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Clinical paper

Echocardiographic patterns of postresuscitation myocardial dysfunction

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ABSTRACT

Background: Postresuscitation myocardial dysfunction (PRMD) can develop after successful resuscitation from cardiac arrest. However, echocardiographic patterns of PRMD remain unknown. This study aimed to investigate PRMD manifestations with serial echocardiography during the post-cardiac arrest period.

Methods: We enrolled non-traumatic out-of-hospital cardiac arrest patients older than 19 years who underwent successful cardiopulmonary resuscitation (CPR). We excluded patients with myocardial infarction or pre-existing cardiac disease, including heart failure or myocardial disease. Transthoracic echocardiography (TTE) was performed within 24 h, between 24 and 48 h, and between 72 and 96 h after restoration of spontaneous circulation (ROSC).

Results: Of 280 patients, 138 (93 men) were analysed. PRMD was observed in 45 patients (33%), including global dysfunction in 28 patients (20%), regional wall motion abnormalities (RWMA) in 10 (7%), and Takotsubo pattern in 7 (5%). There were no differences in clinical characteristics, laboratory findings, or hospital mortality according to PRMD pattern. Global left ventricular (LV) systolic function gradually improved with time and had recovered to normal by Day 3 in all patients except one with the Takotsubo pattern, which remained on follow-up echocardiography two weeks after ROSC.

Conclusions: PRMD occurs in about one-third of patients resuscitated from cardiac arrest. Echocardiographic patterns of post-cardiac arrest LV dysfunction include global hypokinesia, regional wall motion abnormalities, and Takotsubo pattern.

Introduction

Global ischaemia during cardiac arrest and resuscitation often produces post-cardiac arrest syndrome (PCAS), which is manifested by multiple organ dysfunction, including neurological dysfunction, post-resuscitation myocardial dysfunction (PRMD), systemic ischaemic/reperfusion injury, and persistent precipitating pathology [1]. PCAS is associated with significant morbidity and mortality during the post-cardiac arrest period in patients with prolonged cardiac arrest that occurs outside a medical facility [2,3]. PRMD is a phenomenon of myocardial dysfunction caused by the global ischaemia that occurs during cardiac arrest, which is very different from focal ischaemia. PRMD occurs after return of spontaneous circulation (ROSC) and disappears with recovery of ventricular function to the baseline level after 24–48 h without specific treatment [4]. The occurrence of PRMD is not a universal phenomenon following cardiac arrest. The incidence of PRMD has been reported to range from 34 to 75% according to echocardiographic or angiographic observations [5–8]. The occurrence of PRMD is associated with low cardiac output from the reduced LV ejection fraction (EF) and hypotension that typically requires vasopressor support [7]. Therefore, it is important to evaluate myocardial function to maintain optimal haemodynamics in the early post-cardiac arrest phase.

Myocardial stunning from focal ischaemia is manifested by regional wall motion abnormality. However, myocardial stunning from global ischaemia, such as that which occurs in PRMD, can be manifested by various patterns. Manifestations of PRMD include global LV systolic dysfunction with reduced EF, LV diastolic dysfunction, or right ventricular dysfunction [4,9,10]. Among these, global LV systolic dysfunction is the most significant manifestation of PRMD. However, the detailed patterns of PRMD in human have not yet been investigated. In this study, we examined the manifestations of PRMD with serial echocardiographic observations during the post-cardiac arrest period in patients resuscitated from cardiac arrest with a non-cardiac aetiology.

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Methods

Study design and setting

This was a prospective cohort study of cardiac arrest patients who were admitted to the emergency department (ED) of a tertiary university hospital (Wonju Severance Christian Hospital) between January 2009 and March 2016. The study protocol was approved by the Institutional Review Board of Wonju Severance Christian Hospital.

In the Wonju area, patients who experience out-of-hospital cardiac arrest (OHCA) are managed by emergency medical technicians (EMTs) who are dispatched from a fire department. EMTs provide both basic and advanced life support, including defibrillation, adrenaline administration, and advanced airway management for a minimum of five minutes at the scene. If return of spontaneous circulation (ROSC) cannot be achieved, the patient is transported to the nearest ED while the EMTs continue to perform cardiopulmonary resuscitation (CPR) in the ambulance. Once ROSC is achieved, the patient is referred to a tertiary hospital. In the hospital, the patient received comprehensive post-cardiac arrest care including therapeutic hypothermia with maintenance of body temperature at 32–34 °C for 24 h during the period of January 2009 to November 2015, or targeted temperature management with maintenance of body temperature at 33 or 36 °C for 24 h in the period after December 2015.

Participants

We included non-traumatic out-of-hospital cardiac arrest patients older than 19 years who were successfully resuscitated after CPR and survived for at least 48 h. Only patients with cardiac arrest from non-cardiac aetiology were included, to exclude the possibility of myocardial dysfunction from preexisting heart disease. The exclusion criteria were as follows: acute myocardial infarction or previous history of myocardial infarction; history of preexisting cardiac disease, including heart failure, cardiomyopathies, aortic dissection, or other structural heart disease, such as congenital heart disease; and cardiac arrest from a presumed cardiac aetiology (no any other non-cardiac cause as best determined by ED physician).

Study variables

The following clinical and laboratory parameters were obtained: age, sex, witness of cardiac arrest, bystander CPR, estimated total cardiac arrest time, initial presenting rhythm, total duration of CPR, total dose of adrenaline administered, cumulative defibrillation energy, serum high sensitive troponin I and B-type natriuretic peptide (BNP) levels upon admission, survival to hospital discharge, and neurologic outcome at hospital discharge. The potential cause of or disease underlying cardiac arrest was classified as medical or non-medical in reference to clinical history and laboratory results. Medical causes included respiratory failure (pneumonia, chronic obstructive pulmonary disease, asthma, tension pneumothorax), metabolic acidosis (alcoholic ketoacidosis [AKA] or diabetic ketoacidosis [DKA]), hyperkalaemia, anaphylaxis, pulmonary thromboembolism, gastrointestinal bleeding, subarachnoid haemorrhage, or primary arrhythmias. Non-medical causes included asphyxia, drug overdose, drowning, or electrocution.

Transthoracic echocardiography and patterns of PRMD

All patients resuscitated from cardiac arrest underwent two-dimensional transthoracic echocardiography (TTE) to evaluate cardiac function within 24 h after ROSC (Day 1). We subsequently performed TTE again on Day 2 and Day 3. Follow-up TTE was conducted between the first week and the second week after ROSC. Experienced emergency physicians conducted the TTE using the Vivid E9 Cardiac Ultrasound (GE Healthcare, Little Chalfont, UK) with a 2.5-MHz phased array probe to identify the presence of myocardial dysfunction. All emergency physicians performing TTE had been trained by an official training program certified by the Society of Emergency and Critical Care Imaging and had performed at least 300 previous TTE examinations. The echocardiographic images were recorded, including parasternal long and short axis views and apical four-chamber and two-chamber views. Subcostal windows were used if parasternal windows were not available owing to a poor echocardiographic window. Regional wall motion abnormalities (RWMA) of the LV were analysed, and the EF was determined according to the guidelines of the American Society of Echocardiography [11]. The EF was calculated using the modified Simpson's method. The Teichholz method was used if adequate views were not available for volumetric measurement. All echocardiographic images were recorded and stored on the server of the cardiovascular Picture Archiving and Communication System (PACS) (GE Medical Systems, Barrington, IL, USA). The recorded images and calculations were reviewed and interpreted by an experienced cardiologist (SOH) and an emergency physician (KCC) who were blinded to the clinical data. The final interpretation was determined by consensus between the two physicians if there was disagreement on interpretation.

PRMD was defined as reduced global LV systolic function or RWMA of the LV observed during TTE performed within 24 h after ROSC. Normal global LV systolic function was categorised by a calculated EF greater than 50%, while a reduced global LV systolic function was defined by an EF of 50% or less.

Echocardiographic patterns of PRMD were divided into three categories as follows: type I: global dysfunction; type II: RWMA; and Type III: Takotsubo cardiomyopathy-like pattern (Takotsubo pattern). Global dysfunction indicates a generalised decrease in LV systolic wall motion. RWMA suggests a decrease of systolic wall motion in certain segments of the LV. The Takotsubo pattern refers to echocardiographic findings of apical ballooning involving all LV walls with a hyperdynamic base that is not limited to any single coronary territory [12]. Recovery from PRMD was defined as EF greater than 50% or absence of RWMA on follow-up echocardiography.

Data analysis

Continuous data were presented as median with interquartile range and were compared using the independent sample *t*-test, Mann-Whitney *U* test, or Kruskal-Wallis test, as appropriate. Nominal data were calculated as the percentage of the frequency of occurrence and compared using the Chi-square or Fisher's exact test, as appropriate. The level of interobserver agreement for presence and the type of PRMD were assessed using Cronbach's alpha. Multivariate logistic regression analyses were performed to determine whether age, sex, witness of cardiac arrest, bystander CPR, estimated total cardiac arrest time, initial presenting rhythm, total duration of CPR, total dose of adrenaline administered, or cumulative energy of defibrillation affected the development of PRMD. The resulting odds ratios (ORs) were presented with 95% confidence intervals (CIs). A two-sided p-value less than 0.05 was considered statistically significant. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 18.0, for Windows (SPSS, Chicago, IL, USA).

Results

General characteristics

During the study period, 280 patients who regained spontaneous circulation following cardiac arrest underwent TTE in the ED. Among them, 142 patients were excluded from the analysis owing to a previous history of myocardial infarction (23 patients), acute myocardial infarction (21 patients), congestive heart failure (CHF) (12 patients), cardiomyopathy (12 dilated cardiomyopathies, 2 hypertrophic cardiomyopathies, 1 postpartum cardiomyopathy), aortic dissection (1