ORIGINAL RESEARCH

Identification of Dynamic Prehospital Changes With Continuous Vital Signs Acquisition

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Abstract

Objective: In most trauma registries, prehospital trauma data are often missing or unreliable because of the difficult dual task consigned to prehospital providers of recording vital signs and simultaneously resuscitating patients. The purpose of this study was to test the hypothesis that the analysis of continuous vital signs acquired automatically, without prehospital provider input, improves vital signs data quality, captures more extreme values that might be missed with conventional human data recording, and changes Trauma Injury Severity Scores compared with retrospectively compiled prehospital trauma registry data.

Methods: A statewide vital signs collection network in 6 medevac helicopters was deployed for prehospital vital signs acquisition using a locally built vital signs data recorder (VSDR) to capture continuous vital signs from the patient monitor onto a memory card. VSDR vital signs data were assessed by 3 raters, and intraclass correlation coefficients were calculated to test interrater reliability. Agreement between VSDR and trauma registry data was compared with the methods of Altman and Bland including corresponding calculations for precision and bias.

Results: Automated prehospital continuous VSDR data were collected in 177 patients. There was good agreement between the first recorded vital signs from the VSDR and the trauma registry value. Significant differences were observed between the highest and lowest heart rate, systolic blood pressure, and pulse oximeter from the VSDR and the trauma registry data ($P < .001$). Trauma Injury Severity Scores changed in 12 patients (7%) when using data from the VSDR.

Conclusion: Real-time continuous vital signs monitoring and data acquisition can identify dynamic prehospital changes, which may be missed compared with vital signs recorded manually during distinct prehospital intervals. In the future, the use of automated vital signs trending may improve the quality of data reported for inclusion in trauma registries. These data may be used to develop improved triage algorithms aimed at optimizing resource use and enhancing patient outcomes.

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Introduction

Trauma registries are databases designed to document the acute phase of trauma care for patients with injuries.[1] Trauma registries provide a useful method for describing the epidemiology of serious injuries, benchmarking and monitoring temporal changes in outcomes, and assessing the quality of data collected over time.[2,3] According to the American College of Surgeons, a trauma registry is an essential component of any trauma program because trauma registry data provide information that can help inform optimal care of the injured patient.[4] Physiological data are often missing or unreliable in trauma registries because of the difficult dual task consigned to prehospital providers of recording data and simultaneously providing patient care.[5] Patients with missing physiologic data may differ systematically from those with recorded data, and traditional analytic methods that exclude all observations with missing data (ie, complete case analysis) may lead to biased trauma registry group comparisons.[5] In 1 study, failure of emergency medical services (EMS) to document basic measures of scene physiology was associated with increased mortality.[6] Documentation inconsistencies impact attempts to combine databases, establish norms, and assess institutional outcomes. Automatically recorded continuous vital signs technology has the potential to improve the efficiency and validity of data available for abstraction and entry into a trauma registry.

Multiple studies have been published using probabilistic prognostic models based on trauma registry data.[7-13] Multiple imputation has been proposed as 1 strategy to deal with the problem of missing physiologic data in trauma registries;[14-18] however, imputation is a complex process requiring consideration of the missing data mechanism, correct specification of the data imputation model, and correct implementation of the imputation process.[14,19] Although imputation values may have close agreement to actual data, it is expected that improved data capture mechanisms can obviate the reliance on imputation by eliminating or minimizing missing data.

The optimal treatment and triage of trauma patients is dependent on valid and reliable technologies that enable providers and researchers to rapidly assess and integrate information from a complex array of physiologic parameters. Over the past decade, technology has been developed to acquire continuous vital signs data in an effort to study physiologic derangements that occur during the prehospital phase of trauma care.[20] The purpose of this study was to test the hypothesis that automated continuous vital signs data acquisition identifies dynamic prehospital changes more accurately, including extreme values of vital signs that might be missed with conventional human vital signs data recording. As a result, Trauma Injury Severity Scores (TRISS) change when automatically derived data are used as compared with manually derived data.

Methods

Vital Signs Data Collection System

A vital signs data collection network was developed by the authors (PH, AS, CM) for prehospital trauma data acquisition consisting of 3 parts: (1) a prehospital in-flight vital signs data recorder (VSDR) unit, (2) a vital signs interface box used to capture continuous vital signs from a portable Propaq 206 monitor (Welch Allyn Inc, Skaneateles, NY) onto a memory card, and (3) a touch screen personal digital assistant used to record in-flight life-saving interventions (eg, endotracheal intubation, fluid bolus administration, cardiopulmonary resuscitation, and thoracic needle decompression) as an indicator of injury severity and to pilot test the device for use in future studies. Vital signs included a real-time waveform electrocardiogram (ECG); pulse oximeter oxygen saturation (SpO_2); end-tidal carbon dioxide ($ETCO_2$); and numeric values of heart rate (HR), SpO_2, noninvasive blood pressure, and respiratory rate.[20,21]

Three statewide air medical bases, including a total of 6 helicopters, were equipped with the VSDR system. Each helicopter was staffed by 1 nationally registered emergency medical technician-paramedic administered by the Maryland State Police Aviation Command. The network was pilot tested over a 6-month period. Continuous waveforms were captured at 182 Hz (ECG) or 90 Hz (SpO_2 and $ETCO_2$), and numeric trend data were captured at 1 Hz. Data were stored and retrieved using a vital signs database. All patients requiring air medical transport from the scene of injury to our trauma center were included. Patients requiring interfacility transfer or transport for primary medical conditions were excluded.

This study was approved by the Institutional Review Board of the University of Maryland School of Medicine. Each patient or next of kin was informed, and written consent was obtained in person or by mail after discharge, with the understanding that routine clinical and monitoring data were to be collected, stored in a database, and analyzed for research purposes. Only patients who were air medically transported directly from the scene of injury to the trauma center were included.

Demographic data were collected from the R Adams Cowley Shock Trauma Center trauma registry. The trauma registry contains extensive demographic, prehospital, clinical, discharge, and injury data; data fields are similar to the fields required for reporting to the National Trauma Data Bank.[2,19] Vital signs, Glasgow Coma Scale (GCS) score, age, sex, mechanism of injury, Injury Severity Score (ISS), and incident demographics were obtained from the trauma registry.

All the continuous VS data were reviewed, and then key VS data (ie, systolic and diastolic blood pressure, HR, SpO_2, and respiratory rate) were abstracted from the continuous VS data and assessed by 3 independent raters. The first and last vital signs recorded as well as the highest and lowest values for each vital sign were prepared as graphic displays before further review by the raters. These trend graphs were plotted examining VS during the first and last minutes of recording, and the highest and lowest values were recorded from the trend graphs. These 4 measures were used to inspect the range of variation of VS in a field trauma patient. Intraclass correlation coefficients for the 4 measures were calculated using the Spearman-Brown correction to evaluate interrater reliability.[22]

Differences between the highest and lowest VSDR and trauma registry VS were calculated. Trauma registry data were abstracted from EMS prehospital run sheets. Agreement of the 4 measures of VSDR data with the trauma registry data were accomplished using the method described by Bland and Altman[23] and paired *t*-tests. Agreement between VSDR and trauma registry data was compared with the methods of Bland and Altman,[23] including corresponding calculations for precision and bias. A P value of $<.05$ was considered significant, and all tests were 2 tailed. Field TRISS scores were calculated using VSDR and trauma registry VS. Trauma registry–derived TRISS values were calculated based on the vital signs recorded for calculation of the patients' Revised Trauma Score (RTS) upon admission to the trauma center.[24] VSDR-derived TRISS scores were based on the lowest systolic blood pressure and the highest or lowest respiratory rate recorded by the VSDR; GCS scores were calculated based on the flight paramedic's assessment.

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