values are in mean ± SD and *Two sampled T-Test.




(a) (b)

**Figure 2. (a) illustrates the loss rate of the training and validation of the LSTM-RNN model. The plot displays the number of epochs, and the loss rate (MSE) in its x and y-axis. The training loss is recorded as 0.0827, while the validation loss is 0.1568. In Figure 2. (b), the LSTM-RNN model's forecast of the ST volunteer's HR is presented. The plot shows the number of ECG cycles, and the HR (bpm) in its x and y-axis. The mean value of the predicted HR is 112 bpm.**

## CONCLUSION

- **The present work predicts tachycardia using the atrial features-based LSTM-RNN model with the training and validation MSE of 0.0827 and 0.1568.**
- **The logic implemented in the LSTM-RNN model is multivariate time series forecasting.**
- **Therefore, this study may help to delineate the prediction of AF using the atrial-based features along with the R-R interval and HR using LSTM-RNN models in future.**
- **The key benefit of using the LSTM-RNN model is that it predicts missing data effectively, which may minimize false-negative predictions of other arrhythmias.**

## REFERENCES


1. N. Oguri et al., "Progression from paroxysmal to persistent atrial fibrillation in pacemaker patients with tachycardia–bradycardia syndrome: a multicenter study," Heart Vessels, pp. 1-7, Apr. 2023.
2. K. A. Mayuga et al., "Sinus Tachycardia: a Multidisciplinary Expert Focused Review," Circ. Arrhythm. Electrophysiol., vol. 15, no. 9, p. e007960, Sep. 2022.
3. P. W. Macfarlane, A. Van Oosterom, O. Pahlm, P. Kligfield, M. Janse, and J. Camm, Comprehensive electrocardiology. London: Springer Verlag London Ltd, Nov. 2010.
4. N. Prasanna Venkatesh, R. Pradeep Kumar, B. Chakravarthy Neelapu, K. Pal, and J. Sivaraman, "CatBoost-based improved detection of P-wave changes in sinus rhythm and tachycardia conditions: a lead selection study," Phys. Eng. Sci. Med., vol. 46, no. 2, pp. 925-944, Jun. 2023.
5. J. Zheng, J. Zhang, S. Danioko, H. Yao, H. Guo, and C. Rakovski, "A 12-lead electrocardiogram database for arrhythmia research covering more than 10,000 patients," Sci. Data, vol. 7, no. 1, p. 48, Feb. 2020.