WORKSHEET for Evidence-Based Review of Science for Veterinary CPCR

1. Basic Demographics

Worksheet author(s)

Raegan J Wells	**Date Submitted for review:** 4/9/2011

[redacted]

2. Clinical question:

14B:"In dogs and cats with cardiac arrest (P), does the measurement of arterial or venous electrolytes (Na, K, Ca) during resuscitation (I) vs not measuring electrolytes (C) improve the chances of ROSC (O)?

3. Conflict of interest specific to this question:

Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet?
None

4. Search strategy (including electronic databases searched):

4a. Databases

MEDLINE via PUBMED (Limit: Animals)

Question 14B:

1. (("cardiopulmonary resuscitation"[MeSH Terms] OR ("cardiopulmonary"[All Fields] AND "resuscitation"[All Fields]) OR "cardiopulmonary resuscitation"[All Fields]) AND ("arteries"[MeSH Terms] OR "arteries"[All Fields] OR "arterial"[All Fields]) AND ("electrolytes"[MeSH Terms] OR "electrolytes"[All Fields]) AND dog[All Fields]) AND "animals"[MeSH Terms:noexp]
2. (("cardiopulmonary resuscitation"[MeSH Terms] OR ("cardiopulmonary"[All Fields] AND "resuscitation"[All Fields]) OR "cardiopulmonary resuscitation"[All Fields]) AND ("arteries"[MeSH Terms] OR "arteries"[All Fields] OR "arterial"[All Fields]) AND ("electrolytes"[MeSH Terms] OR "electrolytes"[All Fields]) AND ROSC[All Fields]) AND "animals"[MeSH Terms:noexp]
3. (("cardiopulmonary resuscitation"[MeSH Terms] OR ("cardiopulmonary"[All Fields] AND "resuscitation"[All Fields]) OR "cardiopulmonary resuscitation"[All Fields]) AND ("arteries"[MeSH Terms] OR "arteries"[All Fields] OR "arterial"[All Fields]) AND ("sodium, dietary"[MeSH Terms] OR ("sodium"[All Fields] AND "dietary"[All Fields]) OR "dietary sodium"[All Fields] OR "sodium"[All Fields] OR "sodium"[MeSH Terms]) AND dog[All Fields]) AND "animals"[MeSH Terms:noexp]
4. (("cardiopulmonary resuscitation"[MeSH Terms] OR ("cardiopulmonary"[All Fields] AND "resuscitation"[All Fields]) OR "cardiopulmonary resuscitation"[All Fields]) AND ("arteries"[MeSH

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5. (("cardiopulmonary resuscitation"[MeSH Terms] OR ("cardiopulmonary"[All Fields] AND "resuscitation"[All Fields]) OR "cardiopulmonary resuscitation"[All Fields]) AND ("arteries"[MeSH Terms] OR "arteries"[All Fields] OR "arterial"[All Fields]) AND chloride[All Fields] AND dog[All Fields]) AND "animals"[MeSH Terms:noexp]
6. (("cardiopulmonary resuscitation"[MeSH Terms] OR ("cardiopulmonary"[All Fields] AND "resuscitation"[All Fields]) OR "cardiopulmonary resuscitation"[All Fields]) AND ("arteries"[MeSH Terms] OR "arteries"[All Fields] OR "arterial"[All Fields]) AND chloride[All Fields] AND ROSC[All Fields]) AND "animals"[MeSH Terms:noexp]
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9. (("cardiopulmonary resuscitation"[MeSH Terms] OR ("cardiopulmonary"[All Fields] AND "resuscitation"[All Fields]) OR "cardiopulmonary resuscitation"[All Fields]) AND ("veins"[MeSH Terms] OR "veins"[All Fields] OR "venous"[All Fields]) AND ("electrolytes"[MeSH Terms] OR "electrolytes"[All Fields])) AND "animals"[MeSH Terms:noexp]
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11. (("cardiopulmonary resuscitation"[MeSH Terms] OR ("cardiopulmonary"[All Fields] AND "resuscitation"[All Fields]) OR "cardiopulmonary resuscitation"[All Fields]) AND ("veins"[MeSH Terms] OR "veins"[All Fields] OR "venous"[All Fields]) AND chloride[All Fields]) AND "animals"[MeSH Terms:noexp]
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13. (("cardiopulmonary resuscitation"[MeSH Terms] OR ("cardiopulmonary"[All Fields] AND "resuscitation"[All Fields]) OR "cardiopulmonary resuscitation"[All Fields]) AND ("veins"[MeSH Terms] OR "veins"[All Fields] OR "venous"[All Fields]) AND ("calcium"[MeSH Terms] OR "calcium"[All Fields])) AND "animals"[MeSH Terms:noexp]
14. (("cardiopulmonary resuscitation"[MeSH Terms] OR ("cardiopulmonary"[All Fields] AND "resuscitation"[All Fields]) OR "cardiopulmonary resuscitation"[All Fields]) AND ("veins"[MeSH Terms]

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OR "veins"[All Fields] OR "venous"[All Fields]) AND ("magnesium"[MeSH Terms] OR "magnesium"[All Fields])) AND "animals"[MeSH Terms:noexp]

15. (("cardiopulmonary resuscitation"[MeSH Terms] OR ("cardiopulmonary"[All Fields] AND "resuscitation"[All Fields]) OR "cardiopulmonary resuscitation"[All Fields]) AND ("arteries"[MeSH Terms] OR "arteries"[All Fields] OR "arterial"[All Fields]) AND ("magnesium"[MeSH Terms] OR "magnesium"[All Fields])) AND "animals"[MeSH Terms:noexp]

4b. Other sources

-GOOGLE SCHOLAR

Question 14B:

1. cardiopulmonary resuscitation dogs arterial electrolytes
2. cardiopulmonary resuscitation cats arterial electrolytes
3. cardiopulmonary resuscitation dogs arterial electrolytes ROSC
4. cardiopulmonary resuscitation cats arterial electrolytes ROSC
5. cardiopulmonary resuscitation dogs arterial sodium ROSC
6. cardiopulmonary resuscitation cats arterial sodium ROSC
7. cardiopulmonary resuscitation dogs arterial chloride ROSC
8. cardiopulmonary resuscitation cats arterial chloride ROSC
9. cardiopulmonary resuscitation dogs arterial calcium ROSC
10. cardiopulmonary resuscitation cats arterial calcium ROSC
11. cardiopulmonary resuscitation dogs arterial magnesium ROSC
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21. cardiopulmonary resuscitation dogs venous potassium ROSC
22. cardiopulmonary resuscitation cats venous potassium ROSC
23. cardiopulmonary resuscitation dogs venous calcium ROSC
24. cardiopulmonary resuscitation cats venous calcium ROSC
25. cardiopulmonary resuscitation dogs venous magnesium ROSC
26. cardiopulmonary resuscitation cats venous magnesium ROSC

Last search 5/27/2011

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4c. State inclusion and exclusion criteria for choosing studies and list number of studies excluded per criterion

Inclusion criteria
All animals with cardiac arrest.

Exclusion criteria
Human studies.
Pig studies.
No measurement of electrolytes (14B)
Review papers
Opinion papers
Textbook chapters or proceedings

4d. Number of articles/sources meeting criteria for further review:

7 articles met criteria for further review

5. Summary of evidence

Evidence Supporting Clinical Question

Good						
Fair			*Engoren, 2002 (A)* Nieman, 1999 (A)		*Lin, 1994 (A, B, D)*	
Poor					*Mair, 1994 (A, B, C, D)*	
	1	**2**	**3**	**4**	**5**	**6**
Level of evidence (P)						

A = Return of spontaneous circulation C = Survival to hospital discharge E = Other endpoint
B = Survival of event D = Intact neurological survival *Italics = Non-target species studies*

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Evidence Neutral to Clinical question

Good						
Fair			Cairns, 1991 (E)			
Poor						
	1	**2**	**3**	**4**	**5**	**6**
Level of evidence (P)						

A = Return of spontaneous circulation C = Survival to hospital discharge E = Other endpoint
B = Survival of event D = Intact neurological survival *Italics = Non-target species studies*

Evidence Opposing Clinical Question

Good			Best, 1984 (A)			
Fair				Bender, 1995 (A)		
Poor						
	1	**2**	**3**	**4**	**5**	**6**
Level of evidence (P)						

A = Return of spontaneous circulation C = Survival to hospital discharge E = Other endpoint
B = Survival of event D = Intact neurological survival *Italics = Non-target species studies*

6. REVIEWER'S FINAL COMMENTS AND ASSESSMENT OF BENEFIT / RISK:

Previous human CPCR guidelines have suggested the administration of calcium during CPCR. Recent AHA CPCR guidelines no longer support this intervention. Variability in recommendations for electrolyte monitoring practices during canine and feline CPCR exists. Prior to this initiative, a consensus on whether or not monitoring electrolytes in veterinary CPCR patients has not been established.

Cairns et al confirmed that ionized hypocalcemia occurs during prolonged cardiac arrest and resuscitation in dogs, however conclusions regarding the effect on outcome cannot be made based on this study, as this was a terminal study (Cairns 1991). An investigation on ionized calcium during CPCR in the canine model found opposing results, in that ionized hypocalcemia was not identified in 15 dogs with cardiac arrest and CPCR (Best 1985). A 1999 prospective laboratory investigation of a canine model of cardiac arrest and resuscitation found that arterial ionized calcium significantly decreased within 5 minutes of starting CPCR and continued to decrease with subsequent measurements in dogs that could not be resuscitated (Neiman 1999). This study also found that arterial serum potassium was significantly increased within 10 minutes of starting CPCR and continued to increase with subsequent measurements in the dogs that could not be resuscitated (Neiman 1999). A group primarily evaluating the differences between open-chest standard and compression-active-decompression CPCR in pigs found that mixed venous hyperkalemia was associated with lower PVO_2 levels and lack of ROSC (Engoren 2002). A small human retrospective evaluating the efficacy of hemodialysis during CPCR for treatment of severe hyperkalemia found that ROSC was achieved in all 3 patients once the mixed venous potassium was decreased below 8.0mmol/L (Lin 1994).

A comprehensive review of literature evaluating arterial or venous electrolyte (Na^+, K^+, Ca^{2+}) values in animal models, retrospective companion animal studies, human retrospective and prospective studies of cardiac arrest and resuscitation suggests that serum potassium values are useful in predicting ROSC. Multiple citations document that marked hyperkalemia (>8.0mmol/L) is associated with poor response to CPR interventions and likely reflects irreversible cellular injury. There is also decent documentation that ionized calcium decreases with prolonged cardiac arrest and unsuccessful efforts to resuscitate both human and animal patients. Similar to blood gas evaluation, central venous electrolyte values are likely to best reflect tissue perfusion. Specific to severe hypothermia associated cardiac arrest, severe hyperkalemia is likely to predict that the patient died prior to cooling of the core temperature, and advanced and prolonged resuscitative efforts are not likely to be fruitful (Mair 1994). The small human retrospective study evaluating hemodialysis as a method to effectively decrease serum potassium provides evidence that in patients who experience cardiac arrest due to hyperkalemia, efforts to decrease the potassium in concert with other CPCR efforts should be extended, as these patients have a better chance at ROSC once the potassium is lowered. If the patient has arrested from another underlying disease, and serum hyperkalemia is noted, it may not be as rewarding to continue CPCR efforts, as the potassium in this case is likely a reflection of severe and irreversible cellular damage.

7. Conclusion

In cases where the cause of cardiac arrest may be due to electrolyte abnormalities (e.g. hyperkalemia), the measurement of serum electrolytes may allow appropriate therapeutics in addition to standard CPR. In other contexts, electrolyte abnormalities may be prognostic for ROSC, although this has not been investigated in clinical veterinary cases. The imperative for therapy of other identified electrolyte abnormalities (e.g.

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hypocalcemia), and the association with ROSC is less clear. The measurement of electrolytes in certain cases may identify abnormalities that, if corrected, may promote ROSC.

8. Acknowledgement

N/A

9. Citation list

Cairns CB, Niemann JT, Pelikan PC, Sharma J.
Ionized hypocalcemia during prolonged cardiac arrest and closed-chest CPR in a canine model.
Ann Emerg Med. 1991 Nov;20(11):1178-82.

STUDY BACKGROUND: Free or ionized calcium (Ca+2) is known to play a critical role in normal cardiovascular function, and Ca+2 administration in the setting of ionized hypocalcemia has been shown to improve indexes of cardiac function. The value of Ca+2 administration in the setting of cardiac arrest and resuscitation is unproven and controversial, in large part because ionized Ca+2 levels during cardiac arrest and resuscitation have not been adequately studied and exogenous calcium therapy may worsen ischemic cellular injury.

STUDY PURPOSE:

To measure free calcium during prolonged cardiac arrest and CPR in a canine model.

METHODS AND MEASUREMENTS:

Central arterial and venous catheters were positioned in nine dogs, and ventricular fibrillation (VF) was induced electrically. After seven and one-half minutes of VF, countershocks were administered, and CPR was initiated and performed in accordance with current recommendations for 20 minutes. At five-minute intervals during resuscitation efforts, arterial pH, ionized Ca+2, and lactate as well as aortic pressure were measured.

RESULTS:

During resuscitation, average systolic arterial pressure was 50 mm Hg. Within five minutes of instituting CPR, ionized Ca+2 significantly decreased from control values (5.1 +/- 0.1 at control to 4.0 +/- 0.1 mg/dL); after 20 minutes of attempted resuscitation, it averaged 3.2 +/- 0.2 mg/dL (P less than .05 vs control). There was no change in total Ca+2 during the arrest period (9.2 +/- 0.5 at control to 8.6 +/- 0.8 mg/dL at 27.5 minutes). Arterial lactate significantly increased throughout the arrest and resuscitation period (1.9 +/- 0.2 at control to 7.5 +/- 0.4 mM/L at 27.5 minutes). A significant correlation was demonstrated between ionized Ca+2 and lactate concentrations (r = -.72, P less than .001) but not between ionized calcium and pH (r = -.22, P greater than .20).

CONCLUSION:

Ionized hypocalcemia occurs during prolonged cardiac arrest and resuscitation, and ionized hypocalcemia during prolonged arrest and resuscitation may be due to binding by lactate, as has been demonstrated in

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vitro.

LOE 3, Fair, neutral

No dogs survived the study. Ionized calcium was measured at multiple time points (before fibrillation and during attempts at resuscitation). The study concluded that ionized calcium significantly decreases during prolonged cardiac arrest. Unable to draw conclusion regarding affect on outcome, as no animals survived the study.

Engoren M, Severyn F, Fenn-Buderer N, DeFrank M. Cardiac output, coronary blood flow, and blood gases during open-chest standard and compression-active-decompression cardiopulmonary resuscitation. Resuscitation. 2002 Dec;55(3):309-16

Objective: To determine whether open-chest compression-active-decompression (CAD) could improve cardiac output, coronary blood flow, blood gases, and resuscitation compared to open-chest manual compression in a porcine model of cardiac arrest. Design: Prospective, randomized laboratory investigation for measurement of cardiac output, coronary blood flow, arterial and mixed venous blood gases and potassium levels, and return of spontaneous circulation. Subjects: Ten pigs each weighing approximately 36.4 kg. Interventions: Following preparation of the model and opening of the chest, ultrasonic flow probes were placed on the ascending aorta and left anterior descending artery. Cardiac arrest was induced by epicardial pacing. Subjects received either open-chest CAD or open-chest manual compression. After 10 min of arrest, defibrillation was attempted. Measurements and main results: Cardiac output fell to 469 53% (95% CI: 20 to 112) and 419 14% (95% CI: 23 59) (P 0.05) of baseline with CAD and manual methods at 5 min after arrest, respectively. Similarly, coronary blood flow fell to 339 14% (95% CI: 16 50) and 429 16% (95% CI: 22 62) (P 0.05) of baseline at 5 min. Both groups developed similar levels of metabolic acidosis, mixed venous hypoxemia, and hyperkalemia, with potassium levels: 6.59 4.0 meq/l (95% CI: 1.6 11.4) at 5 min and 7.59 4.6 meq/l (95% CI: 1.8 13.2) at 10 min in the CAD group and 5.89 2.0 meq/l (95% CI: 3.4 8.3) at 5 min and 6.19 1.4 meq/l (95% CI: 4.4 7.9) at 10 min in the manual group. Levels of hyperkalemia were inversely proportional to the square of PvO2. One pig in each group was resuscitated after defibrillation. Conclusion: We found no benefit using CAD. Both low coronary blood flow and hyperkalemia may have limited resuscitation.

LOE 3, Fair, supporting, non-target species

The purpose of this study was to evaluate the difference between two types of compressions during CPR in a porcine model of cardiac arrest. Only two pigs had ROSC, one in each treatment group. They did find that hyperkalemia was associated with lower PVO2 levels. Considering that PVO2 can be used as a marker of cellular metabolism, they propose that this finding supports the concept that hyperkalemia during cardiac arrest is on some level associated with lack of ROSC.

Lin JL, Lim PS, Leu ML, Huang CC. Outcomes of severe hyperkalemia in cardiopulmonary resuscitation with concomitant hemodialysis. Intensive Care Med. 1994;20(4):287-90. PubMed PMID: 8046123.

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OBJECTIVE: To investigate the efficacy of hemodialysis during cardiopulmonary resuscitation as an effective adjunct to the treatment of severe hyperkalemia.

DESIGN:
A prospective study.

SETTING:
In hospital dialysis units and intensive care units.

PATIENTS:
Renal failure patients who developed hyperkalemia induced cardiac arrest and failed to recover from conventional cardiopulmonary resuscitation (CPR) were included. Three patients entered into this study: 2 patients with chronic renal failure maintained on regular hemodialysis and one with acute renal failure who suffered from severe hyperkalemia.

INTERVENTIONS:
All three patients developed asystolic cardiac arrest with unrecordable blood pressure due to severe hyperkalemia. Aggressive CPR

together with intravenous epinephrine, sodium bicarbonate and calcium chloride were instituted. External cardiac massage with cardiac defibrillation was unable to restore spontaneous heart action. After lack or response to intensive resuscitation, hemodialysis was performed concomitant with CPR to eliminate the potassium load.

MEASUREMENTS AND RESULTS:
Sinus rhythm and blood pressure were restored in all 3 patients but one of them eventually succumbed to her underlying disease.

CONCLUSION:
Hemodialysis during CPR is probably an effective adjunct to the treatment of severe hyperkalemia in patients with severe hemodynamic compromise and asystolic cardiac arrest.

LOE 5, Fair, supporting, non-target species

This study evaluated the use of hemodialysis in order to decrease serum potassium in 3 human patients experiencing cardiopulmonary arrest. All three of these patients were undergoing chronic intermittent hemodialysis for various types of kidney failure. Each patient that experiences cardiopulmonary arrest (3) also had life-threatening hyperkalemia (>8.0mmol/L). Each patient was treated with standard closed chest CPCR and multiple medical protocols to decrease serum potassium, including dextrose/insulin, bicarbonate infusion, epinephrine and also calcium supplementation for cardioprotection. Hemodialysis was intiated on all 3 patients within 35-105 minutes after initiation of the closed-chest CPCR. The review of these records did indicate that the hemodialysis was effective at decreasing the potassium rapidly. All three of the patients experienced ROSC. One patient did not regain normal consciousness or survive to discharge.

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Best R, Martin GB, Carden DL, Tomlanovich MC, Foreback C, Nowak RM. Ionized calcium during CPR in the canine model. Ann Emerg Med. 1985 Jul;14(7):633-5. PubMed PMID: 4014809.

The purpose of our study was to determine ionized calcium levels during cardiopulmonary resuscitation (CPR). Following placement of ascending aortic catheters in 15 adult mongrel dogs, ventricular fibrillation was induced electrically. After five minutes without therapy, mechanical external CPR was instituted. Animals received either standard CPR (S-CPR, n = 8) or simultaneous compression and ventilation CPR (SCV-CPR, n = 7) for 30 minutes. Ionized calcium levels were obtained prior to fibrillation and every five minutes during CPR. Mean ionized calcium levels during CPR (1.27 ± 0.06 mmol/L) did not differ significantly from prearrest levels (1.27 ± 0.07 mmol/L) at any point during CPR. This was true when the dogs were analyzed together (P = 0.1293) and when the animals receiving S-CPR (P = 0.4465) and SCV-CPR (P = 0.5470) were analyzed by groups. Defibrillation was attempted in all animals and resulted in electromechanical dissociation in three. None of these dogs was hypocalcemic either prior to arrest or during CPR, and none developed an effective rhythm with the administration of calcium. Furthermore, three of the four animals receiving calcium developed markedly elevated ionized calcium levels. Hypocalcemia apparently does not occur during CPR. The beneficial effect of calcium in reported cases cannot be explained routinely by correction of hypocalcemia. Further studies are needed to define the role of calcium administration, if any, in CPR.

LOE 3, good, opposing

This study evaluated the results of arterial ionized calcium in dogs before and during cardiopulmonary arrest induced by ventricular fibrillation. Fifteen dogs were included in the study. The interventions included chest compressions and ventilation from an automated device called a Thumper. In one group, standard closed chest CPCR was performed. In the other group, simultaneous ventilation and compression was performed. Both groups were given a constant IV infusion of epinephrine for the duration of CPR. Arterial ionized calcium was measured in dogs before initiation of ventricular fibrillation and circulatory arrest via direct right ventricular electrical stimulation. Arterial ionized calcium was measured every 5 minutes for the duration of CPR. Electrical defibrillation was attempted at the end of 30 minutes of CPR in all dogs. An infusion of calcium was performed if electromechanical dissociation was identified following defibrillation. 11/15 dogs were successfully defibrillated. Three dogs remained in ventricular fibrillation, while one dog experienced persistent EMD. The take home message from this study is that measurement of arterial ionized calcium does not predict outcome before, during or after CPR in the dog. In one case, where the dog was given calcium as part of the protocol for EMD, dangerously high levels of blood calcium developed. There was no significant difference in pre-arrest or intra-CPR ionized calcium levels in dogs that were successfully resuscitated or those that were not. This study does not support the use of ionized calcium levels to guide

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CPR efforts or predict outcome.

Mair P, Kornberger E, Furtwaengler W, Balogh D, Antretter H. Prognostic markers in patients with severe accidental hypothermia and cardiocirculatory arrest. Resuscitation. 1994 Jan;27(1):47-54

The aim of this retrospective study was to investigate whether plasma potassium, pH and activated clotting time (ACT), obtained from a central venous blood sample immediately after admission to hospital, could predict outcome in patients with severe accidental hypothermia and cardiocirculatory arrest. Twenty-two patients rewarmed with cardiopulmonary bypass were studied retrospectively (12 patients after avalanche accidents, seven patients after cold water submersion and three patients after prolonged exposure to cold). In 12 patients stable spontaneous circulation could not be restored. In 10 patients stable spontaneous circulation could be restored. Two of these 10 patients survived long-term. Plasma potassium, central venous pH and ACT were clinically useful prognostic markers in hypothermic arrest victims after avalanche accidents: a plasma potassium value exceeding 9 mmol/l, a pH equal to or less than 6.50 or an ACT exceeding 400 s was seen in patients in whom spontaneous circulation could not be restored. Plasma potassium, central venous pH and ACT were of only limited prognostic value in hypothermic arrest victims following cold water submersion or prolonged exposure to cold. In hypothermic arrest victims after cold water submersion a central venous pH as low as 6.51 on admission did not exclude long-term survival. Moderate and severe hyperkalemia in arrest victims after prolonged exposure to cold need not necessarily indicate postmortem autolysis. A decision to continue or terminate resuscitation cannot be based on laboratory parameters. Nevertheless, our data suggest that plasma potassium, central venous pH and ACT on admission can be used to identify hypothermic arrest victims in whom death preceded cooling. If several hypothermic arrest victims are admitted simultaneously after avalanche accidents, these 3 parameters can help not to waste limited cardiopulmonary bypass facilities for patients with no hope of survival.

LOE 5, Poor, Supporting, Non-target Species

This was a human retrospective study aimed at identifiying prognostic markers from central venous blood samples in patients with exposure related severe hypothermia and resuscitation. The goal was to evaluate whether there are specific markers that may indicate whether intensive and prolonged resuscitative efforts will result in survival. Markedly elevated central venous potassium in avalanche patients may be an indication that death preceded cooling and that extreme and prolonged efforts at resuscitation may not be fruitful.

Bender PR, Debehnke DJ, Swart GL, Hall KN. Serum potassium concentration as a predictor of resuscitation outcome in hypothermic cardiac arrest. Wilderness Environ Med. 1995 Aug;6(3):273-82

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The purpose of this study was to determine whether serum potassium concentration (SK) can predict resuscitation outcome in a canine model of severe hypothermic cardiac arrest. Fifteen adult mongrel anesthetized dogs were immersed to the neck in a 4 degrees C water bath and ventilated with room air, with ventilation halved at 45 min and stopped at 90 min. After cardiac arrest, 14 of the dogs were kept in the water bath for periods of 2-7 h, and another was held in arrest for 13 h. Following 10 min of closed chest cardiopulmonary resuscitation (CPR) (simulating a short transport time to a hospital), animals were placed on cardiopulmonary bypass and rapidly rewarmed. With appearance of ventricular fibrillation, animals were defibrillated up to three times. Standard advanced cardiac life support was initiated at a core temperature (Tc) of 30 degrees C. Eight of the 15 dogs had return of spontaneous circulation (ROSC), at Tc ranging from 30.4 to 36.5 degrees C. The eight dogs with ROSC did not differ from the seven without ROSC in time to arrest (128 +/- 48 versus 128 +/- 23 min) (mean +/- SD) or Tc at arrest (18.1 +/- 2.2 versus 17.9 +/- 3.1 degrees C), but had higher Tc at the end of the arrest period (9.7 +/- 3.0 versus 5.2 +/- 2.0 degrees C), reflecting a shorter arrest period in the dogs with ROSC (225 +/- 95 versus 420 +/- 193 min). SK (mEq liter(-1)) did not differ between dogs with and without ROSC at baseline (3.5 +/- 0.4 versus 3.7 +/- 0.4) or at arrest (3.4 +/- 0.7 versus 4.3 +/- 2.2), but there was a trend toward higher SK at the end of arrest in the group without ROSC (4.6 +/- 1.5 versus 9.4 +/- 6.3; range 3.2-7.8 versus 3.5-21.4; p = .053). SK was similar after 10 min of CPR in the groups with and without ROSC (6.6 +/- 2.9 versus 9.0 +/- 2.4; range 2.5-11.1 versus 4.5-11.0; p = .107). SK after 10 min of CPR was higher in some animals with ROSC (9.6 and 11.1) than in others which did not have ROSC (4.5 and 7.9). We conclude that very high SK following prolonged hypothermic cardiac arrest may be suggestive of an inability to resuscitate. However, SK after both prolonged hypothermic cardiac arrest and a brief period of CPR is not a good predictor of resuscitation using cardiopulmonary bypass rewarming in an animal model.

LOE 4, Fair, Opposing

This was a laboratory canine study of induced hypothermia and resuscitation. Fifteen dogs were anesthetized and then arrest was induced with a combination of cold water bath and lack of ventilation. Venous potassium was evaluated. The results did not indicate that measuring serum potassium predicts ROSC or outcome, especially in animals undergoing cardiopulmonary bypass as part of their resuscitative efforts.

Neiman JT and CB Cairns. Hyperkalemia and ionized hypocalcemia during cardiac arrest and resuscitation: possible culprits for postcountershock arrhythmias? Annals of Emergency Medicine. 1999 July;34(1)

OBJECTIVES: Early countershock of ventricular fibrillation (VF) has been shown to improve immediate and long-term outcome of out-of-hospital **cardiac arrest**. However, studies indicate that countershock of prolonged VF most commonly results in asystole or a nonperfusing bradyarrhythmia (pulseless electrical

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activity [PEA]), which rarely respond to current therapy. The cause of these postcountershock rhythm disturbances is not well understood but may be related to electrical injury of the globally ischemic myocardium or to local metabolic abnormalities that impair impulse formation and **cardiac** contraction. The purpose of this study was to evaluate changes in serum potassium and free calcium homeostasis during **cardiac arrest** and advanced **cardiac** life support (ACLS) interventions.

METHODS:

After sedation, intubation, anesthesia, and instrumentation, VF was induced in 13 dogs. After 7.5 minutes of VF, animals were immediately countershocked, standard closed-chest CPR was initiated, and epinephrine was administered (1 mg in repeated doses if necessary).

RESULTS:

Ten animals could not be resuscitated despite 20 minutes of ACLS interventions. In these animals, a progressive increase in serum potassium was observed from the onset of ACLS to the termination of resuscitation efforts (4.3+/-.6 to 6.0+/-.8 mEq/L, P<.01). A significant increase was observed within 10 minutes of beginning ACLS measures. This was accompanied by a decrease in **ionized** calcium concentration over the same period (4.95+/-.40 to 3.44 mg/dL, P<.01). The decrease in **ionized** calcium was significant within 5 minutes of ACLS interventions. Nine of these 10 animals had either postcountershock asystole or PEA at the termination of resuscitative efforts. The increase in potassium was not related to acidemia. Successfully resuscitated animals did not demonstrate these electrolyte changes.

CONCLUSION:

Ionized hypocalcemia and **hyperkalemia** occur during prolonged resuscitative efforts and may be related to dysfunctional transcellular ionic transport mechanisms. These cations play important roles in **cardiac** electrical and contractile activity and may play a role in refractory postcountershock rhythm disturbances.

LOE 3, Fair, supporting

This was a prospective laboratory investigation of a canine model of cardiac arrest and resuscitation. Ventricular fibrillation was induced in 13 anesthetized dogs. After 7.5 minutes, defibrillation was attempted and there was initiation of closed-chest CPR. Arterial ionized calcium lactate, potassium and blood gases were measured prior to arrest, after 7.5 minutes of unsupported ventricular fibrillation and at 5 minute intervals during attempts at resuscitation. Ten of the 13 dogs could not be resuscitated. In the dogs that were not resuscitated, arterial serum potassium significantly increased within 10 minutes of starting CPR and continued to increase at each subsequent reading. Additionally, in the dogs that were not resuscitated, arterial ionized calcium significantly decreased within 5 minutes of starting CPR and continued to decrease at each subsequent reading. The results of this study support the use of arterial electrolyte measurement throughout the resuscitative efforts, and indicate that chances of ROSC decrease with increasing potassium levels.

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