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Original Contribution

Is heart rate variability better than routine vital signs for prehospital identification of major hemorrhage?☆,☆☆

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ABSTRACT

Objective: During initial assessment of trauma patients, metrics of heart rate variability (HRV) have been associated with high-risk clinical conditions. Yet, despite numerous studies, the potential of HRV to improve clinical outcomes remains unclear. Our objective was to evaluate whether HRV metrics provide additional diagnostic information, beyond routine vital signs, for making a specific clinical assessment: identification of hemorrhaging patients who receive packed red blood cell (PRBC) transfusion.
Methods: Adult prehospital trauma patients were analyzed retrospectively, excluding those who lacked a complete set of reliable vital signs and a clean electrocardiogram for computation of HRV metrics. We also excluded patients who did not survive to admission. The primary outcome was hemorrhagic injury plus different PRBC transfusion volumes. We performed multivariate regression analysis using HRV metrics and routine vital signs to test the hypothesis that HRV metrics could improve the diagnosis of hemorrhagic injury plus PRBC transfusion vs routine vital signs alone.
Results: As univariate predictors, HRV metrics in a data set of 402 subjects had comparable areas under receiver operating characteristic curves compared with routine vital signs. In multivariate regression models containing routine vital signs, HRV parameters were significant ($P < .05$) but yielded areas under receiver operating characteristic curves with minimal, nonsignificant improvements (+0.00 to +0.05).
Conclusions: A novel diagnostic test should improve diagnostic thinking and allow for better decision making in a significant fraction of cases. Our findings do not support that HRV metrics add value over routine vital signs in terms of prehospital identification of hemorrhaging patients who receive PRBC transfusion.

1. Introduction

A series of investigations have suggested that measures of heart rate variability (HRV) offer a promising capability for the identification of trauma patients who require life-saving interventions (LSIs), which are time-sensitive clinical interventions, such as packed red blood cell (PRBC) transfusion, endotracheal intubation, and operative interventions. Heart rate variability, which can be measured via routine electrocardiography, represents the beat-to-beat fluctuations in the R-R intervals (RRIs) of the electrocardiogram (ECG), revealing the state of the patient's autonomic nervous system. A wide range of different HRV metrics have been investigated [1], including frequency domain metrics [2-7], time domain metrics [2,3,5-11], and complexity metrics [2-4,6,8,10,12].

In trauma patients, it is clear that, on average, those patients who subsequently require an LSI have reduced HRV during prehospital and emergency department (ED) monitoring [4,6,8,12]. There are also significant differences in HRV group averages between trauma patients with and without traumatic brain injury [7,11] and between survivors vs fatalities [2,3,5,7]. Moreover, diagnostic test characteristics have been encouraging, with 80% sensitivity and 75% specificity reported in patients who require surgical intervention in the operating room [9] and 86% sensitivity with 74% specificity reported in patients who

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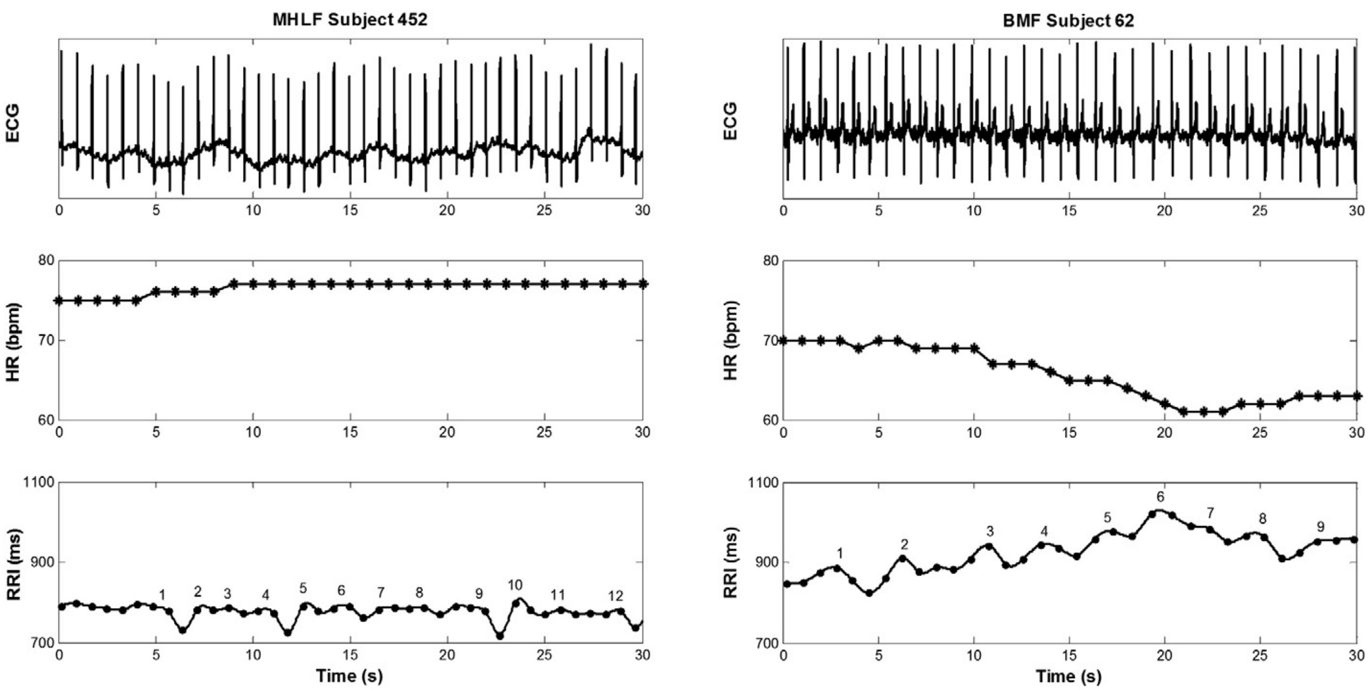
require any LSI [10]. However, these findings are tempered by several other reports, which suggest that, for that subset of trauma patients with normal vital signs, HRV metrics have a low sensitivity (16%) for LSI prediction [6], and their diagnostic potential is reduced by notable intersubject variability as well as intrasubject temporal variability [13].

To date, HRV monitoring has not become routine practice, although PubMed lists more than 10 000 citations relevant to HRV from over 3 decades, spanning a diversity of potential clinical applications. This suggests that there may be some barrier (eg, economic, regulatory, educational, etc) that is hampering the dissemination of a potentially useful technology. Alternatively, it may be that the aforementioned research studies have been suboptimal in terms of answering precisely how (or if) HRV can improve patient care. Many of the published reports about HRV offer intriguing associations but do not provide explicit comparisons vs the routine clinical data used in standard decision making. For instance, if HRV is to be used in deciding whether a trauma patient requires trauma center care, it may be elucidating to compare it against standard criteria for trauma center transport [14]. Likewise, if HRV is to be used for diagnosing traumatic brain injury, it could be compared against standard criteria for neuroimaging after head injury, for example, the Canadian head computed tomography rule [15].

To better understand the value of HRV for decision making, we decided to focus on the identification of trauma patients with major hemorrhage who receive PRBC transfusion because exsanguination is a leading cause of death in both civilian [16] and military [17] trauma populations, whereas many hemorrhagic deaths can be prevented with time-sensitive interventions such as surgery and optimal resuscitation [18,19]. In theory, a reliable and simple diagnostic indicator of which patients require such interventions could enhance the quality and efficiency of clinical decision making, leading to optimal patient outcomes. Fig. 1 illustrates 2 cases in which the patients' vital signs are similar, but HRV metrics indicate whether or not the patients are suffering life-threatening hemorrhage.

To this end, we conducted a multivariate analysis, using routine vital signs as the comparator, to test the hypothesis that HRV metrics can improve the identification of patients with major hemorrhage. By focusing



Subject characteristics	Normal range
HRV metrics	
RSA (cpm): 23	19-26
SDNN (ms): 37.15	23-53
SampEn: 0.48	0.9-1.4
Vital signs	
HR (bpm): 77	77-105
SBP (mmHg): 100	120-147
Injury description: Grade II liver laceration, Grade IV spleen laceration	
24-hr PRBC volume: 13	

Subject characteristics	Normal range
HRV metrics	
RSA (cpm): 18.68	19-26
SDNN (ms): 51.88	23-53
SampEn: 1.51	0.9-1.4
Vital signs	
HR (bpm): 66	77-105
SBP (mmHg): 99	120-147
Injury description: Superficial spleen laceration, thoracic cavity injury with hemo- and pneumo-thorax	
24-hr PRBC volume: 0	

Fig. 1. The 2 cases—30-second excerpts of ECG, HR, and RRI waveforms from 2 different subjects—are selected examples where HRV metrics, but not routine vital signs, can differentiate between patients with (left) and without (right) hemorrhagic injuries requiring substantial 24-hour PRBC transfusion. For each subject, the RRI waveform is illustrated, along with each cycle of sinus arrhythmia that was identified by computer algorithm (each cycle indicated by numerals above the RRI waveform); see text for more details about computation of HRV metrics. The "normal ranges" listed in the tables above represent the interquartile range for subjects who did not receive any 24-hour PRBC transfusion.