Title: COLD WATER DROWNING AND RESUSCITATION IN DOGS

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Introduction. In the U.S.A. about 7,000 people drown each year. Cardiac arrest (1) and lung lesions (2) are reversible. Only anecdotal information exists on the combination of obstructive asphyxia, hypothermia, water inhalation and cardiac arrest. Ice water submersion of up to 40 min can be followed by recovery (3). The objectives of this study are: (a) To observe the pattern of dying in ice water with or without aspiration. (b) To determine whether "miraculous" recoveries can be explained by a diving reflex (4) or protective hypothermia (5) reached before cardiac arrest. (c) To examine cardiac resuscitability. (d) To examine surface rewarming during CPR prior to restoration of spontaneous circulation (ROSC).

Methods. 20 dogs were lightly anesthetized with halothane/$N_2O$-$O_2$ and breathing spontaneously via tracheal tube. Monitored were EKG; EEG; mean arterial pressure (MAP); arterial $PO_2$, $PCO_2$, pH, and BE (measured at 37.0°C); hct; and epidural, rectal and cardiac (thoracic vena cava) T. After 100% $O_2$ for 1 min and then air for 5 min the tracheal tube was clamped at FRC ("laryngospasm") and simultaneously the dog was completely submerged in a 0°C fresh water bath. In Study A (10 dogs) at 3 min the tracheal tube was unclamped and water allowed to flood the lungs. Cardiac arrest occured. ROSC attempts were started at 30 min (pilot studies). In Study B (10 dogs) the tracheal tube remained clamped (no flooding) and resuscitation was started at 40 min. First standard external CPR (SECPR) for 30 min at room temp (Group I, n3, controls); or with surface and inhalation warming (Group II, n7). Then ROSC attempts using the same protocol in both groups: SECPR<30 min, epinephrine 3x, $NaHCO_3$ titrated, countershocks (CS) 6x, warm IV Ringers, warm peritoneal irrigation; then open-chest CPR (OCCPR)<60 min with direct heart warming. After ROSC, life support for 4h.

Results. Dying pattern. In Study A transient hypertension and tachycardia were followed at 3 min by apnea and EEG silence (MAP normal, $PaO_2$<30 torr, epid T 31°C); then bradycardia, hypotension and cardiac arrest at 6.5±1 min, in VF ($PaO_2$<20, pHa<7.1, rect T 35°, epid T 27°). At 30 min of submersion rect T 30°, epid T 15°). In Study B without flooding, cardiac arrest occurred 2½ min later; at 9±1.4 min (card T 33±1.6° and epid T 29±1°); not with VF but rather with EMD, with EKG complexes continuing throughout 40 min. At 40 min, cardiac and rect T about 31° epid T 16°C. Resuscitation. In Study A, ROSC attempts failed due to pulmonary edema and CPR trauma. In spite of warming during 1h of SECPR, rect T decreased further. Peri-rewarming was marginally effective. In Study B during SECPR in Group I, card T declined further, from 30.6±3.8° to 25.1±0.35° and in warmed Group II from 30.7±1.5° to 27.4 ±1.1°. Epid T increased from a mean of 16° to 24.5±1.9° in Group I, and 26.0±2.5° in warmed Group II. ROSC attempts were successful in Group I in 3/3 at 49 (12-78) min; and in warmed Group II in 3/7 at 5 (2-7) min ($p < 0.05$). 4/7 failures were due to complications. Card T at ROSC for both groups was 28.0±1.2°. 4/6 resuscitated animals were watched for 1h with epid T to 35°. All 4 showed return of EEG activity and began breathing spontaneously.

Conclusions. In ice water submersion--(1) lung flooding accelerates onset of cardiac arrest in VF; (2) without flooding arrest is with EMD; (3) lightly anesthetized dogs show no diving reflex; (4) brain hypothermia before cardiac arrest can explain "miraculous" recoveries; (5) ROSC is possible after 40 min with card T 28°C, even with SECPR, but OCCPR is more often effective; and (6) prolonged SECPR causes a further drop in core temp, which is ameliorated but not prevented by surface and inhalation warming during CPR.

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