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Monitoring of serum lactate level during cardiopulmonary resuscitation in adult in-hospital cardiac arrest

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Abstract

Introduction: Serum lactate level may correlate with no-flow and low-flow status during cardiac arrest. Current guidelines have no recommended durations for cardiopulmonary resuscitation (CPR) before transition to the next strategy. We hypothesized that the lactate level measured during CPR could be associated with the survival probability and accordingly be useful in estimating the optimal duration for CPR.

Methods: We conducted a retrospective observational study in a single medical centre and included adult patients who had suffered an in-hospital cardiac arrest between 2006 and 2012. We used multivariable logistic regression analysis to study the association of lactate level measured during CPR and outcomes. We used generalized additive models to examine the nonlinear effects of continuous variables and conditional effect plots to visualize the estimated survival probability against CPR duration.

Results: Of the 340 patients included in our analysis, 50 patients (14.7 %) survived to hospital discharge. The mean lactate level was 9.6 mmol/L and mean CPR duration was 28.8 min. There was an inverse near-linear relationship between lactate level and probability of survival to hospital discharge. A serum lactate level <9 mmol/L was positively associated with patient survival to hospital discharge (odds ratio 2.00, 95 % confidence interval 1.01-4.06). The optimal CPR duration may not be a fixed value but depend on other conditions.

Conclusions: Serum lactate level measured during CPR could correlate with survival outcomes. A lactate level threshold of 9 mmol/L may be used as a reference value to identify patients with different survival probabilities and determine the optimal CPR durations.

Introduction

More than 200,000 hospitalized adult patients experience in-hospital cardiac arrest (IHCA) annually in the USA with an estimated incidence of 1.6 per 1,000 hospital admissions [1]. The survival rate from IHCA has increased over the past decade [2], probably due to earlier recognition of cardiac arrest, higher quality of cardiopulmonary resuscitation (CPR), and improved post-resuscitation care [3, 4]. Despite this progress, mortality following IHCA remains high, with only about 18 % of patients surviving to hospital discharge [1].

The causes of high mortality could be due to the inability to establish rapid return of spontaneous circulation (ROSC) leading to subsequent multi-organ failure. Extracorporeal CPR (ECPR) has been advocated as a novel alternative for cardiac arrests that are considered refractory to initial conventional CPR [5, 6], especially for IHCA [7]. Nevertheless, the term, "refractory cardiac arrest," is ill-defined. Most studies on ECPR have used CPR duration as an indicator of futile resuscitation, which varied from 10 to 15 minutes [7–9] and led to initiation of ECPR within 30 to 60 minutes of CPR.

However, using CPR duration alone may not be an accurate indicator for estimating survival probability and determination of futile CPR. Matos et al. [10] reported that even in the case of equivalent CPR durations, the survival probability still differed greatly between different patient groups. Although studies have suggested that the greater the time prior to initiation of ECPR, the poorer the outcome [7], few studies have been carried out on the optimal transition time to consider alternative resuscitation methods in patients with potentially prolonged CPR. Therefore, finding additional parameters besides CPR duration to assist clinicians in more accurately estimating the survival probability during CPR could help strike a balance between optimizing patient outcomes and avoiding the misuse of scarce critical care medical resources, such as ECPR.

Weil et al. [11] found that serum lactate level measured within 10 minutes of CPR could serve as a sensitive indicator of prognosis. A higher post-ROSC serum lactate level [12–16] or a slower clearance rate of serum lactate after ROSC [12, 17, 18] has also been shown to correlate with poor outcomes after cardiac arrest. We therefore hypothesized that the serum lactate level measured during CPR may be associated with the survival probability and accordingly be useful in estimating the optimal CPR duration before transition to the next strategy for IHCA.

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Methods

Setting

We carried out a retrospective cohort study in a tertiary medical centre, National Taiwan University Hospital (NTUH). Before data collection, the Research Ethics Committee of the National Taiwan University Hospital approved this study (reference number: 201505161RIN) and waived the requirement for written informed consent. The NTUH has 2,600 beds, including 220 beds in intensive care units (ICUs). According to hospital policy, a code team is activated when cardiac arrest events occur in the general wards. Each code team member has been certified to provide advanced cardiac life support. For cardiac arrest events in the ICUs, resuscitation is performed by the staff of the ICU where the cardiac arrest events have occurred and by staff from neighbouring ICUs.

Participants

We included patients who had experienced an IHCA at the NTUH between 2006 and 2012. We used the following inclusion criteria: (1) age ≥18 years; (2) documented absence of pulse with performance of chest compression for ≥2 minutes; (3) without do-not-resuscitate order; and (4) serum lactate level measured during the initial 10 minutes of CPR. If multiple cardiac arrest events occurred in a single patient, we only recorded the first event of the same hospitalization. We excluded patients who had suffered a cardiac arrest related to major trauma.

Data collection and outcome measures

We recorded the following information for each patient: demographics, comorbidities, variables derived from the Utstein template [19], the first serum lactate level measured during CPR, and any critical intervention that was implemented. CPR duration was defined as the time from the first chest compression provided by the code team or ICU members to the termination of resuscitation efforts, either due to ROSC or declaration of death. The definitions of comorbidities are appended in Additional file 1: Table S1.

The primary outcome was survival to hospital discharge. Secondary outcomes included 10-minute ROSC, defined as ROSC within 10 minutes of CPR, and favourable neurological status at hospital discharge, defined as a score of 1 or 2 on the cerebral performance category (CPC) scale [20]. The CPC score was retrospectively determined by reviewing medical records for each patient.

Statistical analysis

We used R 2.15.3 software (R Foundation for Statistical Computing, Vienna, Austria) for data analysis. Categorical data were expressed as counts and proportions; continuous data were expressed as means and standard deviations. Categorical variables were compared by the Fisher's exact test, and continuous variables were examined by the Wilcoxon rank-sum test. A two-tailed p value of ≤0.05 was considered statistically significant.

We selected the odds ratio as the outcome measure. We conducted a multivariable logistic regression analysis to examine the association between independent variables and outcomes. All available variables were considered in the regression model, regardless of whether they were significant by univariate analysis. The stepwise variable selection procedure (with iterations between the forward and backward steps) was applied to obtain the final regression model. Significance levels for entry and for stay were set at 0.15 to avoid exclusion of potential candidate variables. The final regression model was identified by excluding individual variables with a p value >0.05, until all regression coefficients were statistically significant. If the lactate level was excluded during the variable selection procedure, we would re-enter it into the final model to obtain the effect estimate.

We used generalized additive models (GAMs) [21] to examine the nonlinear effects of continuous variables and, if necessary, to identify the appropriate cutoff point(s) for dichotomizing a continuous variable during the variable selection procedure. We used conditional effect plots to visualize the predicted probability of survival to hospital discharge against CPR duration, while maintaining the other independent variables in the final model constant. Based on the conditional effect plot, we used CPR duration of 30 minutes and probability of survival of 18 % [1]