TITLE: **DIFFERENCES BETWEEN ARTERIAL & CENTRAL VENOUS BLOOD GASES DURING CLOSED & OPEN CHEST CARDIOPULMONARY RESUSCITATION**

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Introduction Studies with closed chest cardiopulmonary resuscitation (CPR) in human patients have shown that there are marked discrepancies between the acid-base status of arterial and venous blood.[1,2] In this investigation we utilized an animal CPR model to compare arterial and venous blood gases during both open and closed chest CPR.

Methods Seven mongrel dogs (16.6 to 20.5 kg) were anesthetized with morphine, intubated with succinylcholine and maintained with halothane general anesthesia. A blood sampling catheter was passed through the carotid artery to the proximal aorta and a pulmonary flotation catheter was passed through the right heart via the jugular vein. Venous gas was withdrawn from the CVP port of the pulmonary artery catheter. Cardiac arrest was produced by a bolus injection of potassium chloride. A Michigan Instruments mechanical chest compressor (Thumper®) was set for a compression of 80 beats/minute and a compression force sufficient to produce 2½ cm of chest wall deflection. The ventilator of the Thumper® was utilized during closed chest CPR. Approximately every 16 minutes arterial and venous blood gases were sampled simultaneously. Closed chest compression was continued for an hour to an hour and a half so as to obtain nearly steady values for the pH and pCO_2 values. A left thoracotomy was then performed and open chest cardiac massage was continued for 30 to 40 minutes. Simultaneous arterial and venous blood samples were then obtained at time intervals of between 6 and 8 minutes. Blood samples were analyzed on a Radiometer ABL 1 blood gas analyzer. Recorded variables of interest were: pH, pCO_2, pO_2 and the standard base excess (SBE). Nearly steady values of the measurements were obtained after approximately 1 hour of closed chest massage and 15 to 20 minutes of open chest resuscitation. These quasi-steady values were selected for each combination of sample site and CPR condition - 4 samples from each animal. These 4 treatment groups were analyzed with a One Way ANOVA treating the individual dogs as different blocks. Differences between the means for each of the four conditions were assessed by means of Tukey's studentized range.

Results & Discussion Table I shows the results for all four variables. There is a much larger difference between the venous and arterial pH values with the closed chest compressions than with the chest open. Baseline values of pH for these animals were within the range 7.3 to 7.5.

Baseline pCO_2 values were typically between 25 and 40 torr with the arterial pCO_2 being slightly lower than the venous. During closed chest CPR there was a dramatic drop in pCO_2 on the arterial side and a dramatic rise on the venous side. With initiation of direct cardiac massage there was a dramatic rise and a slight overshoot in both the arterial and the venous pCO_2. When steady conditions were again developed, with open chest massage, the venous pCO_2 returned to nearly the same value as with closed chest CPR. In contrast, there was a significant, steady elevation in the arterial pCO_2 when comparing open and closed chest resuscitation. As expected, pO_2 differences were noted between the two sampling sites and the two resuscitation techniques. The standard base excess (SBE) values calculated by the Radiometer analyzer, are also shown in Table I.

The primary explanation for these observations is the difference in effective cardiac output produced by closed chest vs open chest CPR. With closed chest CPR, the minimal circulation results in very small CO_2 transport to the lungs, continuing mechanical ventilation is sufficient to reduce alveolar and hence arterial $paCO_2$ to very low values. The large negative values of the base excess indicate that metabolic acidosis is a prominent feature while there is a very effective respiratory compensation of this acidosis on the arterial side. With open chest cardiac massage, cardiac output is markedly increased, the amount of CO_2 transported to the lungs is much larger so that alveolar and hence arterial CO_2 are much higher. The venous pCO_2 transiently rises during the initial interval of open chest massage. The increased blood flow is able to remove some of the accumulated CO_2 that was stored in the animal's tissues during closed chest massage.

In general, our results for pH and pCO_2 agree with those of Weil, Rackow, et al.[1] They concluded that "arterial blood gases may fail as appropriate guides for acid base management in the emergency". They reported no change in arterial or venous bicarbonate during CPR, we found marked increases in SBE, with both arterial and venous blood samples. On the basis of our work we recommend that SBE should be the guiding parameter if arterial blood gases are measured during CPR.

Conclusions Arterial pH and pCO_2 values can seriously differ from venous values during closed chest resuscitation. The standard base excess in arterial blood appears to more accurately reflect the metabolic acidosis that is produced in the low flow state of CPR.

With the increase in perfusion that occurs with open chest CPR or return of spontaneous circulation there is an initial transient fall in arterial pH and a rise in arterial pCO_2.

References

1. Weil MH, Rackow EC, Trevino R, grundler W, et al: Difference in acid-base state between venous and arterial blood during cardiopulmonary resuscitation. N Engl J Med 315:153-6, 1986.
2. McGill JW: Central venous pH as a predictor of arterial pH in prolonged cardiac arrest. Ann Emerg Med 13:684-687, 1984.

TABLE I
Blood Gas Variations During Closed & Open Chest CPR

Blood Gas Variable	Sampling Site/Resuscitation Technique: Carotid/Closed	Venous/Closed	Carotid/Open	Venous/Open
pH	7.240** ±0.080	6.959 ±0.096	6.861 ±0.090	6.757 ±0.102
	Tukey's Studentized Range = 0.093			
pCO_2	7.16 ±1.33	57.43 ±9.67	37.86 ±18.04	79.14 ±15.10
	Tukey's Studentized Range = 16.84			
pO_2	359.9 ±112.8	31.13* ± 2.60	157.46 ±130.16	39.27* ±14.08
	Tukey's Studentized Range = 116.5			
SBE	-22.23+ ± 1.92	-18.04 ± 2.62	-25.2x ± 3.01	-22.9+x ± 3.39
	Tukey's Studentized Range = 2.32			

** Mean ± SD
*,+,x No significant difference between mean values marked with same symbols.

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