Limitations of heart period variability for monitoring individual trauma patients in the pre-hospital setting

Rickards CA[1,2], Ryan KL[1], Convertino VA[1]

[1]US Army Institute of Surgical Research, Fort Sam Houston, TX; [2]Deptartment of Health and Kinesiology, University of Texas at San Antonio, San Antonio, TX

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ABSTRACT

Recent studies have demonstrated the potential utility of heart period variability (HPV) for the prediction of life-saving interventions (LSI) and mortality in trauma patients. In these studies, however, at least one standard vital sign (e.g., GCSm) also distinguished the groups (i.e., LSI vs. No-LSI and Lived vs. Died). The aim of this study was to determine the practical utility of HPV as a decision-support tool for identifying the need for LSIs in *individual* trauma patients with normal standard vital signs. Methods: ECG recordings were analyzed from 161 pre-hospital trauma patients with normal standard vital signs (33 LSI, 128 No-LSI). HPV analyses included time, frequency and complexity domain metrics. Unpaired t-tests were used to assess mean differences between groups. For each metric, 95% confidence intervals (CI) were calculated for the LSI and No-LSI groups. The percentage of individual values in the LSI group that were contained within the 95% CI of the No-LSI group was calculated for each metric. Results: Of the 24 metrics assessed, 8 were able to distinguish the LSI and No-LSI groups based on mean values (P≤0.01). However, within these 8 metrics, 21-42% of individual values in the LSI group fell into, or were beyond the upper limit of the 95% CI of the No-LSI group. Conclusion: While mean values were able to distinguish patient groups when standard vital signs were normal, on an *individual* patient basis, up to 2 of every 5 patients would be incorrectly classified as *not* requiring an LSI if a *single* HPV measurement was used as a triage tool. As such, HPV metrics may have limited clinical utility for prediction of LSIs in pre-hospital trauma patients.

BACKGROUND

- In the pre-hospital trauma setting, recent studies have revealed that heart period variability (HPV) could distinguish groups of trauma patients who:
  - needed life-saving interventions (LSI) from those who did not (No-LSI) (2), and;
  - lived or died (1,3,4)
- In addition to HPV, however, at least one standard vital sign [e.g., heart rate, motor component of the Glasgow Coma Scale (GCSm)] also distinguished these patient groups (i.e., LSI vs. No-LSI and Lived vs. Died).
- We were interested in determining if HPV could also distinguish patients who received an LSI from those who did not, when all other standard vital signs were normal.
- The aim of this study was to determine the practical utility of HPV as a decision-support tool for predicting the need for LSIs in *individual* trauma patients with normal standard vital signs.

HYPOTHESIS

We hypothesized that HPV metrics would enable the distinction between pre-hospital trauma patients who received a LSI and patients who did not receive a LSI when all standard vital signs are normal.

METHODS

- **161 pre-hospital trauma patients**
  - **LSI:** 33 patients received an LSI (10F/23M; age, 34 ± 2 yrs)
  - **No-LSI:** 128 patients did not receive an LSI (50F/78M; age, 39 ± 1 yr)
  - All patients had continuous, noise and ectopy-free ECG records of ≥800 RRIs
- **All patients had normal standard vital signs**
  - Systolic Blood Pressure > 90 mmHg
  - GCSm = 6
  - Normal radial pulse
  - Normal capillary refill
- **HPV Metrics of Interest:**
  - **Time Domain:** RRI, RRI standard deviation (RRISD), RRI root mean squared standard deviation (RMSSD), % adjacent RRIs varying by at least 50 ms (pNN50), Poincaré Plot Descriptors Standard Deviation 1 and Standard Deviation 2 (SD1 and SD2), complex demodulation LF (CDM LF), complex demodulation HF (CDM HF)
  - **Frequency Domain:** RRI low frequency power (LF), RRI high frequency power (HF)
  - **Complexity:** Approximate entropy (ApEn), sample entropy (SampEn), Lempel-Ziv entropy (LZEn), fractal dimensions by curve length (FD-L), fractal dimensions by dispersion analysis (FD-DA), stationarity (StatAv), symbol dynamics entropy (SymDyn), normalized symbol dynamics entropy (DisnEn), forbidden words (FW), detrended fluctuations analysis (FDA),
- **Statistical Analysis:**
  - Unpaired t-tests to determine mean differences between groups (LSI vs. No-LSI)
  - 95% confidence intervals (CI) calculated for each metric for LSI and No-LSI groups
  - For each metric, calculated the percentage of individual values in LSI group:
    - contained within 95% CI of No-LSI group
    - ≥ the lower limit of 95% CI of No-LSI group

RESULTS

- Of the 24 metrics assessed, 8 were able to distinguish the LSI and No-LSI groups based on mean values (P≤0.01) (Fig. 1 left panels & Table 1)

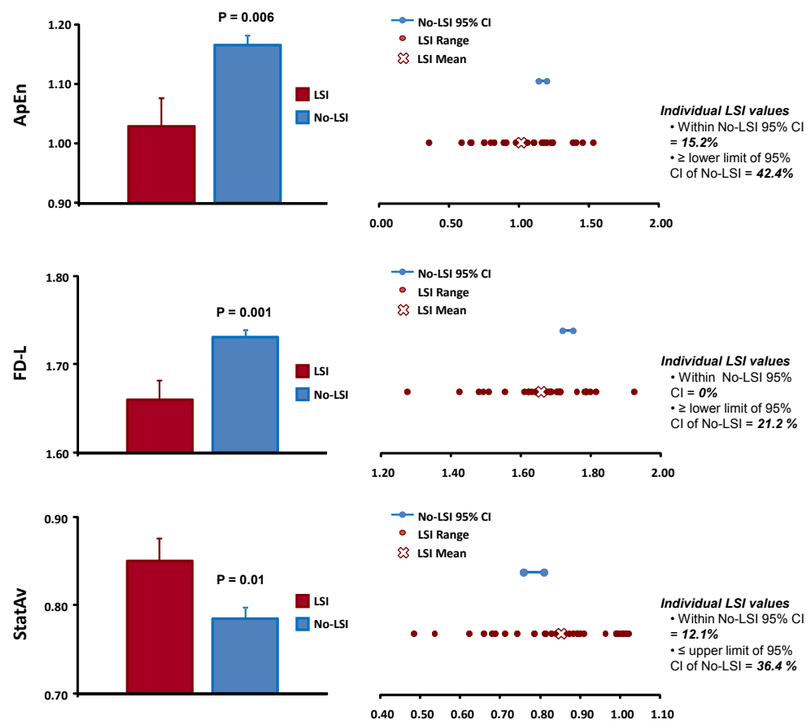

Figure 1 Mean values distinguish LSI and No-LSI groups (left panels), but individual values from the LSI patients cross-over into the 95% CI of the No-LSI patients (right panels).

- Based on the literature, HPV values for LSI patients should be lower than values for No-LSI patients (the reverse for StatAv) (Fig.1, left panels & Table 1). However, within these 8 metrics:
  - Up to 21% of individual values in the LSI group fell within the 95% CI of the No-LSI group (Fig. 1 right panels & Table 1).
  - 21-42% of individual values in the LSI group fell above the lower limit of the 95% CI of the No-LSI group (except StatAv, where values fell below the upper limit of the 95% CI) (Fig.1 right panels & Table 1).

Table 1 Heart period variability metrics that distinguish between LSI and No-LSI patients based on mean values, with individual variability results

Variable	LSI (N=33)	No-LSI (N=128)	P-Value	% LSI values within No-LSI 95% CI	% Above the Lower Limit of 95% CI
SampEn	1.04 ± 0.06	1.22 ± 0.02	0.003	21.2	42.4
LZEn	0.52 ± 0.03	0.60 ± 0.01	0.004	18.2	39.4
SymDyn	0.61 ± 0.02	0.65 ± 0.01	0.01	12.1	30.3
DisnEn	3.67 ± 0.10	3.93 ± 0.04	0.01	6.1	24.2
SD2/SD1	4.86 ± 0.40	4.03 ± 0.13	0.01	6.1	42.4

CONCLUSIONS

- Consistent with our hypothesis, mean HPV values were able to distinguish patient groups (LSI vs. No-LSI) with normal standard vital signs.
- However, on an *individual* patient basis, up to 2 of every 5 patients (40%) would be incorrectly classified as *not* requiring an LSI if a *single* HPV measurement was used as a triage tool.
- To avoid the potential misclassification of patient status, an analysis of *trends* over time must be completed in trauma patients before HPV metrics could be considered for monitoring purposes.
- Based on this analysis, HPV metrics may have limited clinical utility for prediction of LSIs in pre-hospital trauma patients.

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