Feasibility of profound hypothermia as part of extracorporeal life support in a pig model

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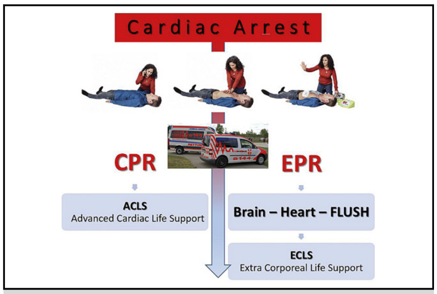
ABSTRACT

Objective: To investigate the feasibility of a refined aortic flush catheter and pump system to induce emergency preservation and resuscitation before extracorporeal cardiopulmonary resuscitation in a normovolemic cardiac arrest swine model simulating near real size/weight conditions of adults.

Methods: In this feasibility study, 8 female Large White breed pigs weighing 70 to 80 kg underwent ventricular fibrillation cardiac arrest for 15 minutes, followed by 4°C aortic flush (150 mL/kg for the brain; 50 mL/kg for the spine) via a new hardware ensued by resuscitation with extracorporeal cardiopulmonary resuscitation.

Results: Brain temperature was lowered from 39.9°C (interquartile range [IQR] 39.6-40.3) to 24.0°C (IQR 20.8-28.9) in 12 minutes (IQR 11-16) with a median cooling rate of 1.3°C (IQR 0.7-1.6) per minute. A median of 776 mL (IQR 673-840) per minute with a median pump pressure of 1487 mm Hg (IQR 1324-1545) were pumped to the brain.

Conclusions: With the new hardware, we were able to cool the brain within a few minutes in a large pig cardiac arrest model. The exact position; the design, diameter, and length of the flush catheter; and the brain perfusion pressure seem to be critical to effectively reduce brain temperature. Redistribution of peripheral blood could lead to sterile inflammation again and might be avoided. (J Thorac Cardiovasc Surg 2017;■:1-8)



Future chain of survival with emergency preservation and resuscitation (*EPR*).

Central Message

One step further toward emergency preservation and resuscitation with a refined aortic flush catheter and pump system showing that it is still worthwhile to go the long pathway to daily clinical use.

Perspective

The developed emergency preservation and resuscitation hardware demonstrated its feasibility in near real size/weight conditions of adults. We were able to cool the brain within a few minutes. The information about the exact position, design, diameter, length of the flush catheter, and the brain perfusion pressure gained will serve as a valuable source for refining the flush hardware.

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Although there have been advances in the treatment of patients with cardiac arrest (CA) in the past decades, survival and good neurologic recovery after CA is still a rare event.[1] There is growing evidence that extracorporeal cardiopulmonary resuscitation (ECPR) could be a promising tool for surviving out-of-hospital (OOH) CA if an experienced team is readily available (Figure 1).[2-6] At the moment,

Scanning this QR code will take you to a supplemental video for the article.

Abbreviations and Acronyms

AFBC	=	aortic flush balloon catheter
CA	=	cardiac arrest
ECG	=	electrocardiogram
ECLS	=	extracorporeal life support
ECPR	=	extracorporeal cardiopulmonary resuscitation
EPR	=	Emergency Preservation and Resuscitation
IQR	=	interquartile range
OOHCA	=	out-of-hospital cardiac arrest
PEEP	=	positive end-expiratory pressure
ROSC	=	restoration of spontaneous circulation
VF	=	ventricular fibrillation

only a few patients have the chance to benefit from ECPR.[2,7] The concept of emergency preservation and resuscitation (EPR) aims to increase the number of potential patients benefiting from ECPR.[8-10] In 1990, a study on therapeutic deep hypothermic circulatory arrest showed that 60 to 90 minutes of circulatory arrest can be survived with good neurologic recovery.[11] In 1999, a cold flush applied by a catheter in the aortic arch could successfully resuscitate dogs after exsanguination CA up to a no-flow time of 120 minutes with good neurologic outcome.[12] Between 2006 and 2012 in a series of experiments, EPR and ECPR has shown after ventricular fibrillation (VF) CA up to a no-flow time of 13 minutes to be superior to conventional resuscitation and ECPR alone.[13-17] There is currently a human clinical trial of aortic flush under way (https://clinicaltrials.gov/ct2/show/NCT01042015). Therefore, the necessity existed to further develop the EPR hardware. The aim of this study was to investigate in near real size/weight conditions of adults the feasibility and performance of a newly developed and refined flush hardware (Video 1).

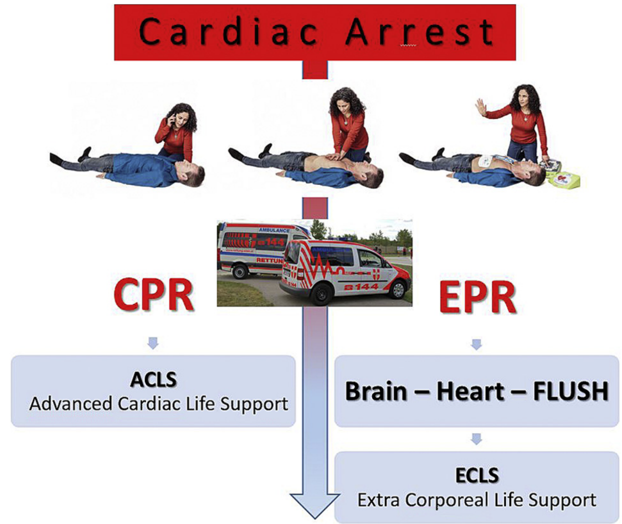

FIGURE 1. Future chain of survival with emergency preservation and resuscitation (*EPR*).

METHODS

The experiments were approved by the animal investigation committee (Ethik-Kommission der Medizinischen Universität Wien zur Beratung und Begutachtung von Forschungsprojekten am Tier; 1488/155-1997/98; 2014/15) and performed by qualified personnel and supervised by veterinarians.[18] In this feasibility trial, 8 female Large White breed pigs weighing 70 to 80 kg were brought to the laboratory stable 7 days before the experiment. After 15 minutes of VFCA, the brain was cooled as low as possible with a flush solution injected via a newly developed flush pump and an aortic flush balloon catheter (AFBC) followed by ECPR. The primary goal of this feasibility study was the achievable brain-cooling rate and attainable minimal brain temperature (not fixing a target temperature), and measurement of flow and pressure regarding to the AFBC and the Flush pump.

Aortic Flush Balloon Catheter

The AFBC (Bavaria Medical Technology, Wessling, Germany) is a 2-balloon 16-F catheter, 90 cm long with 5 separated lumina. Two lumina were used to inflate/deflate the balloons with NaCl 0.9%, the other 3 lumina for applying the flush solution. The main lumen, for the brain flush, ended at the tip of the catheter. The other 2 lumina ended in 6 holes on both sides between the balloons to flush the arteries supplying the spinal cord. To guarantee these 2 separated streams, 2 balloons were necessary: one to occlude the aorta distal to the brain outflow and a second to prevent the flush solution from trickling away into visceral and distal vessels. The first balloon was located near the tip of the catheter with a length of 2 cm and the second balloon within 20 cm distal from the first balloon with a length of 4 cm. The balloons were designed to stabilize the catheter and to fully occlude the aorta during the flush procedure. Preliminary in vitro tests were undertaken to prove the catheters' stability and balloon occlusion with the maximum amounts of flush-fluids (1000 mL/min at the tip [brain] and 500 mL/min at the side holes [spine]) administered.

VIDEO 1. Drs Weiser and Sterz explain the setup to induce profound hypothermia in cardiac arrest as part of extracorporeal life support (ECLS). The aortic catheter is inserted via the femoral artery and advanced into the descending thoracic aorta. The tip lies in the distal arch with a balloon in the proximal descending aorta to isolate the cerebral circulation. There is also a second balloon that sits in the distal descending aorta. Additional infusion ports between the 2 balloons rapidly infuse cold saline to cool the spinal cord. After completion of the predetermined cerebral and spinal flush infusion, the balloons were deflated, the catheter was removed, and ECLS was initiated. Video available at: http://www.jtcvs.org.