Feasibility of selective brain cooling during cardiac arrest: a novel nasopharyngeal approach

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Background

In patients with cardiopulmonary arrest (CPA), selective brain cooling may improve neurological outcome, especially if applied prior to or during reperfusion.[1,2] Thus it is important to develop practically feasible, non-invasive cooling methods for out-of-hospital use.

Objectives

1. To describe the effect of a novel nasopharyngeal cooling method on temperature change in the frontal lobe of the brain during cardiopulmonary resuscitation (CPR).

2. To describe the effect on the same variable during normal circulation and untreated CPA.

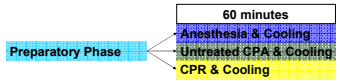
3. To examine the effect of the cooling device on aortic and rectal temperatures.

Materials and methods

Ten domestic swine (40±4.4 kg) were anesthetized, intubated and routine respiratory and cardiovascular parameters were monitored and recorded. Thermocouples were placed in the frontal lobe of the brain (Licox), in the aorta, and in the rectum and the temperatures were continuously recorded.
After the preparatory phase the cooling device was activated for a duration of 60 minutes. The device consists in two blindly ending plastic tubes that are advanced through the nostrils so that their tip is located in the nasopharynx. A mixture of oxygen (40 L/min) and perfluorocarbon (32 ml/min) is conducted through the tubes and escapes through small dorsolateral openings in the nasopharyngeal area as perfluorocarbon mist (*Figure 1*). Immediate evaporation of the perfluorocarbon leads to cooling of the area.

Figure 1: Photograph demonstrating the perfluoro-carbon-oxygen spray in dorsal and lateral direction from the distal end of the nasopharyngeal paired tubing.

During the 60 minute study period, thermokinetic properties of the device were examined in three groups of animals:
1. during stable anesthesia (n=3)
2. after induction of cardiac arrest, during untreated CPA (n=3)
3. after induction of cardiac arrest, during CPR (n=4) administered with a mechanical chest compression device (LUCAS) started immediately after induction of CPA.



Results

The decrease in brain temperature over time was initially more pronounced during intact circulation as compared to untreated CPA (*Table 1*). The temperature changes were rather homogenous among animals within these two groups (*Figure 2*).

	Duration of cooling (min)							
	5	10	15	20	25	30	45	60
No flow	-0.01	-0.12	-0.31	-0.57	-0.90	-1.28	-2.50	-4.28
CPR	-0.13	-0.65	-0.93	-1.20	-1.56	-1.94	-2.62	-3.4
Normal flow	-1.25	-2.09	-2.66	-2.84	-3.01	-3.41	-3.88	-4.66

Table 1: Decrease in brain temperature (°C) over time during absent (untreated CPA), low (CPR) and normal (anesthesia only) blood flow.

In contrast, the temperature decline among animals undergoing CPR was more heterogeneous, with one subject resembling the group with normal blood flow, two resembling the group with no blood flow, and the remaining animal showing an intermediate cooling rate.

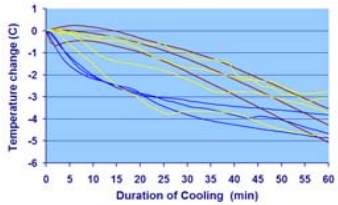


Figure 2: Change in brain temperature during anesthesia (■, n=3), un-treated CPA (■, n=3) and CPR (■, n=4) over time shown for each animal individually.

End-tidal carbon dioxide values ($EtCO_2$), considered a marker for efficacy of chest compressions, varied vastly among the four subjects in the CPR group (*Figure 3*). While the animal with the fastest temperature drop showed the highest $EtCO_2$, this inverse temperature/$EtCO_2$ relationship was not persistently present among the remaining animals.

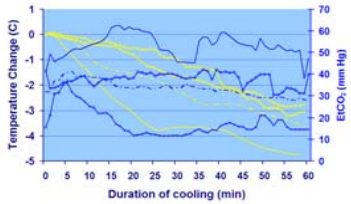


Figure 3: Change in brain temperature (■) and $EtCO_2$ (■) during 60 minutes of CPR (n=4). Each coded line represents one of the four subjects.

Rectal and aortic temperatures changed little during one hour of CPR, while the brain temperature markedly departed from these values early on in two, and later on in all, animals (*Figure 4*).

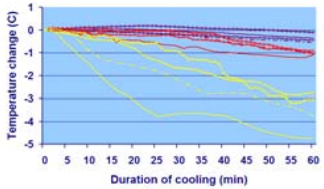


Figure 4: Change in brain (■), aortic (■) and rectal (■) temperatures during 60 minutes of CPR (n=4). Each coded line represents one of the four subjects.

Median decline in brain temperature achieved during CPR was 0.13°C after 5 minutes, 0.93°C after 15 minutes and 3.4°C after 60 minutes of cooling, compared to decreases of only 1.02°C and 0.4°C for the aortic and rectal temperatures, respectively (*Table 2*).

	Duration of cooling (min)							
	5	10	15	20	25	30	45	60
Brain	-0.13	-0.65	-0.93	-1.20	-1.56	-1.94	-2.62	-3.40
Aorta	-0.03	-0.05	-0.14	-0.13	-0.14	-0.24	-0.64	-1.02
Rectum	-0.01	-0.01	-0.02	-0.04	-0.08	-0.12	-0.26	-0.40

Table 2: Decrease in median temperature (°C) over time in different compartments of the body, corresponding to the graph in figure 4.

Discussion and Conclusions

1. In a pig model, preferential cooling of the brain can be achieved with the nasopharyngeal cooling mechanism tested.
2. The rate of cooling in the frontal lobe of the brain varies with the cardiovascular status of the animal, being fastest with normal blood flow, and lowest with absent blood flow.
3. The variability seen in brain temperature decrease during CPR may be due to variations in cerebral blood flow between different animals as a consequence of varying efficacy in CPR. However, cerebral blood flow measurements were not collected in this study.
4. A control group of animals without active nasopharyngeal cooling was not examined, and the influence of passive cooling on the temperature data can thus not be quantified.
5. Based on the blood flow dependency of the brain cooling rates achieved, the assumption can be made, that conduction is the major mechanism of cold distribution during no flow states and that it is hematogenous during normal circulation.
6. Brain temperature was only measured within the frontal lobe of the brain, an area that is, based on anatomic considerations in the pig, distant from the cooling source. Cooling rates in cerebral locations closer to the cooling source may thus be higher, and measurement of spatial temperature distribution within the brain would be important to show these relationships.

Literature cited

1 Abella BS, Zhao D, et al. Intra-arrest cooling improves outcomes in a murine cardiac arrest model. Circulation. 2004;109(22):2786-91.
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Conflicts of interest

Denise Barbut, MD is CEO of BeneChill, Inc.

Acknowledgments

The authors thank Joe Katz and Jill Ralston for technical support with the conduction of the animal experiments and Andrew J Cucchiara for processing the data.

For further information

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