Resuscitation 128 (2018) 51–55

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Experimental paper

Effects of head-up vs. supine CPR on cerebral oxygenation and cerebral metabolism – a prospective, randomized porcine study☆

Gabriel Putzer[a], Patrick Braun[a], Judith Martini[a,*], Ines Niederstätter[a], Julia Abram[a], Andrea Katharina Lindner[a], Sabrina Neururer[b], Miriam Mulino[c], Bernhard Glodny[d], Raimund Helbok[e], Peter Mair[a]

[a] Department of Anaesthesiology and Critical Care Medicine, Medical University of Innsbruck, Austria
[b] Department of Medical Statistics, Informatics and Health Economics, Medical University of Innsbruck, Austria
[c] Department of Neurosurgery, Medical University of Innsbruck, Austria
[d] Department of Radiology, Medical University of Innsbruck, Austria
[e] Department of Neurology, Medical University of Innsbruck, Austria

ARTICLE INFO

Keywords:
Animals
Blood pressure
Cardiac arrest
Cardiopulmonary resuscitation
Cerebral cortex/metabolism
Heart arrest/therapy
Microdialysis/methods
Near infrared spectroscopy
oxygen/blood
oxygen/metabolism
Pigs

ABSTRACT

Background: Recent studies have shown that during cardiopulmonary resuscitation (CPR) head-up position (HUP) as compared to standard supine position (SUP) decreases intracranial pressure (ICP) and increases cerebral perfusion pressure (CPP). The impact of this manoeuvre on brain oxygenation and metabolism is not clear. We therefore investigated HUP as compared to SUP during basic life support (BLS) CPR for their effect on brain oxygenation and metabolism.

Methods: Twenty pigs were anaesthetized and instrumented. After 8 min of cardiac arrest (CA) pigs were randomized to either HUP or SUP and resuscitated mechanically for 20 min. Mean arterial pressure (MAP), ICP, CPP, cerebral regional oxygen saturation (rSO_2) and brain tissue oxygen tension ($P_{bt}O_2$) were measured at baseline, after CA and every 5 min during CPR. Cerebral venous oxygen saturation ($S_{cv}O_2$) was measured at baseline, after CA and after 20 min of CPR. Cerebral microdialysis parameters, e.g. lactate/pyruvate ratio (L/P ratio) were taken at baseline and the end of the experiment.

Results: ICP was significantly lower in HUP compared to SUP animals after 5 min (18.0 ± 4.5 vs. 24.1 ± 5.2 mmHg; p = 0.033) and 20 min (12.0 ± 3.4 vs. 17.8 ± 4.3 mmHg; p = 0.023) of CPR. Accordingly, CPP was significantly higher in the HUP group after 5 min (11.2 ± 9.5 vs. 1.0 ± 9.2 mmHg; p = 0.045) and 20 min (3.4 ± 6.4 vs. −3.8 ± 2.8 mmHg; p = 0.023) of CPR. However, no difference was found in rSO_2, $P_{bt}O_2$, $S_{cv}O_2$ and L/P ratio between groups after 20 min of CPR.

Conclusion: In this animal model of BLS CPR, HUP as compared to SUP did not improve cerebral oxygenation or metabolism.

Introduction

Inadequate brain perfusion during resuscitation is a major reason for the poor neurological outcome of cardiac arrest patients. Even though many patients suffering an out-of-hospital cardiac arrest can be successfully resuscitated, less than 10% of these patients are discharged from the hospital and even fewer survive with favourable neurological outcome [1]. Hypoxic brain injury after cardiac arrest results from a sequence of adverse events such as cerebral hypoperfusion and ischemia, increased intracranial pressure, metabolic derangements and ischemia/reperfusion injury that eventually cause neuronal death with catastrophic patient consequences [2]. In view of the fact that "brain resuscitation" seems to be the key issue during cardiopulmonary resuscitation (CPR) several recent studies have focused on alternative body positions during CPR in order to optimise cerebral blood flow and haemodynamics. Debaty et al. demonstrated that a reverse-Trendelenburg position (30° feet down and head up) as compared to a standard supine position lowers intracranial pressure (ICP), improves cerebral perfusion pressure (CPP) and increases cerebral blood flow measured with microspheres [3]. Improved cerebral venous drainage and thus reduced resistance to forward cerebral blood flow were suggested as the underlying cause for the higher CPP in animals tilted upwards [3–5].

☆ A Spanish translated version of the abstract of this article appears as Appendix in the final online version at https://doi.org/10.1016/j.resuscitation.2018.04.038.

* Corresponding author.
E-mail address: judith.martini@i-med.ac.at (J. Martini).

https://doi.org/10.1016/j.resuscitation.2018.04.038
Received 13 January 2018; Received in revised form 25 April 2018; Accepted 30 April 2018

Further studies showed that elevating only the head and the shoulders was equally sufficient to improve CPP as compared to the supine position. It was proposed that a 30° head-up tilt may be the best body position during CPR to maximize both coronary and cerebral perfusion pressure [4,5]. However, the direct effects of this increase in CPP on brain oxygenation and metabolism have not been studied so far.

We therefore investigated the effects of a head-up (HUP) as compared to a supine position (SUP) on brain oxygenation and metabolism parameters during CPR using a multimodal neuromonitoring pig model that was previously published by our group [6]. Based on published data [3–5,7], we hypothesised that HUP CPR may improve cerebral oxygen delivery and thus cerebral metabolism. In contrast to previous HUP CPR studies, we waived the use of an impedance threshold device (ITD) because we aimed to study the true effect of head elevation during basic life support (BLS) CPR on cerebral oxygenation and metabolism. Head elevation is easy to perform, would require only minimal training and could therefore easily be implemented in standard BLS algorithms. This is an important aspect as optimised BLS interventions were shown to improve the rate of survival [8,9] and this simple but promising manoeuvre could further improve patient outcome after cardiac arrest.

Materials and methods

This experimental animal study was approved by the Institutional Animal Care and Use Committee of the University of Innsbruck and the Austrian Ministry of Science, Research and Economy (Protocol number: BMWFW-66.011/0045-WF/V/3b/2016). The study was conducted at the experimental research unit of the Department of Anaesthesiology and Intensive Care Medicine of the Medical University of Innsbruck between November 2016 and April 2017. Experiments were done in compliance with EU regulations for animal experimentation (Directive 2010/63/EU of the European Parliament and the European Council) and reporting is in accordance with current ARRIVE guidelines.

Animal preparation

This study was performed in 20 healthy, 12- to 16-week-old domestic pigs, weighing 31–45 kg each. Animals were fasted overnight, but had free access to water. The pigs were premedicated with azaperone (4 mg/kg IM; Jansen, Vienna, Austria) and atropine (0.01 mg/kg IM) one hour before transport to the study site. Anaesthesia was induced with a single bolus dose of ketamine (30 mg/kg IM) and propofol (1 mg/kg IV) given via an ear vein. The animals were placed in supine position, and their trachea was intubated with a 7.0 mm internal diameter tracheal tube (Rüsch, Kernen, Germany) during spontaneous ventilation. After intubation, pigs were ventilated volume-controlled (Julian, Draeger, Lübeck, Germany) with 21% inspiratory oxygen and a tidal volume of 10 ml/kg body weight. Ventilations were adjusted to maintain normocapnia (35–45 mmHg). Anaesthesia was maintained with propofol (6–8 mg/kg/h IV) and remifentanil (0.2–0.3 µg/kg/min IV). This anaesthetic regimen has been proven to guarantee an appropriate depth of anaesthesia without causing hemodynamic perturbations that may influence experimental outcomes [6]. Normovolaemia was maintained by administering Elo-Mel isoton (10 ml/kg/h IV; Fresenius Kabi Austria, Graz, Austria). A standard lead II electrocardiogram (ECG) was used to monitor cardiac rhythm and a pulsoximeter was placed on the tail. A 7.0 Fr saline-filled pulmonary artery catheter (Edwards Lifesciences, Irvine, CA, USA) was placed in the pulmonary artery via an 8.5 Fr internal jugular vein catheter (Arrow, Reading, US-PA). A 6.0 Fr saline-filled arterial catheter (Arrow, Reading, PA, USA) was placed in the right femoral artery and advanced into the lower abdominal aorta. An angiographic catheter (MP A2, Cordis Cooperation, Miami Lakes, FL, USA) was advanced into the transverse sinus via the left femoral vein under radiological guidance to collect cerebral venous blood samples. A NIRS optode (INVOS™ System, Somanetics Inc., Troy, MI, USA) was fixed on the right forehead. In the corresponding region of the left hemisphere an intracranial pressure probe (Neurovent-P, Raumedic AG, Helmbrechts, Germany), a brain tissue oxygen catheter (LICOX, Sanova Pharma GmbH, Vienna, Austria) and a cerebral microdialysis catheter (CMA-71, M Dialysis, Stockholm, Sweden) were inserted into the white matter through a burr hole by a neurosurgeon. Isotonic perfusion fluid (Perfusion Fluid CNS, M Dialysis, Stockholm, Sweden) was pumped through the microdialysis system at a flow rate of 2.0 µl/min and samples were analysed with Iscusflex device (M Dialysis, Stockholm, Sweden) for cerebral lactate, cerebral pyruvate, cerebral glucose, and cerebral glutamate concentrations. Intravascular catheters were attached to pressure transducers (Xtrans, Codan, Forstinning, Germany) and calibrated at the level of the right atrium. Haemodynamic and respiratory variables were measured and analyzed using an AS/3 Monitor (Datex-Ohmeda AS/3, GE Healthcare, Buckinghamshire, Great Britain). Blood gases were analyzed with a blood gas analyzer (RAPIDPoint500, Siemens, Erlangen, Germany).

Study protocol

After a period of stabilisation following instrumentation baseline values for haemodynamic, cerebral oxygenation and cerebral metabolism parameters were obtained and blood samples taken. Thereafter, ventricular fibrillation (VF) was induced by applying a 50-Hz, 60 V alternating current via two subcutaneous needle electrodes. Ventilation and intravenous anaesthesia were discontinued at this point. After 8 min of untreated CA external mechanical chest compression (LUCAS2™, Physio Control, Redmond, WA, USA) with a compression depth of 52 mm, a compression rate of 102 min^{-1} and a duty cycle of 50% was started. Asynchronized mechanical ventilation was resumed with 100% inspiratory oxygen at 10 ventilations min^{-1} and a tidal volume of 10 ml/kg body weight. With start of CPR pigs were randomized to the HUP (elevating the head and the shoulders by 30°; the head was elevated approximately 15 cm and the shoulders 5 cm) or the SUP position. CPR was continued for 20 min without administering any medication. After completion of the experiment protocol, the animals were euthanized.

Measurement parameters

Mean arterial pressure (MAP), ICP, rSO_2 and $P_{bt}O_2$ were recorded at baseline, after 8 min of CA and after 5, 10, 15 and 20 min of CPR. CPP was calculated as the difference between MAP and ICP. Arterial and cerebral venous blood gases were obtained at baseline, 8 min after cardiac arrest (CA) and after 20 min of CPR. Cerebral microdialysis samples were taken at baseline and at the end of the protocol.

Statistical analysis

Based on a previous study [4], we expected a difference of 11 mmHg in mean CPP between HUP and SUP after 22 min of BLS CPR. Assuming an alpha level of 0.05 and a power of 95%, we calculated a sample size of seven per group. To account for possible dropouts ten animals per group were included. All statistical analyses were preformed using SPSS Version 24 (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.). All parameters are presented as mean ± standard deviation (SD) or standard error of the mean (SEM), respectively. Intragroup differences were assessed using Wilcoxon tests, while intergroup comparisons were performed using Mann Whitney U tests. p-values < 0.05 were considered statistically significant.

Results

The protocol was completed in 19 animals (HUP n = 10; SUP n = 9). One pig had to be excluded from the analysis due to protocol