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CLINICAL PAPER

An observational, prospective study exploring the use of heart rate variability as a predictor of clinical outcomes in pre-hospital ambulance patients☆

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Summary
Objective: To explore the use of pre-hospital heart rate variability (HRV) as a predictor of clinical outcomes such as hospital admission, intensive care unit (ICU) admission and mortality. We also implemented an automated pre-analysis signal processing algorithm and multiple principal component analysis (PCA) for outcomes.
Materials and methods: We conducted a prospective observational clinical study at an emergency medical services (EMS) system in a medium sized urban setting in the United States. Electrocardiogram (ECG) data was obtained from a sample of 45 ambulance patients conveyed to a tertiary hospital, monitored with a LIFEPAK12 defibrillator/monitor. After extracting the data, filtering for noise reduction and isolating non-sinus beats, various HRV parameters were computed. These included time domain, frequency domain and geometric parameters. PCA was performed on the hospital outcomes for these patients.
Results: We used a combination of HRV parameters, age and vital signs such as respiratory rate, SpO_2 and Glasgow coma score (GCS) in a PCA analysis. For predicting admission to ICU, sensitivity was 100%, specificity was 48.6%, and negative predictive value (NPV) was 100%; for predicting admission to hospital, sensitivity was 78.9%, specificity was 85.7%, and NPV was 75.0%; for predicting death, sensitivity was 50.0%, specificity was 100%, and NPV was 97.4%.

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There was also a significant correlation of several HRV parameters with length of hospital stay.

Conclusions: With signal processing techniques, it is feasible to filter and analyze ambulance ECG data for HRV. We found a combination of HRV parameters and traditional 'vital signs' to have an association with clinical outcomes in pre-hospital patients. This may have potential as a triage tool for ambulance patients.

Introduction

Heart rate variability (HRV) is a non-invasive measurement for investigating autonomic influence on the cardiovascular system that has generated significant interest in recent scientific literature.[1] It has been postulated for centuries that decreased HRV is a predictor of physiological distress. The Chinese physician Wang Su Ho (265—317 A.D.) wrote, in A Treatise on Qualities of the Pulse, ''If the pattern of the heart beat becomes as regular as the tapping of a woodpecker or the dripping of rain from the roof, the patient will be dead in 4 days.''

HRV may be defined as the change in the time interval between heartbeats, from beat to beat. HRV is controlled by the autonomic nervous system, which consists of the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS).[2,3] Observed HRV is believed to be an indicator of the dynamic interaction and balance between the SNS and PNS, providing a measure of nervous system competence.[4]

Measurement and analysis of HRV can be classified into time domain and frequency domain analysis.[2,4] Time domain analysis is based on common statistical measures, usually calculations of the mean sinus RR intervals and variations of the standard deviation of heart rate over time as the unit of analysis.[3] Time domain analysis is thought to be a general measure of autonomic nervous system balance. Frequency domain analysis is also known as power spectral analysis. It delineates the heart signal into its frequency components and quantifies them in terms of their relative intensity, which is called power. These analyses have been used to distinguish the contribution of the PNS and SNS to the variability in heart rate. High-frequency components (0.15—0.40 Hz) are thought to be related to parasympathetic activity and low-frequency components (0.04—0.15 Hz) are to some degree an index of SNS activity, but may also contain contribution from the PNS.[5] The LF/HF ratio is thought to be an index of sympathetic/vagal balance with an increase in the ratio suggesting an increase in sympathetic cardiac modulation, a decrease in parasympathetic modulation, or both.[3]

Decreased HRV has been found to be a predictor of increased mortality in the elderly,[6] for coronary artery disease,[7,8] postmyocardial infarction,[9] congestive heart failure [10] and dilated cardiomyopathy.[11] Altered spectral HRV analysis has been found to be an indicator of severity in congestive heart failure,[12] hypertension,[13] coronary artery disease,[14] angina,[15] myocardial infarction,[15] hypoxia,[16] chronic renal failure[17] and diabetes mellitus.[18] Decreased HRV has also been found in intensive care unit (ICU) patients following head trauma,[19] sepsis[20] and septic shock.[21] HRV has also been used as a marker of severity in emergency department patients with sepsis.[22]

However, there have not been any studies looking at using HRV as a clinical tool for pre-hospital patients. There has also been limited study of the correlation of HRV with outcomes like hospital admission, ICU admission and death.

We aimed to explore the utility of pre-hospital HRV as a predictor of clinical outcomes in pre-hospital patients such as hospital admission, ICU admission and mortality. We also implemented an automated pre-analysis signal processing algorithm and multiple primary component analysis for outcomes.

Materials and methods

We conducted a prospective observational clinical study at an emergency medical services (EMS) system in a medium sized urban setting in the United States. The Institutional Review Board at the Virginia Commonwealth University Health System (VCUHS) granted approval for this research project with a waiver of patient consent.

The Richmond Department of Fire and EMS provides ''first response'' assistance on life or death emergency calls using fire apparatus based at twenty fire stations. The trucks are staffed by emergency medical technicians (EMTs) who can perform manual CPR and defibrillate using automated external defibrillators (AEDs). The Richmond Ambulance Authority (RAA) provides an emergency advanced life support (ALS) ambulance service for the City of Richmond, Virginia (population 197,456; service area 62.5 square miles). An average of 11 (range 8—19) ALS ambulances are in service at any given time. All patients with underlying cardiac/respiratory disease or thought to be possibly unstable and needing close monitoring are routinely put on electrocardiogram (ECG) monitoring during transport using the LIFEPAK® 12 defibrillator/monitor (physio-control, Redmond, WA).

EMS charts and ECG tracings from the monitors were collected between April 2001 and March 2004. ECGs were extracted as text files for HRV analysis using CODE-STAT™ Suite data review software (version 5.0, physio-control) and proprietary ECG extraction software (physio-control). This included continuous leads I—III trace recordings as well as 12-lead ECG data. The LIFEPAK 12 defibrillator/monitor records ECGs at a sampling rate of 500 Hz for 12-lead ECGs and 125 Hz for continuous ECG tracings. The CODE-STAT Suite proprietary software is able to automatically download digitized ECG recordings into a computer platform, which can then be exported into MATLAB (R2007a, The Mathworks, Natick, MA). This was a convenience sample based on consecutive usable downloaded ECG tracings.