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Research Article

Research to Observe the Hemodynamic Changes and Cardiac Function in Active Abdominal Compression-decompression Cardiopulmonary Resuscitation

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ABSTRACT

Objective: Compare the hemodynamic changes and cardiac function between active abdominal compression-decompression cardiopulmonary resuscitation and standard cardiopulmonary resuscitation.

Methods: A prospective controlled trial was conducted. The patients staying in EICU or ICU were the study subjects which were divided into active abdominal compression-decompression cardiopulmonary resuscitation (AACD-CPR) group and standard cardiopulmonary resuscitation (STD-CPR) group randomly. Central venous pressure (CVP), diastolic blood pressure (DBP) and coronary perfusion pressure (CPP) were recorded continuously. Transesophageal echocardiography (TEE) was used to observe the cardiac valves and assess left ventricular end diastolic volume (LVEDV), left ventricular end systolic volume (LVESV), left ventricular ejection fraction (LVEF) during CPR.

Results: During CPR, LVEDV of two groups both decreased compared with pre-cardiac arrest, which was not statistically significant($P>0.05$). LVEDV in AACD-CPR group was larger than STD-CPR group during CPR. But there was not statistically significant ($P>0.05$). During CPR, LVESV of two groups both increased compared with pre-cardiac arrest, which was statistically significant($P<0.01$). LVESV in AACD-CPR group was larger than STD-CPR group（$P<0.05$). But there was not statistically significant($P>0.05$). Both AACD-CPR group and STD-CPR group showed significantly decreased LVEF compared with pre-cardic arrest, of which the difference was statistically significant($P<0.01$). LVEF in STD-CPR group was higher than AACD-CPR group and there was a tatistically significant difference between them（$P<0.05$). When compressing chest , mitral valve and tricuspid valve were open and aortic valve and pulmonary valve were closed during the 8 patients of the STD-CPR group.

Conclusion: During chest compression, heart pump took effect in a part of patients. However, during abdominal compression, heart was just a channel that blood flowed. The cardiac function in STD-CPR was superior to AACD-CPR. However, both of them can produce effective haemodynamics. So, we suggested that AACD-CPR could be used in the patients with the contraindication of STD-CPR.

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Introduction

Cardiac arrest is a catastrophic disease. More than 544,000 died of cardiac arrest in China yearly [1]. So, it is important to conduct a timely and effective CPR. Although emergency medical service (EMS) and the awareness of CPR have been improved, the morbidity and mortality of cardiac arrest is still very high [2]. With decades of development since its emergence, CPR has improved survival rates and return of spontaneous circulation (ROSC) to some extent, but it is still below expectation. Tranditional CPR can't satisfy the current clinical request. We urgently need new techniques. On the basis of predecessors' researches, Wang et al. came up with active abdominal compression-decompression cardiopulmonary resuscitation (AACD-CPR) innovatively which solves the problems of standard cardiopulmonary resuscitation (STD-CPR) and can be used in patients with chest deformity, rib fracture, etc [3]. AACD-CPR generates effective circulating blood flow and ventilation through several mechanisms including "abdominal pump", "thoracic pump", and "lung pump" [3].

The purpose of this study was to compare the hemodynamic changes and cardiac function between AACD-CPR and STD-CPR.

Methods and materials

I Patients

This was a prospective study conducted at Zhengzhou People's Hospital from January 2017 to June 2018. We selected inpatients from Intensive Care Unit (ICU). Inclusion/exclusion criteria are as follows. Finally, there were 47 patients selected into our research. According to the contraindications, 15 patients which had the contraindications of chest compression were selected into AACD-CPR group. The other patients were selected into STD-CPR group.

Inclusion criteria

i. Patients with cardiac arrest that need CPR according to the 2015 AHA guidelines.
ii. The age were more than 18 years old.
iii. Patients had no contraindication of STD-CPR and AACD-CPR. The contraindication of STD-CPR was chest deformity, rib fracture and so on. The contraindication of AACD-CPR was the rupture of abdominal organ, abdominal mass, abdominal aortic aneurysm, pregnancy.
Iv. Body weight between 40kg-150kg

Exclusion criteria

i. The patients had the history of myocardiopathy, valvular disease or pericardial disease, such as myocardial hypertrophy, dilated cardiomyopathy, narrow pericarditis and so on.
ii. Patients with end-stage disease or cachexia.
iii. Patients had contraindications of STD-CPR and AACD-CPR

II Ethical Approval

All the trials got the approval of the Ethical Review Committee of Zhengzhou People's Hospital and Sanmenxia center Hospital (the number of approvals: 2014-006-03). All patient relatives or legal guardians received a detailed explanation of the study's possible risks and benefits and were permitted to request discontinuation of the study at any time.

III Clinical intervention

i. All patients had colour doppler echocardiography when they were admitted into ICU. We recorded left ventricular end diastolic volume (LVEDV), left ventricular end systolic volume (LVESV) and left ventricular ejection fraction (LVEF) of patients.
ii. All patients were monitored through electrocardiograph. And we performed central venous catheterization and invasive arterial pressure measurement for all of them.
iii. When CA happens, all patients received orotracheal intubation, respiration with the aid of a rebreathing bag or breathing machine, electric defibrillation and epinephrine apart from AACD-CPR or STD-CPR.

IV The usage of CPR-LW1000 abdominal lifting/compression device

Using the instrument, the operator should hold the pressure application handles and place the compression plate on the patient's abdomen. After turning on the device, negative pressure is generated which causes a tight bond between these pressure plates and the patient's abdomen. The operator then presses an indicator light prompted by an audio signal with a frequency of 100 times/minute, and the instrument performs alternate vertical downward compressions and upward lifting actions. The duration of compression and lifting was performed in a 1: 1 interval, the pressure was approximately 186mmHg when the indicator light was on, and lifting force was approximately 112 mmHg. Images of the device are shown.

V Methods

When CA happens, our emergency response team immediately performs STD-CPR or AACD-CPR and Transesophageal echocardiography. We recorded the LVEDV, LVESV and LVEF. At the same time, we recorded the DBP and CVP 5 minutes after CPR.

VI Termination of Lifesaving Treatmen

According to 2015 AHA guideline：i) spontaneous artery pulsation. ii) ruddy complexion. iii) spontaneous respiration. iv) retraction of pupils and light reflex. After rescuing for more than 30 minutes and giving the agreement of patients' family, we would stop rescuing if the patients didn't restore spontaneous artery pulsation and spontaneous respiration.

VII Observational index

LVEDV, LVESV and LVEF before CA and during CPR.
DBP and CVP before CA and 5 minutes after CPR.
Coronary perfusion pressure (CPP)=DBP-CVP

VIII Statistical Analysis

Statistical analysis was performed by using the SPSS 20.0 statistical software. Data with normal distribution were presented as mean±standard deviation. The ranked data were presented as mean rank. Analysis for categorical variable were performed using X2 test. The two-sample t-test was applied for comparison of continuous variables between the two groups. The ranked data were tested with the Mann-Whitney-Wilcoxon test. A probability value of $p < 0.05$ was considered to be statistically significant difference.

Results

The differences in age, sex and weight in two groups are not statistically significant (P>0.05), as is shown in (Table 1).

LVEDV, LVESV and LVEF in two groups before and during CA were shown in (Table 2). During CPR, LVEDV of two groups both decreased compared with pre-cardiac arrest stage, which was not statistically significant (P>0.05). However, during CPR, LVESV of two groups were larger than pre-cardiac arrest, which was statistically significant (P<0.01). LVEF of two groups both decreased compared with pre-cardiac arrest, which was statistically significant (P<0.01). During CPR, LVEDV of two groups were not statistically significant (P>0.05). However, LVESV of AACD-CPR group was also larger than the STD-CPR group (P<0.05). The difference of LVEF in two groups was statistically significant (P<0.05). LVEF of STD-CPR group were larger than AACD-CPR group.

In the STD-CPR group, there were 8 patients which mitral and tricuspid valves closed, and aortic and pulmonary valves opened during chest compressions. The four valves in the other patients opened. The four valves in AACD-CPR group all opened.

DBP, CVP and CPP in two groups before and during CA were shown in (Table 3). There was no statistically significant difference in DBP, CVP, CPP between the two groups before CA (*P*>0.05). Both AACD-CPR group and STD-CPR group showed significantly decreased DBP compared with pre-cardic arrest stage, of which the difference was statistically significant (*P*<0.01). There was no statistically significant difference in DBP, CVP and CPP between the two groups during CPR (*P*>0.05).

Table 1: The general information of two group

group	age	size		weight	Etiology		epinephrine	defibrillation	Time:CPR	ROSC(n,%)
		male	female		cardiogenic	Non-cardiac	(mg)	（time）	（min）	
STD-CPR	60.75±21.29	18	14	69.17±10.46	21	11	7.72±2.25	0.88±1.10	32.0±19.72	3（9.4）
AACD-CPR	56.30±16.4	9	6	70.5±12.16	7	8	7.87±3.0	0.73±0.88	30.67±19.35	1（6.7）
X^2/ t value	0.54	0.059		-0.277	1.524		-0.189	0.432	0.217	0.096
P value	0.595	0.808		0.785	0.217		0.851	0.665	0.829	0.756

PS: STD-CPR standard cardiopulmonary resuscitation; AACD-CPR active abdominal compression-decompression cardiopulmonary resuscitation

Table 2: The comparison of cardiac function between two groups

group		N	LVEDV(ml)	LVESV(ml)	LVEF
①	STD-CPR（before CA）	32	106.53±19.12	64.74±20.72	0.38±0.098
②	AACD-CPR（before CA）	15	111.58±17.97	71.51±18.17	0.36±0.117
③	STD-CPR（during CPR）	32	97.76±16.43	83.5±13.41	0.09±0.038
④	AACD-CPR（during CPR）	15	108.06±15.85	103.3±14.79	0.04±0.048
①：② t value			-0.633	-0.092	-0.352
①：②*P* value			0.534	0.928	0.728
①：③t value			1.893	-2.79	8.211
①：③*P* value			0.072	0.047	0.000
②：④t value			0.465	-4.290	7.933
②：④*P* value			0.648	0.000	0.000

③：④t value	-1.21	-3.292	2.895
③：④*P* value	0.057	0.040	0.009

PS:STD-CPR standard cardiopulmonary resuscitation; AACD-CPR active abdominal compression-decompression cardiopulmonary resuscitation;LVEDVleft ventricular end diastolic volume；LVESV left ventricular end systolic volume;LVEF left ventricular ejection fraction

Table 3: The comparison of haemodynamics between two groups

group		N	DBP (mmHg)	CVP (mmHg)	CPP (mmHg)
⑤	STD-CPR （before CA）	32	69.75±16.89	9.33±5.94	60.42±16.08
⑥	AACD-CPR （before CA）	15	70.70±13.75	9.10±4.72	61.60±14.63
⑦	STD-CPR （during CPR）	32	46.67±8.01	11.5±6.61	35.17±11.17
⑧	AACD-CPR （during CPR）	15	50.90±7.87	11.9±4.98	39.0±11.66
⑤：⑥t value			-0.143	0.1	-0.179
⑤：⑥*P* value			0.888	0.921	0.86
⑤：⑦t value			4.273	-0.844	4.468
⑤：⑦*P* value			0.001	0.408	0.000
⑥：⑧t value			3.154	-1.29	3.144
⑥：⑧*P* value			0.005	0.213	0.006
⑦：⑧t value			-1.412	-0.157	-1.606
⑦：⑧*P* value			0.106	0.876	0.124

PS:STD-CPR standard cardiopulmonary resuscitation; AACD-CPR active abdominal compression-decompression cardiopulmonary resuscitation;DBP diastolic blood pressure；CVP Central venous pressure；CPP coronary perfusion pressure

Discussion

CPR has been used for more than 60 years and rescued large numbers of patients. With the development of medicine and update of the guideline, researchers have invented many techniques to improve ROSC rate. However, the ROSC rate is still unsatisfactory. European resuscitation guide indicated that during CPR, the volume of blood flowing through the heart and cardiac output were important factors which would impact ROSC rate [4]. In 1967, Jr et al firstly added abdominal compression during chest compressions in order to increase returned blood volume and cardiac output [5]. After decades of research, many studies indicated that interposed abdominal compression cardiopulmonary resuscitation (IAC-CPR) can improve DBP, CPP and ROSC rate [6-8]. However, if patients have contraindication of chest compression, such as chest deformity, pneumothorax, and rib fracture etc., doctors don’t know what to do. In 2007, in a study of pig ventricular fibrillation model, Geddes et al from American Purdue University indicated that abdominal compression (OAC-CPR) alone produced 60% more coronary perfusion than standard chest-compression CPR, with no damage to visceral organs [9]. On the basis of pre-research, Wang innovatively invented the CPR-LW1000 abdominal lifting/compression device and proposed AACD-CPR.

AACD-CPR, a new technique, pulls up the abdominal wall with a negative pressure device after compressing the abdomen, which decreases the pressure of abdominal cavity, lowers the diaphragm, increases the pressure of thoracic cavity, decreases the pressure of right atrium and vena cava, and increases the returned blood volume. When the abdomen is compressed, the pressure of abdominal cavity increases and the organs in abdomen are compressed, causing blood to flow into heart. In addition, with increased pressure in the abdominal cavity, the diaphragm moves up, the volume of thoracic cavity decreases, and the pressure increases, and the heart enters a systolic state, causing cardiac ejection [3]. During OAC-CPR and STD-CPR, the abdominal wall or thorax restores passively. Moreover, STD-CPR has the risk of rib fracture,which affects the restoration of thorax and lowers the ROSC rate [10, 11]. AACD-CPR can avoid the risk of rib fracture and increase returned blood volume. Animal trial and human trial also demonstrated that AACD-CPR produces effective blood circulation and potentially improves ROSC rate [12-15].

Our result indicated that LVEDV of AACD-CPR group was larger than that of STD-CPR group, because organs in abdomen account for 1/4 of total blood volume and when the abdomen was compressed, the organs were compressed and volume of blood returning to heart increased [16]. Geddes et al pointed out in a study with swine model that when the pigs were normal the mean of coronary perfusion index was 4016 mmHg and when the pigs were in the state of VF, the mean of coronary perfusion index was 922 mmHg, indicating that OAC-CPR provided 1/4 of blood volume, whereas standard chest-compression CPR provided only 17%(645/3781) [19]. There was a statistically significant difference in LVESV between the two groups and the AACD-CPR group was larger than the STD-CPR group. The result showed that the strength for cardiac compression in STD-CPR was stronger than AACD-CPR. STD-CPR generates artificial circulation via "thoracic pump" and "heart pump". When the sternum was compressed, the heart, which is positioned between sternum and spine, is pressed directly. Then atrioventricular valve closes, aortic valve opens, and finally the heart shrinks and generates ongoing blood flow [17]. In AACD-CPR, increased pressure within the abdominal cavity caused the the diaphragm to move up, the volume of the thoracic cavity decreases, and the pressure increases, and the heart is pressed indirectly, causing cardiac ejection and blood flowing ahead [13]. LVEF in two groups had no statistically significant difference. It is probably because the mutual effect and actions between LVEDV and LVESV. The result means that the cardiac function during AACD-CPR is as the same as STD-CPR. In our study, 32 patients underwent chest compressions of which only 8 patients had cardiac pump mechanism, and 24 patients did not see atrioventricular valve closure. In the AACD-CPR group, all patients had not atrioventricular valve closure and almost no heart compression. Therefore, the cardiac pump did not play a role in AACD-CPR, and the heart only served as a channel for blood flow.

Our result showed that DBP of two groups had no statistically significant difference. The result was the same as our previous research result [18].

In 1990, Paradis et al discovered when CPP was more than 15mmHg, the rate of ROSC would increase. The higher CPP, the higher the rate of ROSC [19]. Up to now, CPP is still used to predict the survival rate [20]. Kammeyer et al indicated that rhythmic abdominal compression generated higher CPP than STD-CPR [21]. Georgiou et al also indicated that compared with STD-CPR, CPP was significantly higher in IAC-CPR–treated animals. Although our result didn't get a statistically significant difference between two groups, CPP in AACD-CPR was higher than STD-CPR [22].

Conclusion

Hemodynamics and cardiac function in AACD-CPR was as the same as STD-CPR. We suggested that AACD-CPR could be used in the patients with the contraindication of STD-CPR and the elder.

Limitation

There are limitations to this study that should be considered. The study was performed at a single center, and the number of patients was limited. Autopsies were not performed in no survivors and thus we were not able to determine if abdominal lifting and compression resulted in abdominal injuries.

Competing Interests

The authors declare that they have no competing interests.

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