Title: CEREBRAL PRESERVATION DURING CARDIOPULMONARY RESUSCITATION II

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Introduction. Standard cardiopulmonary resuscitation (SCPR) often allows restoration of spontaneous circulation (ROSC) but does not reliably preserve the heart or brain during resuscitation. Simultaneous Ventilation Compression CPR (SVC-CPR) was introduced to maximize peak intrathoracic pressure (ITP) for improving blood flow. This technique includes: a) high pressure (70-110 cmH2) ventilation (V) simultaneous with chest compression (C), b) C rate of 40/min, c) C duration equal to 60% of the C/relaxation cycle and d) abdominal binding. In dogs, SVC-CPR can improve cerebral blood flow (CBF) (1), but impact on cerebral recovery is unclear. Although the hemodynamic superiority of Open-Chest CPR (OCCPR) has long been recognized, its advantages for the brain have only recently been investigated. It can sustain EEG activity, provides better CBF (2), and leads to improved cardiac (3) and cerebral recovery in dogs (4). This study compared cardiac and cerebral recovery after 4 min of ventricular fibrillation (VF) and either immediate defibrillation (control); or 30 min of either SCPR, SVC-CPR, or OCCPR.

Methods. Thirty-two dogs weighing 10-15 kg and AP/lateral chest diameter ratio of <1.2 were randomized, assigned to 4 equal groups: (1) Control, (2) SCPR, (3) SVC-CPR and (4) OCCPR. Anesthesia was halothane 0.5-2.0% in N_2O/O_2 50%/50% with pancuronium 0.4 mg/kg prn. Catheters were placed in the femoral artery and vein and right atrium via the external jugular vein for pressure monitoring, blood sampling, and drug and fluid administration. Bifrontal needle electrodes were placed for EEG monitoring. After control measurements of all monitored parameters, VF was induced with 100 VAC transthoracically. Arrest time was 4 min; then CPR was begun. SCPR was 60 C/min with V of 10ml/k after every 5th C. C duration was 50%. SVC-CPR was as above, with the abdomen bound with a thigh BP cuff. Both SCPR and SVC-CPR were done by programmable Michigan Instruments THUMPER with C force optimized to produce a "systolic" arterial pressure (SAP, during compression) > 50 mmHg. OCCPR was internal C with CPPV of 15 ml/kg and PEEP of 5-10 cmH_2O. Resuscitations were attempted using American Heart Association (AHA) Advanced Cardiac Life Support (ACLS) algorithms with canine dosages. If ROSC was impossible, autopsy was performed. Survivors were maintained with up to 10 mcg/kg per min of norepinephrine. If BP could not be kept > 80 mmHg, autopsy was performed. Survivors for 20 hrs were weaned and extubated. Before autopsy, neurological deficit (ND) scores were determined, using a standard scale with ND 0=normal and 100%=brain dead. Animals were then reanesthetized, perfusion fixed and gross autopsies performed. Statistical analysis was performed using repeated measures analysis of variance, Student's t-test, and sampling theory for the binomial theorem with $p<0.05$ considered significant.

Results. Systolic arterial pressure averaged 60±20 mmHg (mean±SD) for SCPR, 65±14 mmHg for SVC-CPR, and 84±27 for mmHg for OCCPR (NS). Diastolic arterial pressure was 14±9 mmHg during SCPR, 18±11 mmHg during SVC-CPR, but was 52±17 mmHg during OCCPR ($p<0.001$ compared to SCPR and SVC-CPR). Mean arterial pressure (MAP) was 32±13 mmHg during SCPR, 42±13 mmHg during SVC-CPR and 61±19 mmHg during OCCPR ($p<0.01$ compared to SCPR). Mean central venous pressure (MCVP) was 44±16 mmHg during SCPR, 45±13 mmHg during SVC-CPR, but was 9±2 mmHg during OCCPR ($p<0.001$ compared to SCPR and SVC-CPR). Intrathoracic perfusion pressure (MAP-MCVP) was much higher during OCCPR: 52±19 mmHg versus -12±13 mmHg for SCPR ($p<0.001$) and -3±24 mmHg for SVC-CPR ($p<0.001$). All of the control group was resuscitated, but no ROSC was accomplished by the first two countershocks in the AHA algorithm. All animals in the SCPR and SVC-CPR groups required massive doses of epinephrine, bicarbonate, and multiple countershocks. Despite 30 minutes of resuscitative efforts, ROSC was possible in only 6 of 8 SCPR dogs and 5 of 8 SVC-CPR dogs. All OCCPR animals were resuscitated with a single 10J internal countershock. All control group animals survived 24 hrs and neurological deficit score (NDS) was 9±4%. Only one SCPR animal survived 24 hrs with NDS of the lone survivor of 14%, SCPR group NDS was 89±30%. No SVC-CPR animal survived 24 hrs; all were brain dead after ROSC. In the OCCPR group, 7 of 8 animals survived 24hrs (NS compared to control, $p<0.001$ compared to SCPR and SVC-CPR). Survivors had a NDS of 15±11% (NS compared to control, $p<0.001$ compared to SCPR and SVC-CPR).

Conclusions. This study demonstrates the ability of OCCPR to preserve the brain during 30 min CPR. SCPR produced only one survivor, and SVC-CPR failed completely to preserve brain or heart. SVC-CPR in this preparation offered no advantage over SCPR with respect to improving cerebral outcome. OCCPR should be used more often when SCPR fails to produce a pulse or when advanced life support fails to promptly produce ROSC.

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