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Post-resuscitation arterial oxygen and carbon dioxide and outcomes after out-of-hospital cardiac arrest☆,☆☆

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ABSTRACT

Objective: To determine if arterial oxygen and carbon dioxide abnormalities in the first 24 h after return of spontaneous circulation (ROSC) are associated with increased mortality in adult out-of-hospital cardiac arrest (OHCA).

Methods: We used data from the Resuscitation Outcomes Consortium (ROC), including adult OHCA with sustained ROSC ≥1 h after Emergency Department arrival and at least one arterial blood gas (ABG) measurement. Among ABGs measured during the first 24 h of hospitalization, we identified the presence of hyperoxemia (PaO2 ≥ 300 mmHg), hypoxemia (PaO2 < 60 mmHg), hypercarbia (PaCO2 > 50 mmHg) and hypocarbia (PaCO2 < 30 mmHg). We evaluated the associations between oxygen and carbon dioxide abnormalities and hospital mortality, adjusting for confounders.

Results: Among 9186 OHCA included in the analysis, hospital mortality was 67.3%. Hyperoxemia, hypoxemia, hypercarbia, and hypocarbia occurred in 26.5%, 19.0%, 51.0% and 30.6%, respectively. Initial hyperoxemia only was not associated with hospital mortality (adjusted OR 1.10; 95% CI: 0.97–1.26). However, final and any hyperoxemia (1.25; 1.11–1.41) were associated with increased hospital mortality. Initial (1.58; 1.30–1.92), final (3.06; 2.42–3.86) and any (1.76; 1.54–2.02) hypoxemia (PaO2 < 60 mmHg) were associated with increased hospital mortality. Initial (1.89; 1.70–2.10); final (2.57; 2.18–3.04) and any (1.85; 1.67–2.05) hypercarbia (PaCO2 > 50 mmHg) were associated with increased hospital mortality. Initial (1.13; 0.90–1.41), final (1.19; 1.04–1.37) and any (1.01; 0.91–1.12) hypocarbia (PaCO2 < 30 mmHg) were not associated with hospital mortality.

Abbreviations: ROSC, return of spontaneous circulation; OHCA, out-of-hospital cardiac arrest; ABG, arterial blood gas; ED, Emergency Department; ROC, Resuscitation Outcomes Consortium; CPR, Cardiopulmonary Resuscitation.

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Conclusions: In the first 24 h after ROSC, abnormal post-arrest oxygen and carbon dioxide tensions are associated with increased out of-hospital cardiac arrest mortality.

Introduction

Out-of-hospital cardiac arrest (OHCA) is a major public health problem affecting over 300,000 persons in the United States each year [1]. International consensus recommendations underscore the importance of post-arrest intensive care in facilitating OHCA survival [2]. Post-arrest hyperoxemia has been associated with a range of deleterious effects, including inhibition of mitochondrial function, free-radical formation, oxidative stress and acidosis, worsened myocardial contractility and brain injury [3–8]. In brain injured patients, alterations in carbon dioxide tension may adversely impact cerebral blood flow and perfusion [6,7,9].

While observational studies suggest associations between hyperoxemia, hypoxemia, hypercarbia and hypocarbia and cardiac arrest survival, these research efforts have important limitations [10–22]. While most of these studies were based upon measurements in the intensive care unit, the majority of OHCA patients receive initial post-arrest care in the Emergency Department (ED), where early oxygen and carbon dioxide tension may be most impactful. Prior studies included a heterogeneous mix of in-hospital and out-of-hospital cardiac arrests, used varying approaches to define oxygen and carbon dioxide tension measurements, and arrived at different conclusions regarding associations with survival [22].

There have been few Emergency Department studies of oxygen and carbon dioxide tension in the period immediately following return of spontaneous circulation (ROSC). In this study, we sought to determine the association of 24-h post-ROSC oxygen and carbon dioxide tension with OHCA mortality in the national Resuscitation Outcomes Consortium (ROC).

Methods

Design

We analyzed prospectively collected OHCA data from the ROC Epistry – Cardiac Arrest ("Epistry") [23]. ROC clinical centers collected OHCA data in conformance with United States Department of Health and Human Services regulations for the protection of human subjects and provisions of the Canadian Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans. Additional reviews and approvals were provided by the Institutional Review Boards and research ethics boards for each community.

Study setting

ROC is a multicenter clinical trial network designed to conduct out-of-hospital interventional and clinical research in cardiac arrest and traumatic injury. Participating regional coordinating centers included Birmingham, AL; Dallas, TX; Milwaukee, WI; Pittsburgh, PA; Portland, OR; San Diego, CA; Seattle/King County, WA; British Columbia, Canada; Ottawa and the Ontario Prehospital Advanced Life Support study communities, Ontario, Canada; and Toronto and adjacent regions, Ontario, Canada. A data coordinating center was based in Seattle. Over 264 emergency medical services (EMS) agencies and 287 receiving hospitals participated in the ROC Epistry – Cardiac Arrest [23].

Data source

The ROC Epistry – Cardiac Arrest is a registry of consecutive cardiac arrests at participating ROC sites [23,24]. Using dispatch logs, EMS patient care records, defibrillator files, and hospital and public death records, study personnel at each site determined clinical details of each OHCA, including prehospital response, patient demographics, clinical information, prehospital interventions, prehospital disposition, hospital information and outcomes. Data collection and reporting methods adhered to Utstein standards [25].

Selection of subjects

From the study period April 5, 2011-July 31, 2015, we included all adult (18 years old), EMS-treated non-traumatic OHCA achieving return of spontaneous circulation and surviving $\geq$1 h in the receiving Emergency Department. We further limited the analysis to patients receiving $\geq$1 arterial blood gas measurement (ABG) within the first 24 h of hospitalization. We excluded children (age <18 years), OHCA due to blunt, burn, or penetrating trauma, patients pronounced dead in the field, patients surviving <1 h in the Emergency Department, and cases where the time and date of death were not known.

Exposures

The primary exposures were hyperoxemia (PaO2 $\geq$ 300 mmHg), hypoxemia (PaO2 < 60 mmHg), hypercarbia (PaCO2 > 50 mmHg) and hypocarbia (PaCO2 < 30 mmHg), defined by thresholds used in prior studies of oxygen and carbon dioxide tension [14,21]. We identified the presence of these abnormalities using ABG measurements obtained during the first 24 h of hospitalization, regardless of the patient's location in the hospital.

ROC Epistry protocols included collection of all ABG values during the first 24 h of hospitalization, a period intended to encompass ED and initial intensive care unit care. We did not include ABG measurements collected >24 h after hospital arrival. In the data analysis, we assessed the presence of each oxygen and carbon dioxide abnormality based upon the initial (first), final (last) or any ABG measurement during the first 24 h of hospitalization. ABG measurements were obtained according to local protocols. ROC protocols did not dictate the timing or frequency of ABG measurements.

Outcomes

The primary outcome was hospital death. Study personnel determined the primary outcome from review of hospital records.

Data analysis

We determined the characteristics of oxygen and carbon dioxide tension measurements among included subjects, including the number and patterns of ABG measurements, and the frequency of hyperoxemia, hypoxemia, hypercarbia and hypocarbia.

Using multivariable logistic regression, we fit a series of models assessing the associations between oxygen and carbon dioxide tension measurements and OHCA hospital death. We fit hospital death