# WORKSHEET for Evidence-Based Review of Science for Veterinary CPCR

## 1. Basic Demographics

**Worksheet author(s)**

| | |
|---|---|
| Elizabeth B. Davidow | **Date Submitted for review:** 9-2-2011 |

[redacted]

## 2. Clinical question:

MON22A: In dogs and cats in cardiac arrest (P), does an $EtCO_2$ value above 15 mm Hg during CPCR (I), compared with an $EtCO_2$ value below 15 mm Hg (C), predict ROSC (O)?

MON22B: In dogs and cats in cardiac arrest (P), does the use of $EtCO_2$ (e.g. absolute $CO_2$ values or changes in waveform) (I) compared with not using $EtCO_2$ (C), accurately predict outcomes (e.g. ROSC, survival) (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? No

## 4. Search strategy (including electronic databases searched):

**4a. Databases**

-MEDLINE via PUBMED (performed on April 7th, 2011) using Search end[All Fields] AND tidal[All Fields] AND CO2[All Fields] AND ("heart arrest"[MeSH Terms] OR ("heart"[All Fields] AND "arrest"[All Fields]) OR "heart arrest"[All Fields] OR ("cardiac"[All Fields] AND "arrest"[All Fields]) OR "cardiac arrest"[All Fields]) AND ("dogs"[MeSH Terms] OR "dogs"[All Fields])

14 results, 11 need further review, 3 excluded

- MEDLINE via PUBMED (performed April 15, 2011) using Search end ("cats"[MeSH Terms] OR "cats"[All Fields]) AND ("heart arrest"[MeSH Terms] OR ("heart"[All Fields] AND "arrest"[All Fields])

1 result – excluded due to lack of relevance and in Lithuanian

-MEDLINE via PUBMED (performed April 15, 2011) using Search end - ("heart arrest"[MeSH Terms] OR ("heart"[All Fields] AND "arrest"[All Fields]) OR "heart arrest"[All Fields] OR ("cardiac"[All Fields]

27 results, 17 need further review, 3 excluded as reviews, 1 found previously in canine search, 6 excluded for relevance

-VIN search using "end tidal CO2 monitoring cardiac arrest"

8 results, 1 needs further review, 1 excluded as case report, 6 found in previous searches

References from recent review article by Plunkett, McMichael from ACVIM was reviewed for additional references

4 identified, 3 need further review, 1 previously found

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

**Inclusion criteria** observational or research studies published in peer reviewed journals with at least 5 subjects where ETCO2 was examined in situations of cardiac arrest

**Exclusion criteria**

Review articles (4), case reports (1), not directly related to question above (9)

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

## 5. Summary of evidence

Of the 32 articles requiring further review, 20 had relevance to the clinical questions. An additional article was located during the literature review but 4 of the articles found described the same 2 sets of research subjects and thus 19 studies were included.

No studies were located on cats. Eight studies involved research dogs, 1 study involved rats, 3 involved pigs, and 7 involved humans. No clinical studies were found in dogs.

The preponderance of the evidence supports the relationship of rising ETCO2 with increases in cardiac output (Weil 1985), coronary perfusion pressures (Emerman 1990, Sanders 1985), and likelihood of ROSC (Trevino 1985, von Plant 1988, Asplin 1995, Cantineau 1996, Steedman 1990, Sehra 2003, Sanders 1985, Sanders 1989, Grmec 2001, Garnett 1987) and the lack of a rise with a poor prognosis (Kern 1989,Wayne 1995, Berg 1996). In the only study that looked at overall survival, Sanders demonstrated that survivors to hospital discharge also had higher ETCO2 during resuscitation than non survivors (Sanders 1989).

Use of medications such as sodium bicarbonate and epinephrine during resuscitation may have effects on these relationships. Adrogue did show in 1989 that use of sodium bicarbonate increases the ETCO2 independently of cardiac output and coronary perfusion. In a study by Martin in 1990 of ventricular fibrillation cardiac arrest in 6 dogs, coronary perfusion pressure was highly correlated toETCO2 prior to epinephrine but not afterward. A similar finding with epinephrine was seen by Angelos in a study of 24 dogs and in this study, ETCO2 was not different between non-resuscitated and resuscitated animals. However, epinephrine was used during resuscitation in several of the human observational clinical trials (Wayne 1995) and in one of the research studies in dogs (Sanders 1985) without impact on the prognostic value of ETCO2 on ROSC .

The cause of the arrest does impact the pattern of the rise and fall of ETCO2 with asphyxia causing a marked rise in ETCO2 initially in arrest, in contrast to arrest from ventricular fibrillation, where ETCO2 falls before rising again with ROSC (Berg 1996).

The timing of the rise of ETCO2 and correlation with ROSC differs across studies. In a research study by Kern in 1989, there was only a difference between those dogs with ROSC and those without at the 14 minute measurement. However a prospective observational study in people with out of hospital arrest showed differences in ETCO2 for those with ROSC and those without at 1minute, 2 minutes and for the maximum CO2 measured (Asplin 1995).

Values for ETCO2 that might be predictive of survival or non survival were most closely examined in human studies. An observational human study by Cantineau in 1996 concluded that an ETCO2 of greater than 10 during the first 20 minutes predicted ROSC with a sensitivity of 100% and specificity of 66%. In two other observational human study, ETCO2 values consistently < 10 mm Hg predicted death (Wayne 1995, Grmec 2001). A 1995 human study by Asplin, showed that the maximum ETCO2 levels for survivors were 30.8 +/- 9.5 mm Hg which were higher but showed overlap with those of the non survivors at 22.7 +/- 8.8 mm Hg. In a Sanders 1989 study, the 9 of 35 people who were resuscitated had ETCO2 above 10, but so did several of those who were not.

3 research animal model studies looked at predictive values of ETCO2 for ROSC. In a cardiac arrest model research study by Berg in 1996 on 20 piglets, the 7 piglets without ROSC had ETCO2 readings that remained below 15 mm Hg. In another cardiac arrest model research study in dogs, all dogs were resuscitated and the ETCO2 increased from 13.9 +/-4 to 27 +/- 7 mm Hg at or just prior to ROSC. (Bhende 1996). In another cardiac arrest model research study in dogs, 6 of the 12 dogs were resuscitated. In the dogs with

ROSC, the mean ETCO2 was 9.6+/-3.2 mm Hg versus 3.2+/-1.1 for non resuscitated dogs and the ETCO2 was significantly different at each minute of resuscitation (Sanders 1985)

## Evidence Supporting Clinical Question

| | | | | | | |
|---|---|---|---|---|---|---|
| **Good** | | | | | | |
| **Fair** | | | Adrogue 1989 (A), Bhende 1996 (A), Sanders 1985 (A, E), Emerman 1990 (E), Dohi 1987 (E) | | | *Berg 1996(A), Weil 1985 (E), von Planta 1988 (A), Trevino 1985 (A),* |
| **Poor** | | | | | | *Asplin 1995 (A), Cantineau 1996 (A), Wayne 1995 (A,C), Steedman 1990 (A), Sehra 2003 (A), Sanders 1989 (A,C), Grmec 2001 (A)* |
| | **1** | **2** | **3** | **4** | **5** | **6** |
| **Level of evidence (P)** | | | | | | |

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

# Evidence Neutral to Clinical question

| | | | | | | |
|---|---|---|---|---|---|---|
| **Good** | | | | | | |
| **Fair** | | | Kern 1989 (A) | | | |
| **Poor** | | | | | | *Garnett 1987 (A)* |
| | **1** | **2** | **3** | **4** | **5** | **6** |
| **Level of evidence (P)** | | | | | | |

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

# Evidence Opposing Clinical Question

| | | | | | | |
|---|---|---|---|---|---|---|
| **Good** | | | | | | |
| **Fair** | | | Angelos Resus 1992 (A) | | | |
| **Poor** | | | | | | |
| | **1** | **2** | **3** | **4** | **5** | **6** |
| **Level of evidence (P)** | | | | | | |

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

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

### 7. Conclusion

In multiple species, ETCO2 does rise with increases in coronary perfusion pressure and return of spontaneous circulation. Higher levels appear to predict ROSC while a lack of increase predicts non survival. However, studies have shown variability in exact changes in ETCO2 measurements based on the type of cardiac arrest and medications used during resuscitation. Caution must be taken when interpreting a rise in ETCO2 after using either sodium bicarbonate or epinephrine in dogs.
In humans, an ETCO2 less than 10 mm Hg over a period of minutes is a poor prognostic indicator for ROSC. There is a paucity of information available to make a similar conclusion in veterinary species.

### 8. Acknowledgement

### 9. Citation list

1. Adrogue HJ, Rashad MN, Gorin AB, Yacoub J, Madias NE. Arteriovenous acid-base disparity in circulatory failure: studies on mechanism. Am J Physiol 1989; 257(6 Pt2): F1087-1093.

71 mongrel dogs under anesthesia – 7 different interventions; vasodilation, hemorrhage, cardiac tamponade model of arrest all led to drops in ETCO2. Resolution of tamponade caused almost instantaneous overshoot and correction of ETCO2. Giving NaHCO3 does lead to increase in ETCO2

2. Angelos MG, DeBehnke DJ, Leasure JE. Arterial blood gases during cardiac arrest: markers of blood flow in a canine model. Resuscitation 1992; 23:101-111.

24 mongrel dogs, thiopental and on a ventilator. – electromechanical dissociation induced – measured arterial blood gases, EtCO2 and cardiac output with different therapies- PaCO2 was higher in those animals eventually resuscitated as was coronary perfusion pressure.
Good correlation with EtCO2 with coronary perfusion pressure prior to epinephrine but not after it was administered. EtCO2 was not different between the ROSC and not resuscitated groups in this study – maybe because of the epinephrine

3. Angelos MG, DeBehnke DJ, Leasure JE. Arterial pH and carbon dioxide tension as indicators of tissue perfusion during cardiac arrest in a canine model. Critical Care Medicine 1992; 20:1302-1308.

24 mongrel dogs – VF, standard CPR, cardiac bypass or open chest CPR, 16 dogs resuscitated, PaCO2 was higher in those resuscitated than in those who were not resuscitated

4. Asplin BR, White RD. Prognostic Value of End-tidal Carbon Dioxide pressures during out-of-hospital cardiac arrest. Ann Emerg Med 1995; 25:756-761.

Prospective observational study with convenience sample, non-trauma cases, 27 patients – mainstream caphnograph, - ETCO2 at 1min, 2min and maximum, no HCO3 given; 14/27 ROSC – ETCO2 significantly higher at 1min (23+/-7) versus (13+/-14), 2min (26.8+/-10.8) versus (15.4 +/-5.7) and maximum (30.8+/-9.5) versus (22.7+/-8.8), only 3 survived to hospital discharge

5. Berg RA, Henry C, Otto CW, Sanders AB, Kern KB, et al. Initial end-tidal CO2 is markedly elevated during cardiopulmonary resuscitation after asphyxia cardiac arrest. Pediatr Emerg Care 1996; 12(4): 245-248.

University research study with 20 piglets. Clamping Etube. ETCO2 is much higher with asphyxia than VF but ETCO2 can be used to assess resuscitation after one minute of resuscitation. 7 piglets with no ROSC, had ETCO2 that remained under 15 at 7 minutes. At one minute, 28+/- 11 mean for those with ROSC, 18 +/- 8 for those without ROSC

6. Bhende MS, Karasic DG, Menegazzi JJ. Evaluation of an end-tidal CO2 detector during cardiopulmonary resuscitation in a canine model for pediatric cardiac arrest. Pediatr Emerg Care. 1995 Dec; 11(6): 365-368.

Research lab study
ETCO2 increased from mean 13.9 +/-4 mm Hg to 27 +/-7 mm Hg in all 11 puppies at or within 1 minute prior in all animals at ROSC, all animals had good perfusion pressures during CPR and all were resuscitated so not true life scenario – detector correlated with the capnograph

7. Bhende MS, Karasic DG, Karasic RB. End-tidal carbon dioxide changes during cardiopulmonary resuscitation after experimental asphyxia cardiac arrest. Am J Emerg Med. 1996 Jul; 14(4):349-50.

11 intubated paralyzed dogs, ET tubes clamped for asphyxia cardiac arrest, ETCO2 high initially, dropped and then rose again just before ROSC – increase from 13.9 +/-4 to 27 +/- 7 at or just prior to ROSC, no HCO3 or Epi used in this study

8. Cantineau JP, Lambert Y, Merchkx P, Reynaud P, Porte F, Bertrand C, Duvaldestin P. End-tidal carbon dioxide during cardiopulmonary resuscitation in humans presenting mostly with asystole: A predictor of outcome. Crit Care Med 1996; 24(5): 791-796

Prospective clinical trial – examined use of End tidal CO2 in nontraumatic prehospital cardiac arrest, created cutoff value using data from first 24 patients and then studied in the next 96 patients
8 resuscitated, 16 not resuscitated, End-tidal CO2 significantly different for initial, minimal and maximal values ($p < 0.01$). ETCO2 greater than 10 during the first 20 minutes predicted ROSC with sensitivity of 100%, specificity of 66%.

9. Dohi S, Takeshima R, Matsumiya N. Carbon dioxide elimination during circulatory arrest. Critical Care Medicine 1987; 15:944-946

21 mongrel healthy dogs studied – mechanical ventilation, cardiac arrest with KCL, 8 dogs then had external chest compressions
ETCO2 decreases progressively after arrest, confirmed that ETCO2 did increase with chest compressions, did not resuscitate in this study

10. Emerman CL, Pinchak AC, Hagen JF, Hancock DE. Dye circulation times during cardiac arrest. Resuscitation 1990;19: 53-60.

8 mongrel dogs, halothane anesthesia, ETCO2 was significantly correlated to systolic pressure, end-diastolic pressure, and coronary perfusion pressure. ETCO2 was also correlated to dye circulation time – no epi given, KCL model

11. Garnett AR, Ornato JP, Gonzalez ER, Johnson EB. End-tidal carbon dioxide monitoring during cardiopulmonary resuscitation. JAMA 1987; 257: 512-515.

The end-tidal carbon dioxide (CO2) concentration has been found to correlate with cardiac output during and after cardiopulmonary resuscitation (CPR) in animal models. We monitored end-tidal CO2 values continuously during cardiac resuscitation in 23 humans while ventilation was held constant with a computer-controlled CPR Thumper. This report focuses on ten of the 23 patients who experienced return of spontaneous circulation (ROSC) during monitoring. There was no significant difference in the end-tidal CO2 value of patients without ROSC (1.8% +/- 0.9%) and the end-tidal CO2 value of patients before ROSC in patients who had ROSC (1.7% +/- 0.6%). The end-tidal CO2 concentration increased immediately in all patients who had ROSC, from 1.7% +/- 0.6% to 4.6% +/- 1.4%, then gradually returned to a new baseline (3.1% +/- 0.9%). Change in the end-tidal CO2 value was often the first clinical indicator that ROSC had occurred. Our findings suggest that end-tidal CO2 monitoring may provide clinically useful information that can be used to guide therapy during CPR.

12. Grmec S, Klemen P. Does the end-tidal carbon dioxide (EtCO2) concentration have prognostic value during out-of-hospital cardiac arrest? Eur J Emerg Med 2001; 8: 263-269.

We aimed to investigate the utility of end-tidal carbon dioxide concentration as a prognostic indicator of initial outcome of resuscitation, we conducted a prospective study of EtCO2 in adult victims of out-of-hospital non-traumatic cardiac arrest. We prospectively studied 139 adult patients. The initial, final, average, minimal and maximal EtCO2 was significantly higher in resuscitated patients than in non-resuscitated patients. Using an initial, average and final EtCO2 value of 10 mmHg correctly identified 100% of the patients who were subsequently resuscitated with an acceptable specificity (74.1%; 90%; 81.4%). Important observation from this study is that none of the patients with an average, initial and final EtCO2 level of less than 10 mmHg were resuscitated. Data from this prospective clinical trial indicate that initial, average and final EtCO2 monitoring during CPR is correlated with resuscitation. End-tidal CO2 monitoring has potential as a noninvasive indicator of cardiac output during resuscitation and a prognostic indicator for resuscitation.

13. Kern KB, Sanders AB, Voorhees WD, Babbs CF, Tacker WA, Ewy GA. Changes in expired end-tidal carbon dioxide during resuscitation in dogs: a prognostic guide for resuscitation. J Am Coll Cardiol 1989; 13: 1184-1189

Expired end-tidal PCO2 and coronary perfusion pressures were measured in 15 mongrel dogs undergoing 15 min of closed chest cardiopulmonary resuscitation after a 3 min period of untreated ventricular fibrillation. In six successfully resuscitated dogs, the mean expired end-tidal PCO2 was significantly higher than that in nine nonresuscitated dogs only after 14 min of cardiopulmonary resuscitation (6.2 +/- 1.2 versus 3.4 +/- 0.8 mm Hg; p less than 0.05). No differences in expired end-tidal PCO2 values were found at 2, 7 or 12 min of cardiopulmonary resuscitation. A significant decline in end-tidal PCO2 levels during the resuscitation effort was seen in the nonresuscitated group (from 6.3 +/- 0.8 to 3.4 +/- 0.8 mm Hg; p less than 0.05); the successfully resuscitated group had constant PCO2 levels throughout the 15 min of cardiac arrest (from 6.8 +/- 1.1 to 6.2 +/- 1.2 mm Hg)

14. Martin GB, Gentile NT, Paradis NA, Moeggenberg J, et al. Effect of Epinephrine on End-tidal carbon dioxide monitoring during CPR. Ann Emerg Med 1990; 19:396-398.

6 mongrel dogs- novametrix capnograph, VF induced, epinephrine given at 0.045mg/kg after 5 minutes of CPR, significant correlation bet CPP and ETCO2 before Epi given – Epi may cause shunting in the pulmonary vasculature, Epi increases CPP but may decrease CO

15. Sanders AB, Ewy GA, Bragg S, Atlas M, et al. Expired PCO2 as a Prognostic indicator of successful resuscitation from cardiac arrest. Ann Emerg Med 1985; 14: 948-952.

12 dogs – pentobarbital and intubated, VF model, epinephrine was used for resuscitation, 6 resuscitated – mean ETCO2 was 9.6+/-3.2 mm Hg versus 3.2+/-1.1 for non resuscitated, significantly different at each minute of resuscitation, ETCO2 was also highly correlated to coronary perfusion pressure

16. Sanders AB, Kern KB, Otto CW, Milander MM, et al. End-tidal carbon dioxide monitoring during cardiopulmonary resuscitation. JAMA 1989; 262: 1347 – 1351.

35 human patients, 9 ROSC (15+/-4 vs 7 +/- 5), 3 who survived (17+/-6 versus 8 +/-5) for 32 nonsurvivors

17. Sehra R, Underwood K, Checchia P. End Tidal CO2 is a quantitative measure of cardiac arrest. Pacing Clin Electrophysiol 2003; 26: 515-517.

31 VF/cardiac arrest episodes in 11 humans, ETCO2 increased by 37+/-16% during ROSC, lowest value was 15 in one person during VF arrest

18. Steedman DJ, Robertson CE. Measurement of end-tidal carbon dioxide concentration during cardiopulmonary resuscitation. Arch Emerg Med 1990; 7: 129-134.

12 prospective human cardiac arrest, ROSC in 5 patients, ETCO2 was higher significantly in those with ROSC versus those without – infrared red absorption CO2 analyser

19. Trevino RP, Bisera J, Weil MH, Rackow EC, Grundler WB. End-tidal CO2 as a guide to successful cardiopulmonary resuscitation: A preliminary report. Crit Care Med 1985; 13(11): 910-911.

Research lab study
12 minipigs – 6 fatal arrests, 6 resuscitated, in those 6, ETCO2 increased by 93%, 30 seconds after resuscitation
90 sec after starting compressions, ETCO2 increased to 46% of baseline in survivors but only 26% in nonsurvivors.

20. von Planta I, Weil MH, von Planta M, Bisera J. et al. Cardiopulmonary resuscitation in the rat. J Appl Physiol. 1988; 65: 2641-2647.

14 rats with VF induced cardiac arrest, 8 resuscitated, ETCO2 increased to 11 +/-1 mmHg in resuscitated but only 4+/-1 mm Hg non-resuscitated, ETCO2 over 9 prognostic for survival in 7 of 8 animals

21. Wayne AM, Levine RL, Miller CC. Use of End-tidal Carbon Dioxide to Predict outcome in prehospital cardiac arrest. Ann Emerg Med 1995; 25: 762-767.

Prospective observational study – 90 patients pulseless electrical activity. Initial ETCO2 was the same. After 20 minutes, 3.9 (0-12 range) for non-survivors 75(?) and 31 (16-35) for ROSC (16, only 7 discharged alive). ETCO2 of < 10 mm Hg predicts death, mainstream capnograph, Epinephrine did not appear to lower ETCO2 in this study

22. Weil MH, Bisera, J, Trevino RP, Rackow EC. Cardiac output and end-tidal carbon dioxide. Critical Care Medicine 1985; 13: 907-909.

19 mini-pigs, pentobarbital and pancuronium, intubated and ventilated, thermodilution CO monitoring, VF model of arrest, high correlation of CO with ETCO2

**Identified in Searches but excluded**:

1.Angell-James JE, Daly MD. The effects of artificial lung inflation on reflexly induced bradycardia associated with apnoea in the dog. J Physiol 1978; 274: 349-366. *Not relevant*

2. Berg RA, Otto CW, Kern KB, Sanders AB, et al. High-dose epinephrine results in greater early mortality after resuscitation from prolonged cardiac arrest in pigs: A prospective, randomized study. Critical Care Medicine 1994; 22: 283-290 *20 pigs, high and low dose epi, did measure ETCO2 but did not discuss difference between 18 pigs with ROSC and 2 pigs without*

3. Crozier TA, Luger A, Dravecz M, Sydow M, et al. Gas embolism with cardiac arrest during hysteroscopy. A case report on 3 patients. Anaesthesiol Intensivmed Notfallmed Schmerzther 1991; 26: 412-415. *Case report in German*

4. Dickinson ET, Verdile VP, Schneider RM, Salluzzo RF. Effectiveness of Mechanical versus manual chest compressions in out-of-hospital cardiac arrest resuscitation: a pilot study. Am J Emerg Med 1998; 16: 289-292. *Human prospective randomized effectiveness trial. No survivors in the study – 20 patients total. Thumper produced higher ETCO2 but no difference in ROSC*

5. Emerman CL, Pinchak AC, Hancock D, Hagen JF. The effect of bolus injection on circulation times during cardiac arrest. Am J Emerg Med 1990; 8: 190-193. *Not relevant – does not deal with ROSC or ETCO2*

6. Emerman CL, Pinchak AC, Hagen JF, Hancock D. Hemodynamic effects of the intra-aortic balloon pump during experimental cardiac arrest. Am J Emerg Med 1989; 7: 378-83. *Not directly relevant*

The low flow states and limited coronary perfusion provided by conventional cardiopulmonary resuscitation (CPR) have prompted investigations into alternative, more invasive, methods of resuscitation. Previous case reports and limited animal evidence have suggested that the intra-aortic balloon pump (IABP) may have a role in resuscitation. We used a canine cardiac arrest model to study the hemodynamic effects of the IABP during closed-chest CPR. A sensor attached to the chest plate of a Thumper was used to time a Datascope Model 3520 ventricular assist console such that the balloon inflated on the upstroke and deflated on the downstroke of the Thumper. There was no increase in systolic blood pressure with the balloon pump. Diastolic blood pressure and coronary perfusion pressure were significantly higher with the IABP. Circulation times were shorter and end-tidal CO2 was higher with the IABP. It was concluded that the IABP improves hemodynamic parameters during experimental cardiac arrest.

7. Gazmuri RJ, Weil MH, Tang W. Rational management of cardiac arrest. Rev Med Chil. 1991; 119: 1301-1310. *Review in Spanish*

8. Grauer K, Cavallaro D, Gums J. New developments in cardiopulmonary resuscitation. Am Fam Physician 1991; 43: 832-844. *Review*

9. Hatlestad D. Capnography as a predictor of the return of spontaneous circulation. Emerg Med Serv 2004; 33: 75-80. *Review*

10. Hoekstra OS, van Lambalgen AA, Groenveld AB, van den Bos GC, Thijs LG. Abdominal compressions increase vital organ perfusion during CPR in dogs: relation with efficacy of thoracic compressions. Ann Emerg Med 1995; 25: 375-385. *Not relevant – no ETCO2 measurements*

11.Malzer R, Zeiner A, Binder M, Domanovits H, et al. Hemodynamic effects of active compression-decompression after prolonged CPR. Resuscitation 1996; 31: 243-253. *Not relevant*

12. Morray JP, Geiduschek JM, Caplan RA, Posner KL, Gild WM, Cheney FW. A comparison of pediatric and adult anesthesia closed malpractice claims. Anesthesiology. 1993; 78: 461-7. *Not relevant*

13. Nishiyama T, Hanaoka K. Gas Embolism during hysteroscopy. Can J Anaesth. 1999; 46: 379-380. *Not relevant*

14. Pilvinis V, Vaitkaitis D, Stasiukyniene V, Pranskunas A. Physiological aspects of cardiopulmonary resuscitation in adults. Medicina 2006; 42: 346-353. *In Lithuanian and review article*

15. Pokorna M, Andrlik M, Necas E. End tidal CO2 monitoring in condition of constant ventilation: a useful guide during advanced cardiac life support. Prague Med Rep 2006; 107: 317-326 *Case reports of 3 humans*

16. Prause G, Hetz H, Doppler R. Preclinical blood gas analysis. 1. The value of preclinical blood gas analysis. Anaesthesist. 1998; 47: 400-405. *In German*

17. Prause G, Hetz H, Lauda P, Pojer H, Smolle-Juettner F, et al. A comparison of the end-tidal CO2 documented by capnometry and the arterial pCO2 in emergency patients. Resuscitation 1997; 35: 145-148. *Not relevant to question*

18. Punjasawadwong Y, Srisawasdi S, Werawatganon T, Taratarnkoolwatana K, et al. The Thai Anesthesia Incidents Study of ambulatory anesthesia: II. Anesthetic profiles and adverse events. J Med Assoc Thai 2008; 91: 188-195. *Not relevant*

19. Raffin L, Michel-Cherqui M, Sperandio M, Bonnette P, et al. Anesthesia for bilateral lung transplantation without cardiopulmonary bypass: initial experience and review of intraoperative problems. J Cardiothorac Vasc Anesth 1992; 6: 409-417. *Not relevant*

20. Sanders KC, Clum WB 3rd, Nguyen SS, Balasubramaniam S. End-tidal carbon dioxide detection in emergency intubation in four groups of patients. J Emerg Med 1994; 12: 771-777. *Not relevant – intubation study*

21. Sayah AJ, Peacock WF, Overton DT. End-tidal CO2 measurement in the detection of esophageal intubation during cardiac arrest. Ann Emerg Med. 1990; 19:857-860. *Not relevant – intubation study*

22.Suominen PK, Stayer S, Wang W, Chang AC. The effect of temperature correction on blood gas values on the accuracy of end-tidal carbon dioxide monitoring in children after cardiac surgery. ASAIO J 2007; 53: 67-674. *Not relevant to question*

We evaluated accuracy of end-tidal carbon dioxide tension (PETco2) monitoring and measured the effect of temperature correction of blood gas values in children after cardiac surgery. Data from 49 consecutive mechanically ventilated children after cardiac surgery in the cardiac intensive care unit were prospectively collected. One patient was excluded from the study. Four arterial-end-tidal CO2 pairs in each patient were obtained. Both the arterial carbon dioxide tension (Paco2) values determined at a temperature of 37 degrees C and values corrected to body temperature (Patcco2) were compared with the PETco2 values. After the surgical correction 28 patients had biventricular, acyanotic (mean age 2.7 +/- 4.8 years) and 20 patients had a cyanotic lesion (mean age 1.0 +/- 1.7 years). The body temperature ranged from 35.2 degrees C to 38.9 degrees C. The Pa-PETco2 discrepancy was affected both by the type of cardiac lesion and by the temperature correction of Paco2 values. Correlation slopes of the Pa-PETco2 and Patc-PETco2 discrepancies were significantly different ($p = 0.040$) when the body temperature was higher or lower than 37 degrees C. In children, after cardiac surgery, end-tidal CO2 monitoring provided a clinically acceptable estimate of arterial CO2 value, which remained stabile in repeated measurements. End-tidal CO2 monitoring more accurately reflects temperature-corrected blood gas values.

23.Varon AJ, Morrina J, Civetta JM. Clinical utility of a colorimetric end-tidal CO2 detector in cardiopulmonary resuscitation and emergency intubation. J Clin Monit 1991; 7: 289-293 Intubation study but no patient with ETCO2 less than 2% was resuscitated

24. Walsh VP, Machon RG, Munday JS, Broome CJ. Suspected fatal venous air embolism during anaesthesia in a Pomerian dog with pulmonary calcification. NZ Vet J. 2005; 53: 359-362. *Case report*

25. Wik L, Bircher NG, Safar P. A comparison of prolonged manual and mechanical external chest compression after cardiac arrest in dogs. Resuscitation 1996; 32(3):241-250. *12 dogs, ½ manual, ½ mechanical resuscitation, all resuscitated, coronary perfusion pressure and ETCO2 higher with mechanical resuscitation – could not comment on ROSC and ETCO2 since all resuscitated*