



Experimental paper

The feasibility of inducing mild therapeutic hypothermia after cardiac resuscitation using iced saline infusion via an intraosseous needle^{☆,☆☆}

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ABSTRACT

Objective: This study was done, using a swine model of prolonged ventricular fibrillation out-of-hospital cardiac arrest, to determine the feasibility of inducing therapeutic hypothermia after successful resuscitation by giving an intraosseous infusion of iced saline.

Methods: This study was IACUC approved. Liter bags of normal saline, after being refrigerated for at least 24 h, were placed in an ice filled cooler. Female Yorkshire swine weighing between 27 and 35 kg were sedated and instrumented under general anesthesia. A temperature probe was inserted 10 cm into the esophagus. Ventricular fibrillation was electrically induced and allowed to continue untreated for 10 min. Animals were randomized to one of two resuscitation schemes for the primary study ($N=53$). One group had central intravenous access for drug delivery and the other had an intraosseous needle inserted into the proximal tibia for drug administration. Animals in which spontaneous circulation was restored were immediately cooled, for this secondary study, by means of a rapid, pump-assisted infusion of 1 L of iced saline either through the intraosseous needle ($n=8$), the central access ($n=6$), or a peripheral intravenous catheter ($n=7$) in a systematic, non-randomized fashion. Room, animal, and saline temperatures were recorded at initiation and upon completion of infusion. The data were analyzed descriptively using Stata SE v8.1 for Macintosh.

Results: The baseline characteristics of all three groups were mathematically the same. The average ambient room temperature during the experimental sessions was 25.5°C ($\text{SD}=1.3^{\circ}\text{C}$). There were no statistically significant differences between the three groups with regard to saline temperature, rate of infusion, or decrease in core body temperature. The decrease in core temperature for the intraosseous group was 2.8°C (95% CI = 1.8, 3.8) over the infusion period.

Conclusions: Mild therapeutic hypothermia can be effectively induced in swine after successful resuscitation of prolonged ventricular fibrillation by infusion of iced saline through an IO needle.

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1. Introduction

Mild induced therapeutic hypothermia is currently recommended for survivors of out-of-hospital cardiac arrest who meet specified criteria.^{1,2} It is generally believed that post-resuscitative hypothermia should be induced as early as possible. This notion has led many emergency medical services to initiate this process by a combination of surface cooling and infusion of cold saline

immediately upon return of spontaneous circulation in the pre-hospital setting. The induction of mild therapeutic hypothermia with a rapid infusion of 4°C crystalloid via peripheral intravenous (IV) has recently been shown to effectively lower body temperature in out-of-hospital cardiac arrest survivors prior to hospital arrival without causing any adverse consequences.^{3–5}

Given that timely IV access is not always possible when tending to out-of-hospital cardiac arrest victims, the intraosseous (IO) route of drug administration is now being promoted as a viable first option to facilitate resuscitation.⁶ The preference for the IO alternative under these circumstances may be justified since failure to obtain peripheral IV access on the first attempt typically occurs in one out of four patients and successful cannulation of a vessel usually requires 4–5 precious minutes.^{7,8}

With the reemphasis on IO placement during out-of-hospital cardiac resuscitation, this study was done to determine if rapid infusion of iced normal saline via IO access is an effective method for inducing therapeutic hypothermia.

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2. Materials and methods

An established swine model of prolonged ventricular fibrillation cardiac arrest was used for this study.^{9,10} The Institutional Animal Care and Utilization Committee reviewed and approved the protocol. Female Yorkshire swine weighing between 27 and 35 kg were sedated with an intramuscular cocktail of telazol, ketamine, and xylazine. While spontaneously breathing, they underwent endotracheal intubation and a size appropriate venous catheter (20-gauge) was placed in an auricular vein and secured in place. They were then further instrumented under general anesthesia (inhaled isoflurane initially followed by IV propofol): an arterial introducer (8.5 Fr) was placed under direct visualization into the right femoral artery and a venous introducer (8.5 Fr) into the right femoral vein. During the preparation phase, the animals were ventilated on room air, using a volume-cycled ventilator. A nasopharyngeal probe (Type T, Copper-Constantan Thermocouple, AD Instruments, Colorado Springs, CO) was inserted through the mouth and advanced 10 cm into the animal's esophagus.

Immediately before induction of ventricular fibrillation, a 2-mg bolus of pancuronium was given. Ventricular fibrillation was induced by delivery of a 3 s, 60 Hz, 100 mA transthoracic alternating current using a PowerStat variable transformer. Ventricular fibrillation was allowed to continue untreated for 10 min. The animals were then block randomized to one of two resuscitation schemes for the primary study ($N=53$). One group (IV group) made use of the central IV access for epinephrine administration and the other (IO group) had a pediatric IO needle inserted into the proximal tibia for epinephrine delivery. Correct placement of the IO needle was confirmed by marrow aspiration upon insertion and direct examination on necropsy. There were no placement failures though one subject required a second insertion because of a technical problem unscrewing the stylet hub. Both groups received epinephrine (0.1 mg/kg) followed by 2.5 min of mechanical chest compressions before the first 120J rescue shock attempt. After successful rescue shock, standardized post-resuscitative care was provided to a 20-min endpoint. Failed rescue shock was followed by continued mechanical chest compressions with positive pressure ventilation in both groups, repeat doses of epinephrine (0.01 mg/kg) every 3 min, and rescue shock every minute as long as a shockable rhythm persisted.

Animals in which spontaneous circulation was restored were entered into this secondary study and immediately cooled by infusion of 1 L of iced normal saline through one of three routes: IO needle ($n=8$), central line ($n=6$), or peripheral IV ($n=7$). The three arms of this study were completed sequentially (IO, central, then peripheral) in a systematic non-randomized fashion. A sample of



Fig. 1. The Zoll Medical Corporation's Power Infuser® fluid resuscitation pump used to standardize the infusion of iced saline across the groups.

animals that were not actively cooled because they failed to achieve return of spontaneous circulation was also included for comparison as the control group. Data from these animals were gathered during continued resuscitation efforts. The control group was composed of a convenience sample of animals that did not achieve return of spontaneous circulation, enrolled either before or after a treatment group animal, so that we had laboratory conditions similar to those present for the treatment group animals.

The 1-L bags of normal saline used for the study were stored in a 1.8 cu. ft. commercial grade refrigerator (Danby model DAR192w; Guelph, Ontario) on the maximum cold setting [mean temperature of 0.14 °C (SD = 1.98 °C, range: 6.67 °C)] for at least 24 h and then placed into a cooler with ice on the day of the experiment. Upon return of spontaneous circulation, the room, animal, and saline temperatures were recorded at the initiation of iced normal saline infusion. The infusions were standardized by use of Zoll Medical Corporation's Power Infuser® fluid resuscitation pump (Fig. 1). All infusions were delivered through the same IV tubing attached directly to the 15-gauge IO needle, the femoral introducer, or the peripheral 20-gauge IV catheter.

Table 1
Baseline characteristics.

	IO needle ($n=8$)	Central access ($n=6$)	Peripheral IV ($n=7$)	Control ($n=7$)
Weight (kg)	32.9 (30.5, 35.3)	29.8 (27.5, 32.2)	32.9 (30.0, 35.7)	31.9 (29.6, 34.1)
Anesthesia time (min)	27 (22, 32)	26 (21, 31)	21 (18, 24)	26 (20, 32)
End tidal carbon dioxide (mmHg)	41 (40, 42)	40 (39, 41)	41 (40, 43)	42 (41, 42)
Temperature (°C)	38.0 (37.4, 38.6)	37.8 (37.1, 38.5)	37.8 (37.0, 38.6)	37.8 (36.9, 38.7)
Mean arterial pressure (mmHg)	97 (90, 104)	94 (80, 107)	102 (88, 115)	101 (95, 107)
Heart rate (bpm)	129 (112, 146)	109 (85, 133)	125 (106, 145)	113 (94, 131)
Blood glucose (mg/dL)	96 (68, 124)	86 (57, 116)	68 (60, 75)	84 (55, 113)
Sodium (mequiv/L)	140 (139, 142)	139 (136, 142)	139 (137, 141)	140 (137, 142)
Potassium (mequiv/L)	4.0 (3.8, 4.2)	3.9 (3.7, 4.2)	4.2 (4.0, 4.4)	4.1 (4.0, 4.2)
Ionized calcium (mmol/L)	1.37 (1.31, 1.43)	1.43 (1.41, 1.46)	1.37 (1.30, 1.44)	1.42 (1.37, 1.47)
Hematocrit (%)	29.0 (24.2, 33.8)	27.8 (26.3, 29.4)	26.7 (25.4, 28.0)	26.6 (23.9, 29.3)
pH (units)	7.50 (7.47, 7.54)	7.49 (7.46, 7.53)	7.50 (7.46, 7.54)	7.49 (7.46, 7.53)
Partial pressure of carbon dioxide (mmHg)	39 (37, 40)	38 (36, 40)	38 (34, 41)	38 (36, 41)
Partial pressure of oxygen (mmHg)	87 (75, 99)	99 (91, 106)	91 (82, 100)	91 (80, 101)
Chest compression pressure (mmHg)	48 (45, 51)	63 (40, 87)	59 (55, 63)	54 (44, 65)
Coronary perfusion pressure (mmHg)	66 (54, 79)	53 (33, 73)	54 (35, 72)	29 (11, 47)

All values are group means (95% confidence intervals).

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