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Clinical Paper

The prevalence and significance of abnormal vital signs prior to in-hospital cardiac arrest☆

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ABSTRACT

Background: Patients suffering in-hospital cardiac arrest often show signs of physiological deterioration before the event. The purpose of this study was to determine the prevalence of abnormal vital signs 1–4 h before cardiac arrest, and to evaluate the association between these vital sign abnormalities and in-hospital mortality.

Methods: We included adults from the *Get With the Guidelines®* – *Resuscitation* registry with an in-hospital cardiac arrest. We used two a priori definitions for vital signs: abnormal (heart rate (HR) ≤ 60 or ≥100 min^{-1}, respiratory rate (RR) ≤ 10 or >20 min^{-1} and systolic blood pressure (SBP) ≤ 90 mm Hg) and severely abnormal (HR ≤ 50 or ≥130 min^{-1}, RR ≤ 8 or ≥30 min^{-1} and SBP ≤ 80 mm Hg). We evaluated the association between the number of abnormal vital signs and in-hospital mortality using a multivariable logistic regression model.

Results: 7851 patients were included. Individual vital signs were associated with in-hospital mortality. The majority of patients (59.4%) had at least one abnormal vital sign 1–4 h before the arrest and 13.4% had at least one severely abnormal sign. We found a step-wise increase in mortality with increasing number of abnormal vital signs within the abnormal (odds ratio (OR) 1.53 (CI: 1.42–1.64) and severely abnormal groups (OR 1.62 (CI: 1.38–1.90)). This remained in multivariable analysis (abnormal: OR 1.38 (CI: 1.28–1.48), and severely abnormal: OR 1.40 (CI: 1.18–1.65)).

Conclusion: Abnormal vital signs are prevalent 1–4 h before in-hospital cardiac arrest on hospital wards. In-hospital mortality increases with increasing number of pre-arrest abnormal vital signs as well as increased severity of vital sign derangements.

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Introduction

Over 200,000 adult in-hospital cardiac arrests (IHCA) occur in the United States yearly.[1,2] Mortality remains high, with 22–23% surviving to hospital discharge,[1] and early identification of patients at risk for deterioration is crucial.[3,4] Multiple intra-event factors have been associated with cardiac arrest mortality.[5,6] However, the impact of pre-event abnormalities on post-event outcomes has not been examined previously in a large cohort.

Several small studies have shown that abnormal vital signs before IHCA are common[7–11] and predictive of progression to

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[2] See Appendix A for a full list of Get With The Guidelines® – Resuscitation Investigators.

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cardiac arrest.[12,13] Retrospective expert reviews have found that 18–66% of cardiac arrests may be preventable.[14,15] Common reasons for preventability in one study included not acting on clinical signs prior to the event and "inappropriate" area of treatment such as a general ward when an intensive care unit setting was warranted.[14] These investigations led to the widespread use of rapid response teams as a means of preventing progression to cardiac arrest on hospital wards by optimizing early treatment.[16] Previous studies in out-of-hospital[17,18] and in-hospital cardiac arrest[19] have shown that pre-arrest factors (such as abnormal vital signs) may be associated with post-event outcome. However, neither the prevalence of abnormal vital signs prior to in-hospital cardiac arrest nor their association with post-event survival has been examined previously in a large multicenter cohort.

The present study aimed to characterize the prevalence of abnormal vital signs 1–4 h before a treated cardiac arrest using a large national registry database, and to evaluate the association between these vital sign abnormalities and in-hospital mortality.

Methods

Study design

We conducted a post hoc analysis of prospectively collected data from a large United States registry of IHCA.

Data source

Data were collected from the *Get With the Guidelines*® – *Resuscitation* (GWTG-R) registry, a national American Heart Association (AHA) sponsored quality improvement IHCA registry. Details of data collection and reliability have been described previously.[20] Patients were excluded if they had prior do-not-resuscitate orders or cardiopulmonary resuscitation events beginning outside of the hospital.

The registry utilizes the Utstein-style template, standardized to facilitate uniform reporting across hospitals.[21,22] Data integrity is ensured through rigorous certification of data entry personnel and data are evaluated for completeness and accuracy with standardized software.[23] Pre-arrest vital signs were a mandatory field during our study period.

Study population, vital signs and outcomes

We included adult patients from acute-care hospitals that submitted clinical data to the GWTG-R registry between July 2007 and September 2010. We included only index events occurring on an inpatient ward. We included locations coded as "General Inpatient Area" and "Telemetry Unit or Step-Down Unit". The GWTG-R registry collects up to four sets of vital signs taken in the 4 h prior to the cardiac arrest. No detailed data on how the vital signs are recorded are provided but no rounding rules are provided to data abstractors. We excluded patients with missing data on survival or vital signs 1–4 h before the arrest. We included only sets of vital signs with at least heart rate, respiratory rate and systolic blood pressure. If there was more than one set of vital signs within the 1–4 h time period we used the set closest to 4 h. This was done to avoid confounding by acute interventions performed by the rapid response team or including patients actively being moved to the intensive care unit, and to best assess the predictive nature of vital sign derangements, even when more temporally remote from the event.

We defined abnormal vital signs a priori based on standard clinical definitions and consensus within the author team: Heart rate $\leq$60 or $\geq$100 min^{-1}, respiratory rate $\leq$10 or >20 min^{-1} and systolic blood pressure $\leq$90 mm Hg. We defined a subgroup of severely abnormal vital signs, based on consensus and previous studies related to rapid response teams,[24,25] as follows: Heart rate $\leq$50 or $\geq$130 min^{-1}, respiratory rate $\leq$8 or $\geq$30 min^{-1} and systolic blood pressure $\leq$80 mm Hg.

Statistical analyses

The study population was characterized using descriptive statistics. Categorical variables are reported as counts and frequencies, continuous variables as medians with 1st and 3rd quartiles due to non-normal distribution of the data. Categorical data were compared using the Chi-Square test, continuous data with the Wilcoxon Rank Sum test.

First, we assessed the relationships between individual vital signs and mortality. We assumed these were non-linear and delineated pre-defined vital sign categories. We assessed the mortality within each category using descriptive statistics, then compared the different categories using univariate logistic regression where the reference category was that with the lowest mortality.

To assess the independent association between individual pre-arrest vital signs and mortality we applied a multivariable logistic regression model with generalized estimating equations with an exchangeable (compound symmetry) correlation matrix to account for within hospital clustering. The following pre-determined variables (see Table 1) were entered into the multivariable model: age, gender, race, illness category, pre-existing conditions, whether the arrest was monitored or witnessed, location, time of week, time of day, first documented pulseless rhythm, whether a hospital wide response was activated and year of arrest (with 2007 as the reference). We included all three vital signs in the same model and also included the time from vital signs to loss of pulse.

We then conducted a univariate logistic regression analysis to assess the association between the number of abnormal vital signs before cardiac arrest and mortality. The number of abnormal vital signs was treated as a continuous variable (ranging from 0 to 3). We next applied a similar multivariable logistic regression model as outlined above and with the same co-variables to assess the independent association between the number of pre-cardiac arrest abnormal vital signs and mortality.

For the multivariable analyses we included only patients with no missing data on any included covariates (91% of all patients). As a sensitivity analysis we performed all univariate analysis including only patients with full data. The results were similar to those performed with the full cohort, presented here. As a secondary sensitivity analysis we conducted all multivariable logistic regressions excluding variables occurring after the recording of the vital signs (whether the event was witnessed and monitored, the location of the arrest and the initial rhythm) that could theoretically be causally affected by the vital signs. The results were similar to the main analysis (changes in odds ratio (OR) point estimates between 0 and 13%) so are not reported here. We performed a sensitivity analysis such that if patients had more than one set of vital signs within the 1–4 h time period we included the set closest to the 1 h time point (as opposed to the 4 h time point). Results were essentially identical to our primary analysis and are not presented here. As a post hoc sensitivity analysis, we performed multiple imputations as described in the supplemental material.

All results from the logistic regressions are presented as OR with 95% confidence intervals (CI). Statistical analyses were conducted with the use of SAS software, version 9.3 (SAS Institute, Cary, NC, USA). All hypothesis tests were two-sided, with a significance level of $p < 0.05$.

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