Heart Rate Variability and Patient Mortality

An Application of Machine Learning in Healthcare

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Introduction

In a clinical setting, methods for predicting patient outcomes, and particularly patient mortality, are often used to enhance the decision-making of health-care professionals [1-3].

Heart rate variability (HRV) is a term describing the natural variation in the timing between subsequent heart beats, also called RR-intervals. HRV analysis can provide insights on cardiovascular health [4]. Evidence also shows that HRV is a potential predictor of patient mortality in cases of COVID-19, traumatic brain injury, and sepsis [5-7]. Further validation may allow for use of HRV measurements for both targeted and general use patient outcome prediction models.

This research aims to establish the efficacy of HRV statistic-based machine learning algorithms in predicting patient mortality in a diverse critical care environment, and illuminate future challenges and considerations in implementing such statistics into prediction models.

Methods

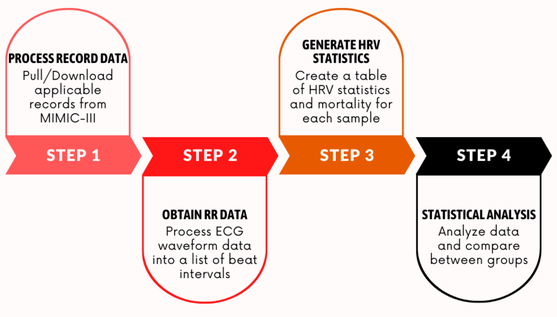

Figure 1. *Data cleaning and processing steps for ECG waveform data. Processing was handled using Python scripts and the wfdb tool provided by Physionet*

Data was pulled from the MIMIC-III clinical database, which stores deidentified patient health records and demographic data from upwards of forty thousand patients from their stays in the Beth Israel Deaconess Medical Center, and the MIMIC-III waveform database (matched subset), which stores the ECG recordings that have been matched to patient data in the clinical database.

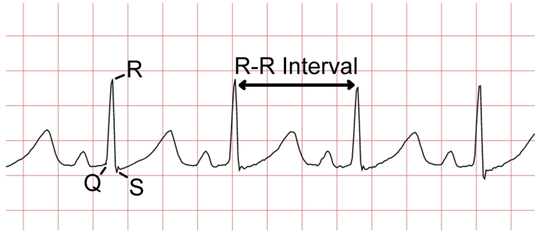

Figure 2. *Example ECG data from the MIMIC-III Waveform Database Matched Subset, displayed using the PhysioNet waveform visualization tool and with relevant signal features annotated*

Several measures were derived for each sample:

- Mean heart rate (**hr**)
- Standard deviation of normal beat intervals (**sdnn**)
- Root mean square of the successive differences between beats (**rmssd**)
- Percentage of successive normal beat intervals that differ by more than 50 milliseconds (**pnn50**)

These measures were calculated over a 5-minute moving window throughout the entire recording.

Data Analysis/Results

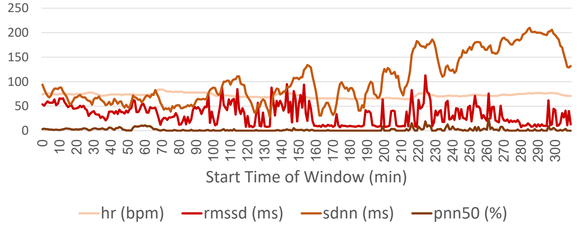

Figure 3. *5-minute moving window heart rate and HRV statistics generated from an ICU patient ECG recording, over roughly five hours of recording time*

Table 1. *5-minute heart rate and HRV statistics for 4259 independent hospital admissions, from 2664 patients. Statistical significance was calculated using a Mann-Whitney U rank test, using the scipy Python library.*

		HR (bpm)*	SDNN (ms)*	PNN50 (%)*
Gender	Male (n = 2,366)	86.35 ± 22.02	34.00 ± 26.22	6.46 ± 10.50
	Female (n = 1,893)	88.49 ± 22.40	35.21 ± 27.50	7.57 ± 10.92
	Significance	p < 0.001	p = 0.009	p < 0.001
Mortality	Patient Deceased, 90 days (n = 803)	88.80 ± 22.80	34.65 ± 27.82	7.76 ± 22.79
	Patient Alive, 90 days (n = 3,456)	86.96 ± 22.06	34.51 ± 26.56	6.76 ± 10.62
	Significance	p = 0.002	p = 0.766	p < 0.001
Gender and Mortality	Male, Deceased (n = 434)	87.96 ± 21.75	33.47 ± 26.71	7.61 ± 10.69
	Male, Alive (n = 1,932)	85.99 ± 22.07	34.12 ± 26.11	6.19 ± 10.44
	Significance	p = 0.003	p = 0.669	p < 0.001
	Female, Deceased (n = 369)	89.80 ± 23.95	36.05 ± 29.01	7.93 ± 11.36
	Female, Alive (n = 1,524)	88.18 ± 21.99	35.01 ± 27.11	7.49 ± 10.81
	Significance	p = 0.230	p = 0.990	p = 0.518

Logistic regression modeling of the data achieved little success in differentiating between groups when examining 90-day, 30-day, 7-day, and 24-hour mortality periods, with minimal ability to identify patients that would pass away in those time frames based solely on a single 5-minute recording.

Conclusion

Heart rate and PNN50 are statistically linked to 90-day patient mortality. While unable to predict patient mortality on their own, including these measures into a pre-existing patient mortality model may improve overall accuracy. Computational restraints limited the amount of analysis that was done for each patient; future work should handle all possible ECG data to provide a more complete picture. Future work in this area should also examine recording context, as HRV can vary drastically in one individual under different circumstances. Use of 24 hour HRV measures may also protect against this effect. Overall, the use of machine learning techniques and publicly available data is important for the continued development of healthcare models.

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