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Outcomes of adults with in-hospital cardiac arrest after implementation of the 2010 resuscitation guidelines☆

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ABSTRACT

Background: The 2015 guidelines for cardiopulmonary resuscitation (CPR) are based on an update of the 2010 guidelines with minor revisions. It is important to assess the 2010 guidelines to ensure their efficacy, which may help promote widespread adoption of the 2015 guidelines.
Methods: We conducted a retrospective observational study in a single center that evaluated patients with in-hospital cardiac arrest (IHCA) between 2006 and 2014. Multivariable logistic regression analysis was used to evaluate associations between independent variables and outcomes.
Results: A total of 1525 patients were included. For patients with initial non-shockable rhythms, the elapsed time to first adrenaline injection was significantly shorter for patients who received CPR according to the 2010 guidelines (2010-CPR) than for those who were treated according to the 2005 guidelines (2005-CPR). During post-cardiac arrest care, the percentage of patients with fever was significantly lower and the implementation of critical interventions was significantly higher in patients who received 2010-CPR than in those who received 2005-CPR. After adjusting for the effects of confounding factors, patients who received 2010-CPR had improved neurological outcomes (odds ratio [OR], 1.75; 95% confidence interval [CI], 1.05–2.93; $p = 0.03$) and survival (OR, 1.50; 95% CI, 1.06–2.12; $p = 0.02$) at hospital discharge than patients who received 2005-CPR.
Conclusions: Hospital adoption of the 2010 guidelines may improve the neurological and survival outcomes for IHCA patients. This improvement might result from an emphasis on the importance of high-quality CPR, post-cardiac arrest care, and teamwork in the 2010 guidelines.

1. Introduction

In the United States, approximately 209,000 patients experience in-hospital cardiac arrest (IHCA) each year [1]. Despite ongoing efforts to improve the "chain of survival" protocol, patient outcomes after IHCA remain poor. Approximately 24% of IHCA patients survive to hospital discharge; among these patients, approximately 14% experience significant neurological disability [1].

The International Liaison Committee on Resuscitation has published resuscitation guidelines since 2000 in 5-year cycles. The 2010 guidelines [2] significantly changed the process of cardiopulmonary resuscitation (CPR). The 2010 guidelines [2] stressed more the importance of high-quality CPR compared with the 2005 guidelines [3]. The 2010 guidelines [2] changed the procedure of basic life support (BLS) from airway, breathing, chest compressions (A-B-C) to C-A-B. The recommendation for a predefined period of CPR before first defibrillation was removed in the 2010 guidelines [2].

In a manikin-based simulation study, Sekiguchi et al. [4] reported that chest compression could be initiated earlier provided that healthcare workers were educated according to the 2010 guidelines [2]. By contrast, Jones et al. [5] found that adherence to the 2010 guidelines [2] caused a greater proportion of lay rescuers to perform chest compressions at an erroneously fast rate, which could worsen BLS efficacy. The 2010 guidelines [2] recommend deeper and faster chest

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compressions to enhance the return of spontaneous circulation (ROSC). However, Beom et al. [6] reported that adherence to the 2010 guidelines [2] resulted in significantly more patients with rib fracture than the 2005 guidelines [3], suggesting that the 2010 guidelines led to higher occurrence of complications that nullified the enhanced ROSC rate and reduced overall survival [7,8].

Müller et al. [9] reported that the ROSC rate of IHCA patients increased significantly from 48% to 72% after implementation of the 2010 guidelines [2], but the survival rate did not improve significantly. Zhu and Zhang [10] performed a meta-analysis comparing the 2005 and 2010 guidelines and showed that the pooled ROSC (47% and 48%, respectively) and the survival rate (15% and 14%, respectively) for IHCA patients did not change significantly despite different protocols. The combined results of these studies [5,6,9,10] suggest that the 2010 guidelines [2] may not be superior to the 2005 guidelines [3] in terms of overall survival outcome. However, Müller et al. [9] did not account for potential confounders in the comparison, and the between-study heterogeneity in the meta-analysis by Zhu and Zhang [10] was as high as 98% for both pooled ROSC and survival rate.

The most current 2015 guidelines [11] are based on the 2010 guidelines [2] with minor revision and update. Therefore, it is important to assess the 2010 guidelines [2] in a less-biased way to ensure their efficacy. In this study, we attempted to evaluate changes in the resuscitation process caused by the 2010 guidelines [2] and assess the efficacy of the 2010 guidelines [2] on IHCA outcomes.

2. Methods

2.1. Setting

This retrospective cohort study was performed in the tertiary medical center National Taiwan University Hospital (NTUH). NTUH has 2600 beds, including 220 beds in intensive care units (ICUs). This study was conducted in accordance with the Declaration of Helsinki amendments. The Research Ethics Committee of the NTUH approved this study (reference number: 201703057RINB) and waived the requirement for informed consent before data collection. According to hospital policy, a code team is activated when a cardiac arrest event occurs in the general wards. A code team consists of a senior resident, several junior residents, a respiratory therapist, a head nurse, and several ICU nurses. A code team is not mobilized for cardiac arrest events in the ICUs; instead, resuscitation is performed by the ICU staff where the event occurs and by staff from neighboring ICUs.

Each code team member is certified to provide BLS and advanced cardiac life support (ACLS) according to the current resuscitation guidelines. Hospital policy requires all staff who would attend patients in clinical practice to receive BLS/ACLS training courses every two years. However, there are no officially accredited resuscitation guidelines for BLS/ ACLS course instructors to use as lecture materials in Taiwan. The Resuscitation Council of Asia released its first adult BLS guideline in 2015 [12]. Before 2015, ACLS course instructors at NTUH used guidelines of American Heart Association (AHA) [13,14] as the lecture materials. The two-day BLS/ACLS training courses include classroom-based lectures, hands-on workshops, and ACLS Megacode Simulator scenario practices. Each trainee has to pass a written examination and Megacode practice tests to be certified.

2.2. Participants

Patients who experienced IHCA at NTUH from 2006 to 2014 were screened. Patients who met the following criteria were included in the study: (1) aged 18 years or older, (2) documented absence of pulse with performance of chest compression for at least 2 min, and (3) no documentation of a do-not-resuscitate order before arrest. If multiple cardiac arrest events occurred in a single patient during hospitalization, only the first event was recorded. Patients who experienced cardiac arrest related to major trauma were excluded from the study.

2.3. Data collection and outcome measures

The following information was recorded for each patient: age, gender, comorbidities [15], variables derived from the Utstein template [16], the first arterial oxygen partial pressure (PaO_2) value obtained after sustained ROSC, vital signs during the initial 24 h following sustained ROSC, and critical interventions implemented at the time of cardiac arrest and after sustained ROSC. Sustained ROSC was defined as ROSC lasting ≧20 min without resumption of chest compression.

Duration of CPR 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 sustained ROSC or declaration of death. Tracheal intubation included endotracheal intubation, tracheostomy, and cricothyroidotomy. Fever was defined as body temperature ≥ 37.8 °C [17]. Hyperoxia was defined as PaO_2 ≧ 300 mm Hg [18]. The goal of targeted temperature management strived for a body temperature of 33 °C throughout the study period [17,19].

The primary outcome was favorable neurological status at hospital discharge, and the secondary outcome was survival to hospital discharge. Favorable neurological outcome was defined as a score of 1 or 2 on the Cerebral Performance Category (CPC) scale [20]. The CPC score [20] is a validated 5-point scale of neurological disability (1, good cerebral performance; 2, moderate cerebral disability; 3, severe cerebral disability; 4, coma/vegetative state; 5, death). Patients with a CPC score of 1 or 2 had sufficient cerebral function to live independently. The CPC score was retrospectively determined by reviewing medical records for each patient.

2.4. Statistical analysis

Data were analyzed using R 3.3.1 software (R Foundation for Statistical Computing, Vienna, Austria). Categorical data were expressed as counts and proportions; continuous data were expressed as medians and interquartile ranges. Categorical variables were compared using Fisher's exact test; continuous variables were examined using Wilcoxon's rank-sum test. A two-tailed p-value of <0.05 was considered as statistically significant.

The odds ratio (OR) was selected as the outcome measure. Multivariable logistic regression analyses were performed to examine the associations between independent variables and outcomes. All available independent variables without missing data were considered in the regression model, regardless of whether they were scored as 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 to 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.

We used generalized additive models [21] to examine nonlinear effects of the continuous variables and if necessary, to identify the appropriate cut-off point(s) for dichotomizing a continuous variable during the variable selection procedure. We assessed the goodness-of-fit of the fitted regression model using c statistics, adjusted generalized R^2, and the Hosmer-Lemeshow goodness-of-fit test.

3. Results

A total of 1538 adult patients at NTUH received chest compressions for ≥2 min between 2006 and 2014. Of these, 13 patients were excluded because of trauma-related cardiac arrest. The remaining 1525 patients were enrolled in our study for further analysis.

The baseline characteristics, peri-cardiac arrest events, and resuscitation outcomes for all patients are presented in Tables 1 and 2. Patients who were hospitalized between 2006 and 2010 received CPR according to the 2005 guidelines [3] (2005-CPR), whereas patients who were hospitalized between 2011 and 2014 received CPR according to the 2010 guidelines [2] (2010-CPR). Compared with patients who received 2005-CPR, those who received 2010-CPR appeared to have higher incidence of cardiovascular diseases, such as higher incidences of heart failure, myocardial infarction, arrhythmia, shockable rhythms, implementation of pulmonary artery catheter, or intra-aortic balloon pumping. Patients who received 2005-CPR appeared to be more critically ill than those who received 2010 CPR; for example, the percentage of patients with favorable neurological status 24 h before cardiac arrest was significantly higher for patients who received 2010-CPR, and the frequency of mechanical ventilation or vasopressor implementation at the time of arrest was significantly lower in patients who received 2010-CPR. However, there was no significant difference in the Charlson comorbidity index between patients receiving 2005-CPR and 2010-CPR.

In regard to CPR process, for patients with initial non-shockable rhythms, the interval between arrest and first adrenaline injection was significantly shorter for those receiving 2010-CPR than for those receiving 2005-CPR. As for post-ROSC care, among patients who received 2010-CPR, the percentage of patients with critical interventions was significantly higher than that of patients who received 2005-CPR, whereas the percentage of patients with fever was significantly lower.

All independent variables listed in Tables 1 and 2 (except for those with missing values) were used in the regression analyses for variable selection. The ORs of factors that significantly affect clinical outcomes are presented in Tables 3 and 4. After adjusting for confounder effects, patients who received 2010-CPR had higher probability of favorable

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