



Core temperature variation is associated with heart rate variability independent of cardiac index: A study of 278 trauma patients[☆]

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Abstract

Purpose: The purpose of this study is to determine if temperature extremes are associated with reduced heart rate variability (HRV) and “cardiac uncoupling.”

Materials and Methods: This was a retrospective, observational cohort study performed on 278 trauma intensive care unit admissions that had continuous HR, cardiac index (CI), and core temperature data from “thermodilution” Swan-Ganz catheter. Dense (captured second-by-second) physiologic data were divided into 5-minute intervals (N = 136 133; 11 344 hours of data). Mean CI, mean temperature, and integer HR SD were computed for each interval. *Critically low HRV* was defined as HR SD from 0.3 to 0.6 beats per minute. *Temperature extremes* were defined as less than 36°C or greater than 39°C.

Results: Low HRV and CI vary with temperature. Temperature extremes are associated with increased risk for critically low HRV (odds ratio, >1.8). Cardiac index increases with temperature until hyperthermia (>40°C). At temperature extremes, changes in CI were not explained solely by changes in HR.

Conclusions: The conclusions of this study are (1) temperature extremes are associated with low HRV, potentially reflecting cardiac autonomic dysfunction; (2) CI increases with temperature; and (3) HRV provides additional physiologic information unobtainable via current invasive cardiac monitoring and current vital signs.

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1. Introduction

Since ancient times, practitioners have used skin temperature as a prognostic sign. Long held as a traditional vital sign, temperature has been correlated with infection. Temperature deviations greater than 4°C from normal produce life-threatening cellular dysfunction. The autonomic nervous system plays a key role in maintaining body

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temperature by regulating blood flow, conducting heat from internal organs to the skin, and innervating sweat glands. Changes in heart rate variability (HRV) may reflect alterations in the command and control function of the autonomic nervous system [1].

The body's ability to thermoregulate remains intact under most pathologic states. However, occasionally, thermoregulation fails, and the body is exposed to the detrimental effects of temperature extremes [2]. Both hypothermia and hyperthermia can occur because of external (exposure, exercise, and environment) or internal (pathogens, allergens) stressors. Vital organs fail at extreme temperatures if there is insufficient delivery of nutrients and oxygen.

Previous work using spectral analysis has demonstrated associations between HRV and autonomic function in surgical intensive care unit (ICU) patients [3,4]. Reduced HRV has been correlated with increased morbidity and mortality in various populations [5-9], potentially reflecting autonomic dysfunction. Our previous work using integer HR measurements has demonstrated that low HRV is an early predictor of mortality in trauma patients [10,11]. We have demonstrated that the prediction remains robust as early as 12 hours [12] and extends for ICU stay.

Several studies have sought to define the relationship between core temperature and its effects on the autonomic nervous system. Animal models have shown a direct correlation between body temperature and HRV [13,14], but these high-risk studies cannot be duplicated in human subjects. We have the unique opportunity to observe in our clinical population changes in HRV at extremes of temperature.

Multiple hypotheses explaining the relationship between temperature extremes and autonomic dysfunction have been proposed: the slowing of nerve conduction velocities within the autonomic nervous system [15], abnormalities within the cardiac conduction [16], and endocrine (renin-angiotensin) systems [17]. Furthermore, autonomic dysfunction has been associated with changes in HRV [1].

The purpose of this study is 2-fold: (1) to explore the relationship between temperature, HRV, and the potential role of the autonomic nervous system; and (2) to document the adaptive changes in the cardiovascular system as they relate to HRV and temperature.

2. Materials and methods

2.1. Setting

Vanderbilt University Medical Center (VUMC) is the only level 1 trauma center serving an over 200,000 square kilometer catchment area. Of the 3200 annual trauma admissions, more than 1800 are admitted to a 31-bed dedicated trauma unit. The 14 trauma unit beds classified as ICU beds accommodate 700 to 800 admissions per year. At present, 14 of the 31 beds are ICU beds equipped with

Signal Interpretation and Monitoring (SIMON), a continuous physiologic monitoring system.

2.2. Data sources

Vanderbilt University Medical Center's clinical information infrastructure provided the linked patient physiologic, demographic, and outcome required for this study. Key components of the infrastructure relevant to this analysis include

1. *SIMON*. The SIMON project is an ongoing collaborative effort between the VUMC Division of Trauma and the Vanderbilt University School of Engineering. Since December 2000, physiologic data from bedside medical devices have been continuously captured and stored from trauma ICU beds. Physiologic variables captured include HR, invasive and noninvasive blood pressures, intracranial and cerebral perfusion pressures, arterial and venous oxygen saturations, core temperature, pulmonary and central venous pressures, cardiac index (CI), and end-diastolic volume index.
2. *Trauma Registry of the American College of Surgeons (TRACS)*. The VUMC Division of Trauma has maintained a trauma registry since 1986 and has participated in the TRACS since 1996. All patients admitted to VUMC with trauma or burns are entered into this database, which includes all patients with SIMON data. Data are maintained locally and shared quarterly with the national repository. Currently, more than 300 variables are captured via retrospective chart review including patient demographics, injuries, diseases, operative procedures, hospital dispositions, complications, costs, resource use, and length of stay at various levels of care.
3. *De-identified repository*. Both SIMON and TRACS meet regulatory requirements for data repository status and are approved as such by the Vanderbilt University Institutional Review Board. Signal Interpretation and Monitoring data are prospectively captured during the course of clinical care, whereas TRACS data are captured retrospectively. For this and other studies, data requests are processed in accordance with institution and Health Insurance Portability and Accountability Act (HIPAA) regulations including de-identification before analysis.

2.3. Study population

This institutional review board-approved study includes all trauma admissions to VUMC that

1. were trauma admissions from June 2003 through November 2004 ($n = 5745$);
2. were admitted to the trauma ICU ($n = 1146$, or 19.9%); and

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