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Experimental paper

The effect of resuscitation position on cerebral and coronary perfusion pressure during mechanical cardiopulmonary resuscitation in porcine cardiac arrest model☆

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ABSTRACT

Objective: It is unknown whether patient position is associated with the optimal cerebral (CePP) and coronary (CoPP) perfusion pressure.
Methods: This study utilized a randomized experimental design and anesthetized, intubated and paralyzed female pigs (n = 12) (mean 42, SD 3 kg). After 6 min of untreated ventricular fibrillation, mechanical CPR with was performed for 3 min in 0° supine position. The CPR was then performed for 5 min in a position randomly assigned to either 1) head-up tilt (HUT) by three angles (30°, 45°, or 60°) or 2) head-down tilt (HDT) by three angles (30°, 45°, or 60°) and at 3) supine position between HUT and HDT positions. 4 Pigs were assigned to each angle of HUT or HDT position and 12 pigs were assigned to supine position. CePPs and CoPPs were measured and compared using MIXED procedure with pig as a random effect among angles and compared between angles with Tukey post-hoc analysis.
Results: With 60°, 45°, 30° head-down, 0° (supine), and 30°, 45°, 60° head-up positioning, mean(SD) CePPs increased consistently as follows: 2.4(0.4), 9.3(1.6), 16.5(1.6), 27.0(1.5), 35.1(0.4), 39.4(0.6), and 39.9(0.3) mmHg, respectively. CoPPs were followings according to same angle: 12.9(2.5), 13.3(2.5), 12.8(0.4), 18.1(0.7), 30.3(0.4), 24.1(0.6), and 26.5(0.9) mmHg, respectively. The CePPs were peak at HUT(45°) and HUT(60°), but CoPP was peak in HUT(30°) and higher than HUT(45°) and HUT(60°).
Conclusion: Cerebral perfusion pressure during mechanical CPR were similar and highest in the HUT(45° and 60°) positions whereas the peak coronary perfusion pressure was observed with HUT(30°).

Background

Out-of-hospital cardiac arrest (OHCA) is one of the most important public health issues in terms of high incidence and low survival rate including South Korea.[1–3] East Asian emergency medical services (EMSs) in South Korea, Japan, Taiwan, Hong Kong, and Singapore have unique EMS protocols and prehospital clinical settings for OHCA different from North America or European countries.[4,5] The EMS systems encourage providers to transport patients with OHCA with providing CPR during ambulance transport and not allow them to stop CPR at the field.[6]

Low survival rates in these communities may be due to the constrained difficulty to provide ongoing CPR while transporting patients in a small elevator with the current ambulance stretcher

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cart, which is designed to lay flat at the 0° supine position.[7,8] In order to provide ongoing high quality CPR during patient transport in a confined space like the elevator, a change in resuscitation position to bend patient's body has been proposed to reduce the overall length of the stretcher cart.[9,10]

In a recent collaborative study that examined the effects of tilted position at different angles while receiving CPR in porcine model, significant increase in cerebral perfusion pressure, oxygenation, and cerebral blood flow in the head-up position during CPR compared with either 0° supine or head-down position.[11] This finding is striking as increased perfusion pressure indicates increased circulation to the heart and brain, which minimizes the risk for brain damage. The study examined the CePP of 0°, 30°, −30° and showed the best CePP at the 30° and the highest CoPP at 0°. It is unclear whether the much higher head-up angle is associated with better cerebral and coronary perfusion pressure.

In previous studies on body position and physiologic parameters, leg elevation showed significantly higher coronary perfusion pressure and higher carotid blood flow.[12] Head-up position in stroke patients showed significant decrease in carotid blood flow in recent small case control study.[13] In severe head trauma patients, intracranial pressure was significantly decreased by head-up position while the cerebral perfusion pressure was not changed.[14] However, these studies were performed in patients without cardiac arrest. The patients with cardiac arrest has no auto-regulatory vascular function, which may be far different from patients with their own heart function.

We hypothesize that the much greater head-up position would augment the CePP with linearity but not increase the CoPP because the venous return will be also decreased by more acute head up position and result in decrease in CoPP. This study aims to assess the effect of much greater change in position on both cerebral and coronary perfusion pressure during providing CPR.

Methods

This study was approved by the Institutional Animal Care and Use Committee of the study institution. All animal care was complaint with the Laboratory Animal Act of the Korean Ministry of Food and Drug Safety. A certified and licensed veterinarian assured the protocols were performed in accordance with the aforementioned guideline.

Surgical preparation

Pigs were positioned on a tilt table with a bolted-in backboard to connect to the mechanical CPR device with their legs tied to the ends of the tilt table. Pigs were initially sedated with intramuscular injection of 5 mg/kg of tiletamin/zolazepam hypochloride (Zoletil®, Virbac laboratories, France) and 2 mg/kg of xylazine (Rompun®, BayerKorea, South Korea), followed by inhaled isoflurane at a dose of 1–1.5%. While sedated and ventilated, tracheal intubation was performed using an internal diameter of 7.5 mm endotracheal tube. After creating a burr hole at the middle of the distance between the occipital bony prominence and the right eyebrow, a micromanometer-tipped catheter (Mikro-Tip® transducer, Millar Inc., Houston, TX, USA) into the parietal lobe to measure intracranial pressure (ICP). Second Mikro-tip® Transducer was inserted through the left femoral artery under ultrasonic guidance and placed in descending thoracic aorta to measure the aortic blood pressure. Another Mikro-tip® Transducer was inserted in the right atrium via the right external jugular vein to record the right atrial pressure. The position of the transducer was confirmed by characteristic pressure tracings. Pigs were ventilated with a volume-control ventilator adjusted at a tidal volume of 10 ml/kg, a respiratory rate adjusted to continually maintain end-tidal CO_2 ($ETCO_2$) of 40 mmHg and O_2 saturation above 94%. All animals received intravenous heparin bolus (100 units/kg). Animals were fasted overnight and received 1000–1200 ml of normal saline to maintain the mean right atrial pressure between 3 and 5 mmHg. The pigs' rectal temperature was maintained between 37.0 °C to 38.0 °C using a warming blanket (Blanketrol® II, Cincinnati Sub-Zero Medical Division, Cincinnati, OH, USA) throughout the experiment duration. Additionally, electrocardiography (ECG), oxygen saturation (SpO_2) monitoring from ear lobe surface, and end tidal CO_2 ($PETCO_2$) levels were monitored and recorded throughout the experiment. All data measurements were recorded using a digital data acquisition software (PowerLab®, ADInstruments Inc., Colorado Springs, CO, USA).

Experiment protocol

Ventricular fibrillation (VF) was induced by delivering direct current via a pacing wire placed in right ventricle. The ventilator was disconnected and the animal was left untreated VF for 6 min. Then, at supine position, mechanical CPR was performed using the LUCAS®2 Chest Compression System (Zolife AB, Lund, Sweden) device at a compression rate of 100 times per minute and a compression depth of 4 to 5 cm for 3 min. An impedance threshold device with the opening pressure of −10 cm H_2O (ResQPOD® ITD, Advanced Circulatory Systems Inc., Roseville, MN, USA) was attached to the endotracheal tube. The tidal volume was maintained at 10 ml/kg and the respiratory rate at 10 breaths/min. At this time, a computer-generated randomization position sequence was assigned (Fig. 1).

Randomization protocol was as follows: randomization sequence was computer-generated on the basis of the study design, which is a block randomized experimental trial. The three trial groups included supine (0°), head-up tilt (HUT) (30°, 45°, and 60°), and head-down tilt (HDT) (30°, 45°, 60°). The randomization list specified the position sequence as well as randomly assigned tilt degree for each head-up and head-down. The randomization assigned one sequence between the two such as (1) head-up, supine, and followed by head-down, or reversely (2) head-down, supine, and followed by head-up. After assigning the sequence, the angle among 30°, 45°, and 60° were assigned for each head-up and head-down position. Each pig experienced three positions (one time of head-up, supine, and one time of head-down). 4 pigs were assigned to each angle of head-up and head-down position except supine position where 12 pigs were allocated to.

Following the assigned sequence, 5 min of LUCAS-CPR was performed in each position. The tilt table was specially customized to be locked at a designated tilt degree and to support ongoing LUCAS-CPR during the position change. Hemodynamic data were continuously recorded throughout the trial. After total of 18 min of CPR, pigs were placed in the supine position and defibrillated with 200 J biphasic shocks. Upon completion of the experiment protocol, pigs were then sacrificed with a 20 ml injection of saturated potassium chloride.

Measurements

Cerebral perfusion pressure (CePP) was calculated as the difference between mean aortic pressure and mean ICP. Coronary perfusion pressure (CoPP) was calculated as the difference between aortic pressure and right atrial pressure during the CPR decompression phase. At each angle, about 500 times of measurement of perfusion pressure were calculated. Each parameters were measured using integrated measurement system for blood pressure, right atrial pressure, intracranial pressure via micro-tip catheter and transducer (Mikro-Tip® transducer, Millar Inc., Houston, TX,