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

## 1. Basic Demographics

**Worksheet author(s)**

| | |
|---|---|
| Pedro Boscan, DVM, MSc, PhD, DACVA | **Date Submitted for review:** 07-08-11 |

[redacted]

## 2. Clinical question:

In dogs and cats with ROSC after cardiac arrest (P), does normocapnia (+/- via PPV) (I) compared to hyper- or hypocapnia (C), result in improved outcome (O) (survival to discharge neurological function)?

## 3. Conflict of interest specific to this question:

None

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

-PubMed

## 4a. Databases

- PUBMED (1950 to June 2011) (performed on July 5-6, 2011)

1. Capnograph
2. CO2
3. Ventilation
4. CPR
5. CPCR
6. Cardiac arrest
7. Respiratory arrest

8. Fibrillation
9. Outcome

1 and 4: 3 relevant hits out of 6 total hits.

1 and 5: 0 total hits.

1 and 6: 2 relevant hits out of 6 total hits.

1 and 7: 0 relevant hits out of 9 total hits.

1 and 8: 1 relevant hit out of 1 total hit.

2 and 4: 9 relevant hits out of 188 total hits.

2 and 5: 0 total hits.

2 and 6: 2 relevant hits out of 245 total hits.

2 and 7: total of 764 hits so added keyword 9: 0 relevant hits out of 54 total hits.

2 and 8: 1 relevant hits out of 108 total hits.

3 and 4: total of 2034 hits so added keyword 9: 8 relevant hits out of 463 total hits.

3 and 5: 0 relevant hits out of 6 total hits.

3 and 6: total of 2700 hits so added keyword 9: 10 relevant hits out of 572 total hits.

3 and 7: total of 9810 hits so added keyword 9 and obtained 950 hits. Then, I added the keyword “dog” and obtained 2 total hits with no relevant hits. I changed the keyword “dog” for “cat” and obtained 1 total hit that is relatively relevant. I changed the keyword “cat” for “human” and obtained 911 total hits. To this last search, I added the keyword “CO2” and obtained 22 total hits with 0 relevant hits.

3 and 8: total 1064 hits so added keyword 9: 1 relevant hits out of 244 total hits.

-CAB (1981 to June 2011 because my CAB only allowed me to go back as far as 1981) (performed on July 6, 2011)

1. Capnograph
2. CO2
3. Ventilation
4. CPR
5. CPCR
6. Cardiac arrest
7. Respiratory arrest
8. Fibrillation

9. Outcome

1 and 4: 0 total hits.

1 and 5: 0 total hits.

1 and 6: 0 total hits.

1 and 7: 0 total hits.

1 and 8: 0 total hit.

2 and 4: 0 relevant hits out of 10 total hits.

2 and 5: 0 relevant hits out of 2 total hits.

2 and 6: 0 relevant hits out of 7 total hits.

2 and 7: 0 relevant hits out of 5 total hits.

2 and 8: 0 relevant hits out of 14 total hits.

3 and 4: 0 relevant hits out of 8 total hits.

3 and 5: 0 relevant hits out of 4 total hits.

3 and 6: 0 relevant hits out of 50 total hits.

3 and 7: 0 relevant hits out of 40 total hits.

3 and 8: 0 relevant hits out of 19 total hits.

**4b. Other sources**

-In addition to all references of identified, I went over the human ILCOR worksheet 2010 containing the same query for human evidence-based guidelines (ALS-PA-053B).

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

**Inclusion criteria**

Human or animal studies that described $CO_2$ levels during the CPR recovery period and documented possible outcomes (eg. intracranial pressure, survival rate)

**Exclusion criteria**

Only abstract or editorials forms, conference presentations, non-peer reviewed publications, review publications with no original data, papers with different language than english.

**4d. Number of articles/sources meeting criteria for further review:** Of the 54 articles identified as relevant hits, 6 articles met the above criteria for further review and 18 articles had information that could be of importance for the criteria due to the lack of evidence.

**LOE 1**

None

**LOE 2**

None

**LOE 3**

None

**LOE 4**

None

**LOE 5**

A total of 3 studies:

Vanicky I, Marsala M, Murár J, Marsala J.
Neurosci Lett. 1992 Feb 3;135(2):167-70.
Prolonged postischemic hyperventilation reduces acute neuronal damage after 15 min of cardiac arrest in the dog.

Todd MM, Tommasino C, Shapiro HM.

Crit Care Med. 1985 Sep;13(9):720-3.
Cerebrovascular effects of prolonged hypocarbia and hypercarbia after experimental global ischemia in cats.

Safar P, Xiao F, Radovsky A, Tanigawa K, Ebmeyer U, Bircher N, Alexander H, Stezoski SW.
Stroke. 1996 Jan;27(1):105-13.
Improved cerebral resuscitation from cardiac arrest in dogs with mild hypothermia plus blood flow promotion.

**LOE 6**

A total of 3 human studies:

Sunde K, Pytte M, Jacobsen D, Mangschau A, Jensen LP, Smedsrud C, Draegni T, Steen PA.
Resuscitation. 2007 Apr;73(1):29-39. Epub 2007 Jan 25.
Implementation of a standardised treatment protocol for post resuscitation care after out-of-hospital cardiac arrest.

Esteban A, Anzueto A, Frutos F, Alía I, Brochard L, Stewart TE, Benito S, Epstein SK, Apezteguía C, Nightingale P, Arroliga AC, Tobin MJ; Mechanical Ventilation International Study Group.
JAMA. 2002 Jan 16;287(3):345-55.
Characteristics and outcomes in adult patients receiving mechanical ventilation: a 28-day international study.

Stauffer JL, Fayter NA, Graves B, Cromb M, Lynch JC, Goebel P.
Chest. 1993 Oct;104(4):1222-9.
Survival following mechanical ventilation for acute respiratory failure in adult men.

## 5. Summary of evidence

### Evidence Supporting Clinical Question

My clinical question is to compare normocapnia (+/- via PPV) vs hyper- or hypocapnia regarding outcome. Thus, evidence supporting the clinical question can be either supporting normo-, hyper- or hypocapnia. However, due to the small amount of available evidence, it is irrelevant which evidence the study supports. See below section 6 for details. The same applies for the rest of section 5.

| | | | | | | |
|---|---|---|---|---|---|---|
| **Good** | | | | | | |
| **Fair** | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Poor** | | | | | Vanicky 1992 – E (hypocapnia, dog)<br>Todd 1985 – E (hypo-, hypercapnia, cats) | |
| | **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 Neutral to Clinical question**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Good** | | | | | | |
| **Fair** | | | | | | *Sunde 2007 – C (human)* |
| **Poor** | | | | | | *Stauffer 1993 – B-C (human, no $CO_2$ reported)* |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | *Esteban 2002 – B-C (human, no $CO_2$ reported)* |
| | **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 *studies* D = Intact neurological survival *Italics = Non-target species*

**Evidence Opposing Clinical Question**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Good** | | | | | | |
| **Fair** | | | | | Safar 1996 – B-D-E (normocapnia, dogs) | |
| **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:**

The normocapnia, hypocapnia or hypercapnia to hospital discharge evidence after ROSC is poor or pretty much non-existent. According to the literature, $CO_2$ may still influence CNS blood flow, perfusion and ICP after ROSC. Thus, hypocapnia may predispose to decrease in blood flow, perfusion, CNS oxygenation and ICP, while hypercapnia may predispose to increase blood flow, perfusion and ICP. However, the information is limited and controversial. Two studies support hypocapnia to decrease histopathological neuronal damage after ROSC by maintaining PaCO2 of 15-20 mmHg, when compared to PaCO2 of 35-45 mmHg (Vanicky 1992; Todd 1985). Two studies support normocapnia to improve CNS blood flow, neurological function and histopathological neuronal damage (PaCO2 of 39-45 mmHg; *Sunde 2007;* Safar 1996). However, none of the studies were clinically oriented or manipulated CO2 intentionally to affect outcome and/or included multiple variables to determine outcome.

Additional studies reviewed addressing the effect of CNS blood flow, perfusion and ICP with different models or situation such as head trauma, basic research models, CNS ischemia showed similar controversy regarding the CO2 reactivity to influence CNS blood flow, perfusion and ICP.

Beyond my clinical question, the effect of CO2 during resuscitation or within minutes after ROSC has been reported. For example, hypercapnia (PCO2 of 60-80 mmHg) worsens ROSC from 75% to 13% in a swine model with VF (Idris AH et al 1995). This is in addition to the well reported predictive value from PCO2 or ETCO2 regarding outcome during cardiac arrest, resuscitation and within a few minutes post ROSC (eg. Asplin and White 1995; Grmec and Klemen 2001; Salen P et al 2001; Hatlestad D 2004; Einav S et al 2011).

A 2$^{nd}$ consideration is the effect of IPPV to establish a particular PCO2 in patients after ROSC. IPPV in humans, dogs and cats appear to predispose to pneumothorax, pneumonia, acute lung injury, etc.

In 2 human and 1 cat studies, a portion of the population studied 1.9% from the total human population of 15757 (*Esteban A et al 2002*), 68 persons from the total of 383 persons studied (*Stauffer JL et al 1993*) and 9 cats (17%) from the total studied (Lee JA et al 2005) were post cardiac and/or respiratory arrest. *Esteban et al 2002*, showed that if IPPV peak pressure or the plateau pressure were above 50 cmH2O or 35 cmH2O respectively, increased the mortality odds ratio by 2.5 and 2.64 respectively. *Stauffer et al 1993,* showed that if the caused to start IPPV was cardiac or respiratory arrest, the mortality odds ratio increased by 6.73, when compared to the rest of the group that had a 43% chance to hospital discharge. Lee et al 2005, showed that from all cats included in the cat-IPPV study (9 cats were post cardiac arrest), the survival rate was 15%, mortality rate 36% and euthanasia in 49% of the cats.

Along the same lines, a study from Moon SW et al. 2007 showed that by increasing: respiratory dead space ratio (V[dA]/V[t]), PaCO2 – ETCO2, serum lactate and decreasing MAP worsens outcome and hospital discharge in humans after gaining ROSC from cardiac arrest.

Thus, the evidence does not support or refute the benefit from normo-, hypo- or hypercarpnia after ROSC. The data suggests that hyperventilation may induce CNS ischemia and hypoventilation may induce increase in ICP but not consistent information was available.

Benefits found in the literature reviewed regarding CO2 monitoring after ROSC are:
1. ETCO2 is a variable but good and linear indicator of CO/CI, even when CO/CI are very low such as in some ROSC cases (Prause G et al 1997; Idris AH et al 1994a; Idris AH et al 1994b).
2. ETCO2 – PCO2 are by definition to monitor ventilation and correct ventilator derangements.
3. ETCO2 – PCO2 help to determine and treat acid/base derangements.
4. ETCO2 – PCO2 indirectly help assess tissue perfusion.
5. ETCO2 – PCO2 indirectly help assess tissue metabolism.
6. ETCO2 – PCO2 allows to measure and monitor respiratory dead space.
7. ETCO2 allows assessing proper endotracheal intubation.
8. ETCO2 – PCO2 monitoring help prevent increases in ICP due to PCO2.

## 7. CONCLUSION:

**Consensus on Science statement:**
Minimal data with poor evidence to support either normo-, hypo- or hypercapnia ventilation after ROSC.

**Treatment recommendation:**
At the moment, with the evidence found, I cannot recommend normo-, hypo- or hypercapnia ventilation after ROSC. However, the literature strongly supports the use of CO2 monitoring during and after resuscitation for the benefits previously described.
Normocapnia appears to decrease the controversy between hyperventilation induced CNS ischemia or hypoventilation induced increase in ICP but not evidence base information was available.

## 8. ACKNOWLEDGEMENTS:

None

## 9. CITATION LIST:

**Asplin BR, White RD.**
Ann Emerg Med. 1995 Jun;25(6):756-61.
**Prognostic value of end-tidal carbon dioxide pressures during out-of-hospital cardiac arrest.**
Department of Anesthesiology, Mayo Clinic, Rochester, Minnesota, USA.
Abstract
STUDY OBJECTIVE:
To assess the prognostic value of initial end-tidal CO2 pressures (PETCO2) during CPR in patients with out-of-hospital cardiac arrest (OHCA).
DESIGN:
A prospective observational study using a convenience sample.

SETTING:
Primary service area of an advanced life support (ALS) ambulance service, including a city with a population of 70,745 and the surrounding area, with a population of 30,000.
PARTICIPANTS:
Adults with nontraumatic OHCA.
INTERVENTIONS:
Quantitative monitoring of PETCO2 during CPR after endotracheal intubation using an infrared capnograph.
RESULTS:
PETCO2 after 1 and 2 minutes and the maximum PETCO2 during CPR were compared between the group in which restoration of spontaneous circulation (ROSC) was achieved and the group in which it was not. PETCO2 was measured during CPR in 27 patients. After 1 minute, PETCO2 was higher in patients who had on-scene ROSC than in patients without ROSC (23.0 +/- 7.4 versus 13.2 +/- 14.7 mm Hg, P = .0002). After 2 minutes, PETCO2 was higher in patients with ROSC (26.8 +/- 10.8 versus 15.4 +/- 5.7 mm Hg, P = .0019). The maximum PETCO2 during CPR was also higher in the ROSC group (30.8 +/- 9.5 versus 22.7 +/- 8.8 mm Hg, P = .0154). Thirteen of 27 patients presented in ventricular fibrillation (VF). The 1-minute (24.3 +/- 6.8 versus 12.0 +/- 4.2 mm Hg, P = .0022), 2-minute (28.2 +/- 11.4 versus 12.4 +/- 4.3 mm Hg, P = .0088), and maximum (33.0 +/- 10.2 versus 20.6 +/- 11.1 mm Hg, P = .0316) PETCO2 values during CPR were all significantly higher in patients in VF with ROSC.
CONCLUSION:
In this observation study of 27 patients, initial PETCO2 during CPR with automated ventilation was prognostic for ROSC in patients with OHCA. Patients with ROSC have higher PETCO2 values after 1 and 2 minutes than do patients without ROSC.

**Buunk G, van der Hoeven JG, Meinders AE.**
Stroke. 1997 Aug;28(8):1569-73.
**Cerebrovascular reactivity in comatose patients resuscitated from a cardiac arrest.**
Department of General Internal Medicine (Medical Intensive Care Unit), University Hospital Leiden, The Netherlands. snoeken@worldonline.nl
Abstract
BACKGROUND AND PURPOSE:
Cerebral blood flow after cardiac arrest is reduced during the delayed hypoperfusion phase, while cerebral metabolic rate of oxygen returns to baseline values. Hypocapnia can induce cerebral ischemia in neurosurgical patients who already have reduced cerebral blood flow. The purpose of the present study was to determine whether comatose patients resuscitated from a cardiac arrest have a normal cerebrovascular reactivity to changes in PaCO2 and whether hypocapnia causes cerebral ischemia.
METHODS:
We measured mean flow velocity (MFV) and pulsatility index (PI) in the middle cerebral artery, jugular bulb oxygen saturation (SjbO2), and arterial-jugular lactate difference (AJLD) during normo-, hypo-, and hyperventilation in 10 comatose patients resuscitated from a cardiac arrest. The first measurements were made within 6 hours after cardiac arrest and repeated 6, 12, and 24 hours later.
RESULTS:
During hypoventilation we observed a significant decrease in PI and an increase in MFV and SjbO2. During hyperventilation PI and MFV did not change, but SjbO2 showed a significant decrease. This was accompanied by an increase in AJLD, suggesting cerebral ischemia. In four patients the SjbO2 decreased below the ischemic threshold of 55%.

CONCLUSIONS:
The cerebrovascular reactivity to changes in arterial carbon dioxide tension is preserved in comatose patients resuscitated from a cardiac arrest. Hyperventilation may induce cerebral ischemia in the postresuscitation period.

**Conrad CJ, Provo TA, Lurie KG.**
Circulation. 2004 Apr 27;109(16):1960-5. Epub 2004 Apr 5.
**Hyperventilation-induced hypotension during cardiopulmonary resuscitation.**
Aufderheide TP, Sigurdsson G, Pirrallo RG, Yannopoulos D, McKnite S, von Briesen C, Sparks CW, Department of Emergency Medicine, Medical College of Wisconsin, Milwaukee, USA.
Abstract
BACKGROUND:
A clinical observational study revealed that rescuers consistently hyperventilated patients during out-of-hospital cardiopulmonary resuscitation (CPR). The objective of this study was to quantify the degree of excessive ventilation in humans and determine if comparable excessive ventilation rates during CPR in animals significantly decrease coronary perfusion pressure and survival.
METHODS AND RESULTS:
In humans, ventilation rate and duration during CPR was electronically recorded by professional rescuers. In 13 consecutive adults (average age, 63+/-5.8 years) receiving CPR (7 men), average ventilation rate was 30+/-3.2 per minute (range, 15 to 49). Average duration per breath was 1.0+/-0.07 per second. No patient survived. Hemodynamics were studied in 9 pigs in cardiac arrest ventilated in random order with 12, 20, or 30 breaths per minute. Survival rates were then studied in 3 groups of 7 pigs in cardiac arrest that were ventilated at 12 breaths per minute (100% O2), 30 breaths per minute (100% O2), or 30 breaths per minute (5% CO2/95% O2). In animals treated with 12, 20, and 30 breaths per minute, the mean intrathoracic pressure (mm Hg/min) and coronary perfusion pressure (mm Hg) were 7.1+/-0.7, 11.6+/-0.7, 17.5+/-1.0 ($P<0.0001$), and 23.4+/-1.0, 19.5+/-1.8, and 16.9+/-1.8 ($P=0.03$), respectively. Survival rates were 6/7, 1/7, and 1/7 with 12, 30, and 30+ CO2 breaths per minute, respectively ($P=0.006$).
CONCLUSIONS:
Professional rescuers were observed to excessively ventilate patients during out-of-hospital CPR. Subsequent animal studies demonstrated that similar excessive ventilation rates resulted in significantly increased intrathoracic pressure and markedly decreased coronary perfusion pressures and survival rates.

**Davis DP.**
Resuscitation. 2008 Mar;76(3):333-40. Epub 2007 Sep 17.
**Early ventilation in traumatic brain injury.**
UC San Diego Department of Emergency Medicine, 200 West Arbor Drive, #8676, San Diego, CA 92103-8676, United States. davismd@cox.net
Abstract
While airway and ventilatory compromise are significant concerns following traumatic brain injury (TBI), there is little data supporting an aggressive approach to airway management by prehospital personnel, and a growing number of reports suggesting an association between early intubation and increased mortality. Recent clinical and experimental data suggest that hyperventilation is an important contributor to these adverse outcomes in TBI patients. Various mechanisms appear to be responsible for the worsened outcomes, including hemodynamic, cerebrovascular, immunologic and cellular effects. Here, relevant experimental and clinical data regarding the impact of ventilation on TBI are reviewed. In addition, experimental data regarding potential

mechanisms for the adverse effects of hyperventilation and hypocapnia on the injured brain are presented. Finally, the limited data regarding the impact of hypoventilation and hypercapnia on outcome from TBI are discussed.

**Einav S, Bromiker R, Weiniger CF, Matot I.**
Acad Emerg Med. 2011 May;18(5):468-75. doi: 10.1111/j.1553-2712.2011.01067.x.
**Mathematical modeling for prediction of survival from resuscitation based on computerized continuous capnography: proof of concept.**
Adult (SE) and Neonatal (RB) Critical Care Units, Shaare Zedek Medical Center, Hadassah-Hebrew University Medical Center, Jerusalem. einav_s@szmc.org.il
Abstract
OBJECTIVES:
The objective was to describe a new method of studying correlations between real-time end tidal carbon dioxide (ETCO(2) ) data and resuscitation outcomes.
METHODS:
This was a prospective cohort study of 30 patients who underwent cardiopulmonary resuscitation (CPR) in a university hospital. Sidestream capnograph data were collected during CPR and analyzed by a mathematician blinded to patient outcome. The primary outcome measure was to determine whether a meaningful relationship could be drawn between detailed computerized ETCO(2) characteristics and the return of spontaneous circulation (ROSC). Significance testing was performed for proof-of-concept purposes only.
RESULTS:
Median patient age was 74 years (interquartile range [IQR] = 60-80 years; range = 16-92 years). Events were mostly witnessed (63%), with a median call-to-arrival time of 150 seconds (IQR = 105-255 seconds; range = 60-300 seconds). The incidence of ROSC was 57% (17 of 30), and of hospital discharge 20% (six of 30). Ten minutes after intubation, patients with ROSC had higher peak ETCO(2) values ($p = 0.035$), larger areas under the ETCO(2) curve ($p = 0.016$), and rising ETCO(2) slopes versus flat or falling slopes ($p = 0.016$) when compared to patients without ROSC. Cumulative maxETCO(2) > 20 mm Hg at all time points measured between 5 and 10 minutes postintubation best predicted ROSC (sensitivity = 0.88; specificity = 0.77; $p < 0.001$). Mathematical modeling targeted toward avoiding misdiagnosis of patients with recovery potential (fixed condition, false-negative rate = 0) demonstrated that cumulative maxETCO(2) (at 5-10 minutes) > 25 mm Hg or a slope greater than 0 measured between 0 and 8 minutes correctly predicted patient outcome in 70% of cases within less than 10 minutes of intubation. Conclusions: This preliminary study suggests that computerized ETCO(2) carries potential as a tool for early, real-time decision-making during some resuscitations.

**Esteban A, Anzueto A, Frutos F, Alía I, Brochard L, Stewart TE, Benito S, Epstein SK, Apezteguía C, Nightingale P, Arroliga AC, Tobin MJ; Mechanical Ventilation International Study Group.**
JAMA. 2002 Jan 16;287(3):345-55.
**Characteristics and outcomes in adult patients receiving mechanical ventilation: a 28-day international study.**
Unidad de Cuidados Intensivos, Hospital Universitario de Getafe, Carretera de Toledo Km 12, 5, 28905 Getafe, Madrid, Spain. aesteban@hug.es

Abstract
CONTEXT:
The outcome of patients receiving mechanical ventilation for particular indications has been studied, but the outcome in a large number of unselected, heterogeneous patients has not been reported.
OBJECTIVE:
To determine the survival of patients receiving mechanical ventilation and the relative importance of factors influencing survival.
DESIGN, SETTING, AND SUBJECTS:
Prospective cohort of consecutive adult patients admitted to 361 intensive care units who received mechanical ventilation for more than 12 hours between March 1, 1998, and March 31, 1998. Data were collected on each patient at initiation of mechanical ventilation and daily throughout the course of mechanical ventilation for up to 28 days.
MAIN OUTCOME MEASURE:
All-cause mortality during intensive care unit stay.
RESULTS:
Of the 15 757 patients admitted, a total of 5183 (33%) received mechanical ventilation for a mean (SD) duration of 5.9 (7.2) days. The mean (SD) length of stay in the intensive care unit was 11.2 (13.7) days. Overall mortality rate in the intensive care unit was 30.7% (1590 patients) for the entire population, 52% (120) in patients who received ventilation because of acute respiratory distress syndrome, and 22% (115) in patients who received ventilation for an exacerbation of chronic obstructive pulmonary disease. Survival of unselected patients receiving mechanical ventilation for more than 12 hours was 69%. The main conditions independently associated with increased mortality were (1) factors present at the start of mechanical ventilation (odds ratio [OR], 2.98; 95% confidence interval [CI], 2.44-3.63; P<.001 for coma), (2) factors related to patient management (OR, 3.67; 95% CI, 2.02-6.66; P<.001 for plateau airway pressure >35 cm H(2)O), and (3) developments occurring over the course of mechanical ventilation (OR, 8.71; 95% CI, 5.44-13.94; P<.001 for ratio of PaO(2) to fraction of inspired oxygen <100).
CONCLUSION:
Survival among mechanically ventilated patients depends not only on the factors present at the start of mechanical ventilation, but also on the development of complications and patient management in the intensive care unit.

**Grmec S, Klemen P.**
Eur J Emerg Med. 2001 Dec;8(4):263-9.
**Does the end-tidal carbon dioxide (EtCO2) concentration have prognostic value during out-of-hospital cardiac arrest?**
Emergency Medical Services, Prehospital Unit, Education Hospital Maribor, Slovenia.
Abstract
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.

**Hatlestad D.**
Emerg Med Serv. 2004 Aug;33(8):75-80; quiz 115.
**Capnography as a predictor of the return of spontaneous circulation.**
Inter-Canjon Fire/Rescue, Morrison, CO, USA. prioritymed@mindspring.com
Abstract
EtCO2 monitoring is a valuable tool for clinical management of patients in cardiac arrest, near-arrest and post-arrest. During cardiac arrest, EtCO2 levels fall abruptly at the onset of cardiac arrest, increase after the onset of effective CPR and return to normal at return of spontaneous circulation (ROSC). During effective CPR, end-tidal CO2 has been shown to correlate with cardiac output, coronary perfusion pressure, efficacy of cardiac compression, ROSC and even survival. Colorimetric detectors (shown to correlate with infrared capnometry) have been shown to have prognostic value in both adult and pediatric CPR. The higher the initial value of EtCO2, the greater was short-term survival. EtCO2 is a useful tool during patient resuscitation for evaluating the current and potential effects of treatment, and could be potentially useful in determining when to terminate resuscitation efforts.

**Idris AH, Wenzel V, Becker LB, Banner MJ, Orban DJ.**
Chest. 1995 Aug;108(2):522-8.
**Does hypoxia or hypercarbia independently affect resuscitation from cardiac arrest?**
Department of Surgery (Division of Emergency Medicine), University of Florida College of Medicine, Gainesville 32610-0390, USA.
Abstract
STUDY OBJECTIVE:
In a previous cardiopulmonary resuscitation (CPR) study in swine, ventilation was associated with improved rate of return of spontaneous circulation (ROSC) compared with nonventilated animals, which had greater hypoxia and hypercarbic acidosis. We used the same model to determine the independent effect of hypoxia and hypercarbic acidosis on ROSC after cardiac arrest.
DESIGN:
Laboratory model of cardiac arrest.
SETTING:
University teaching hospital laboratory.
PARTICIPANTS:
Domestic swine (23 to 61 kg).
INTERVENTIONS:
Twenty-four swine were randomly assigned to three groups receiving ventilation during CPR with 85% O2/15% N2 (control), 95% O2/5% CO2 (hypercarbia), or 10% O2/90% N2 (hypoxia). All animals had ventricular fibrillation for 6 min without CPR, then CPR with one of the ventilation gases for 10 min, then defibrillation. Animals without ROSC received epinephrine, 85% O2, CPR for another 3 min, and defibrillation.
MEASUREMENTS AND RESULTS:
During the tenth minute of CPR, the hypercarbic group had more mean (SD) arterial hypercarbia than the control group (PCO2, 47 +/- 6, compared with 34 +/- 6; $p < 0.01$), and greater mixed venous hypercarbia (PCO2, 72 +/- 14, compared with 59 +/- 8; $p < 0.05$), while mean arterial and mixed venous PO2 was not

significantly different. The hypoxic group had significantly less mean arterial (43 +/- 9 compared with 228 +/- 103 mm Hg) and mixed venous (22 +/- 5 compared with 35 +/- 7 mm Hg) PO2 when compared with the control group ($p < 0.01$), while mean arterial and mixed venous PCO2 were not significantly different. Thus, the model succeeded in producing isolated hypercarbia without hypoxia in the hypercarbic group and isolated hypoxia without hypercarbia in the hypoxic group. The rate of ROSC was 6/8 (75%) for the control group, 1/8 (13%) for the hypercarbic group, and 1/8 (13%) for the hypoxic group ($p < 0.02$).
CONCLUSIONS:
Both hypoxia and hypercarbia independently had an adverse effect on resuscitation from cardiac arrest. In this model with a prolonged interval of untreated cardiac arrest, adequate ventilation was important for resuscitation.

**Idris AH, Staples ED, O'Brien DJ, Melker RJ, Rush WJ, Del Duca KD, Falk JL.**
Ann Emerg Med. 1994 Mar;23(3):568-72.
**End-tidal carbon dioxide during extremely low cardiac output.**
Department of Internal Medicine, University of Florida College of Medicine, Gainesville.
Abstract
STUDY OBJECTIVE:
A number of studies have shown that expired CO2 concentration is closely related to cardiac output, but that cardiac output was not controlled as an independent variable. In addition, the partial pressure of end-tidal CO2 (PETCO2) during extremely low cardiac output has not been reported. The objective of the present study was to measure PETCO2 during well-controlled, very low blood flow rates under conditions of constant minute ventilation.
DESIGN:
Ten anesthetized, intubated, and mechanically ventilated swine (weight, 43 to 102 kg) were placed on two ventricular assist devices in order to control cardiac output. Minute ventilation was measured and kept constant. Ventricular assist device output (measured with an ultrasonic flow probe); PETCO2; and aortic, pulmonary artery, and central venous pressures were recorded continuously.
INTERVENTIONS:
After electrical induction of ventricular fibrillation, pump output was decreased in steps.
MEASUREMENTS AND MAIN RESULTS:
Cardiac index ranged from 0 to 5,371 mL/min/m2; 59% of PETCO2 measurements were made at cardiac indexes of less than 1,313 mL/min/m2 (30 mL/min/kg). The relationship of PETCO2 levels to cardiac index was determined with linear regression analysis; $P < .05$ was statistically significant. PETCO2 correlated significantly with cardiac index ($P < .0001$). The best-fit line by least-squares analysis produced the equation: PETCO2 = 4.98 + 0.012 [cardiac index] ($r2 = .82$).
CONCLUSION:
Under conditions of constant minute ventilation, PETCO2 correlated closely with cardiac index over a large range of blood flow rates, including extremely low rates.

**Idris AH, Staples ED, O'Brien DJ, Melker RJ, Rush WJ, Del Duca KD, Falk JL.**
Crit Care Med. 1994 Nov;22(11):1827-34.
**Effect of ventilation on acid-base balance and oxygenation in low blood-flow states.**
Department of Surgery, University of Florida College of Medicine, Gainesville 32610-0392.

Abstract
OBJECTIVES:
To investigate how minute ventilation affects the partial pressure of end-tidal CO2 and arterial and mixed venous pH, PCO2, PO2, and the concentration of bicarbonate during low blood-flow states. We tested the null hypothesis that acid-base conditions during low rates of blood flow are not significantly different when minute ventilation is doubled or halved.
DESIGN:
Prospective, experimental, animal study.
SETTING:
University hospital laboratory.
SUBJECTS:
Domestic swine.
INTERVENTIONS:
We studied ten anesthetized and mechanically ventilated swine (weight, 43 to 102 kg) in a new model of controlled systemic and pulmonary blood flow in which each animal was maintained on ventricular assist devices. After electrical induction of ventricular fibrillation, ventricular assist device blood flow was decreased in steps. At each decrease, control minute ventilation, two times the control minute ventilation (hyperventilation), and one-half the control minute ventilation (hypoventilation) were administered; each ventilatory change was maintained for 6 mins.
MEASUREMENTS AND MAIN RESULTS:
Aortic, pulmonary arterial and central venous pressures, ventricular assist device blood flow, and end-tidal CO2 were recorded continuously. Acid-base conditions were studied at three different mean blood flow rates: 49%, 30%, and 12% of baseline prearrest cardiac index. Arterial pH and PaO2 and mixed venous pH varied directly ($p < .003$) with minute ventilation, while PaCO2 and mixed venous PCO2, and end-tidal CO2 varied inversely ($p < .0001$) with minute ventilation. Mixed venous PO2 was not significantly related to minute ventilation ($p = .6$). PaCO2 and arterial bicarbonate; mixed venous pH, mixed venous PO2, and mixed venous bicarbonate, and end-tidal CO2 varied directly ($p < .001$) with blood flow, while mixed venous PCO2 varied inversely with blood flow ($p < .05$). Arterial pH was not significantly related to blood flow ($p = .3$). When minute ventilation changed from hyperventilation to hypoventilation at a mean blood flow rate of 49%, mean arterial pH decreased 0.22 +/- 0.06 ($p < .05$), mean PaCO2 increased 28 +/- 6 torr (3.7 +/- 0.8 kPa) ($p < .05$), and mean PaO2 decreased 99 +/- 77 torr (13.2 +/- 10 kPa); mean mixed venous pH decreased 0.11 +/- 0.02, mean mixed venous PCO2 increased 16 +/- 2.2 torr (2.1 +/- 0.3 kPa) ($p < .05$), and mean mixed venous PO2 did not change; mean end-tidal CO2 increased 18 +/- 2 torr (2.4 +/- 0.3 kPa) ($p < .05$). The effect of changes in minute ventilation on blood gases and end-tidal CO2 was similar for mean blood flow rates of 30% and 12% of baseline cardiac index.
CONCLUSIONS:
During low rates of blood flow similar to those rates found in shock and cardiopulmonary resuscitation, alterations in minute ventilation significantly influenced end-tidal CO2 and both arterial and mixed venous pH and PCO2. These findings may have clinical importance in improving the treatment of shock and cardiac arrest.

**Kågström E, Smith ML, Siesjö BK.**
Acta Physiol Scand. 1983 Jul;118(3):281-91.
**Cerebral circulatory responses to hypercapnia and hypoxia in the recovery period following complete and incomplete cerebral ischemia in the rat.**

Abstract
In this study we examined the reactions of cerebral vessels to hypercapnia and hypoxia during the recovery period following cerebral ischemia. We used ventilated, lightly anesthetized rats and induced complete ischemia by CSF compression, incomplete ischemia by bilateral carotid occlusion combined with hypotension. After 15 min of ischemia and 60 min of recirculation the animals were rendered hypercapnic or hypoxic for 2-3 min and local CBF was then measured autoradiographically with 14C-iodoantipyrine. Following complete ischemia vascular CO2 responsiveness was abolished or attenuated in most structures analysed. However, there was a considerable interstructural heterogeneity. For example, in the cerebellum and the red nucleus flow rates were observed which approached values obtained in hypercapnic control animals, whereas CO2 responsiveness was abolished in several cortical areas and hippocampus. The response to CO2 following incomplete ("forebrain") ischemia varied considerably. In the cerebral cortices areas with low flow rates were often mixed with hyperemic zones, and in most structures that had very low flow rates during ischemia, CO2 responsiveness was lost or grossly attenuated. Structures that had suffered moderate or only mild ischemia had better retained or completely preserved CO2 response. The cerebrovascular reaction to hypoxia was found to be attenuated in most, but not abolished in any of the structures examined. In general, the vascular response to hypoxia was better preserved than that to hypercapnia. Reactivity was similar following complete and incomplete ischemia. As observed during hypercapnia, there were pronounced interstructural variations with considerable increases in flow rates e.g. in the substantia nigra and the cerebellum.

**Lee JA, Drobatz KJ, Koch MW, King LG.**
J Am Vet Med Assoc. 2005 Mar 15;226(6):924-31.
**Indications for and outcome of positive-pressure ventilation in cats: 53 cases (1993-2002).**
Section of Critical Care, Department of Clinical Studies, School of Veterinary Medicine, University of Pennsylvania, Philadelphia, PA 19104-6010, USA.
Abstract
OBJECTIVE:
To determine indications for and outcomes of positive-pressure ventilation (PPV) in cats, document ventilator management, and identify factors associated with outcome.
DESIGN:
Retrospective study.
ANIMALS:
53 cats that underwent PPV.
PROCEDURE:
Information on signalment, history, concurrent diseases, clinical findings, results of venous blood gas analyses and clinicopathologic testing, treatment, ventilator settings, and outcome was retrieved from the medical records. Data for cats that survived were compared with data for cats that died or were euthanatized while undergoing PPV RESULTS: PPV was initiated for management of respiratory failure (36 cats [68%]), cardiac arrest (9 [17%]), neurologic impairment (6 [11%]), and nonresponsive hypotension (2 [4%]). Eight cats (15%) survived, 19 (36%) died, and 26 (49%) were euthanatized while undergoing PPV. Cats that survived had a longer duration of ventilation than did those that died or were euthanatized and had a significantly higher incidence of ventilator-associated pneumonia. Signalment and ventilator settings were not associated with outcome. Cats that had no clinical evidence of pulmonary disease but required PPV because of primary neurologic disease had a higher survival rate (2/6) than did cats that required PPV because of respiratory failure (5/36), cardiac arrest (1/9), or nonresponsive hypotension (0/2).
CONCLUSIONS AND CLINICAL RELEVANCE:

Results suggest that the survival rate for cats requiring PPV may be lower than reported survival rates for dogs. Death was attributable to progressive respiratory failure, non-responsive hypotension, kidney failure, or neurologic impairment.

**Moon SW, Lee SW, Choi SH, Hong YS, Kim SJ, Kim NH.**
Resuscitation. 2007 Feb;72(2):219-25. Epub 2006 Nov 13.
**Arterial minus end-tidal CO2 as a prognostic factor of hospital survival in patients resuscitated from cardiac arrest.**
Department of Emergency Medicine, College of Medicine, Korea University, Seoul, Republic of Korea.
Abstract
AIMS:
The purpose of this study was to determine the clinical value of arterial minus end-tidal CO(2) [P(a-et)CO(2)] and alveolar dead space ventilation ratio (V(dA)/V(t)) as indicators of hospital mortality in patients that have been resuscitated from cardiac arrest at emergency department.
MATERIALS AND METHODS:
Forty-four patients with a return of spontaneous circulation (ROSC) after cardiac arrest were studied in the emergency department of a university teaching hospital from March 2004 to February 2006. Mean arterial pressure (MAP), serum lactate, arterial blood gas studies, end-tidal CO(2) (EtCO(2)), P(a-et)CO(2), and V(dA)/V(t) were evaluated at 1 h after ROSC. We compared these variables between hospital survivors and non-survivors.
RESULTS:
The rates of ventricular fibrillation and pulseless ventricular tachycardia in hospital survivors were higher than those of non-survivors (53.0 and 9.7%, respectively, p=0.002). Hospital survivors had significantly higher MAP, lower serum lactate, lower P(a-et)CO(2), and lower V(dA)/V(t) value than non-survivors. Receiver operator characteristic (ROC) curves of serum lactate, P(a-et)CO(2), and V(dA)/V(t) showed significant sensitivity and specificity for hospital mortality. Specifically, lactate > or = 10.0 mmol/L, P(a-et)CO(2) > or = 12.5 mmHg, and V(dA)/V(t) > or = 0.348 were all associated with high hospital mortality (p=0.000, 0.001 and 0.000, respectively).
CONCLUSIONS:
This study showed that high serum lactate, high P(a-et)CO(2) and high V(dA)/V(t) during early ROSC in cardiac arrest patients suggest high hospital mortality. If future studies validate this model, the P(a-et)CO(2) and V(dA)/V(t) may provide useful guidelines for the early post-resuscitation care of cardiac arrest patients in emergency departments.

**Prause G, Hetz H, Lauda P, Pojer H, Smolle-Juettner F, Smolle J.**
Resuscitation. 1997 Oct;35(2):145-8.
**A comparison of the end-tidal-CO2 documented by capnometry and the arterial pCO2 in emergency patients.**
Department of Anaesthesiology and Intensive Care Medicine, University of Graz, Austria.
gerhard.prause@kfunigraz.ac.at
Abstract
Satisfactory artificial ventilation is defined as sufficient oxygenation and normo- or slight arterial hypocarbia. Monitoring end tidal CO2 values with non-invasive capnometry is a routine procedure in anaesthesia, emergency medicine and intensive care. In anaesthesia the ventilation volume is adjusted to the capnometric end tidal CO2 (ETCO2), taking into account a normal variation from the pACO2 of 3-8 mmHg. We evaluated

the usefulness and practicability of using ETCO2 for correctly adjusting ventilation parameters in prehospital emergency care, by comparing arterial pCO2 and ETCO2 of 27 intubated and ventilated patients. We used the side-stream capnometry module of the Defigard 2000 (Bruker, ChemoMedica Austria) and a portable blood gas analyzer (OPTI 1, AVL Graz, Austria). Evaluation of the group of patients as a whole showed that there was no correlation whatsoever between the end expiratory and arterial CO2. Dividing the patients into three subgroups (1, During CPR; II, respiratory disturbances of pulmonary and cardiac origin; III, extrapulmonary respiratory disturbances), we found that only patients without primary cardiorespiratory damage showed a slight, but not statistically significant, correlation. This can be explained by the fact that almost any degree of cardiorespiratory failure causes changes of the ventilation-perfusion ratio, impairing pulmonary CO2 elimination. We conclude, that the ventilation of emergency patients can only be correctly adjusted according to values derived from an arterial blood gas analysis and ETCO2 measurements cannot be absolutely relied upon for accuracy except, perhaps, in patients without primary cardiorespiratory dysfunction.

**Safar P, Xiao F, Radovsky A, Tanigawa K, Ebmeyer U, Bircher N, Alexander H, Stezoski SW.**
Stroke. 1996 Jan;27(1):105-13.
**Improved cerebral resuscitation from cardiac arrest in dogs with mild hypothermia plus blood flow promotion.**
Safar Center for Resuscitation Research, University of Pittsburgh, Pa. 15260, USA.
Abstract
BACKGROUND AND PURPOSE:
In past studies, cerebral outcome after normothermic cardiac arrest of 10 or 12.5 minutes in dogs was improved but not normalized by resuscitative (postarrest) treatment with either mild hypothermia or hypertension plus hemodilution. We hypothesized that a multifaceted combination treatment would achieve complete cerebral recovery.
METHODS:
With our established dog outcome model, normothermic ventricular fibrillation of 11 minutes (without blood flow) was followed by controlled reperfusion (with brief normothermic cardiopulmonary bypass simulating low flow and low PaO2 of external cardiopulmonary resuscitation) and defibrillation at < 2 minutes. Controlled ventilation was provided to 20 hours and intensive care to 96 hours. Control group 1 (n = 8) was kept normothermic (37.5 degrees C), normotensive, and hypocapnic throughout. Experimental group 2 (n = 8) received mild resuscitative hypothermia (34 degrees C) from about 10 minutes to 12 hours (by external and peritoneal cooling) plus cerebral blood flow promotion with induced moderate hypertension, mild hemodilution, and normocapnia.
RESULTS:
All 16 dogs in the protocol survived. At 96 hours, all 8 dogs in control group 1 achieved overall performance categories 3 (severe disability) or 4 (coma). In group 2, 6 of 8 dogs achieved overall performance category 1 (normal); 1 dog achieved category 2 (moderate disability), and 1 dog achieved category 3 (P < .001). Final neurological deficit scores (0% [normal] to 100% [brain death]) at 96 hours were 38 +/- 10% (22% to 45%) in group 1 versus 8 +/- 9% (0% to 27%) in group 2 (P < .001). Total brain histopathologic damage scores were 138 +/- 22 (110 to 176) in group 1 versus 43 +/- 9 (32 to 56) in group 2 (P < .001). Regional scores showed similar group differences.
CONCLUSIONS:
After normothermic cardiac arrest of 11 minutes in dogs, resuscitative mild hypothermia plus cerebral blood flow promotion can achieve functional recovery with the least histological brain damage yet observed with the same model and comparable insults.

**Salen P, O'Connor R, Sierzenski P, Passarello B, Pancu D, Melanson S, Arcona S, Reed J, Heller M.**
Acad Emerg Med. 2001 Jun;8(6):610-5.
**Can cardiac sonography and capnography be used independently and in combination to predict resuscitation outcomes?**
St. Luke's Hospital Emergency Medicine Residency, Bethlehem, PA 18015, USA. salenp@slhn.org
Abstract
OBJECTIVE:
To measure the ability of cardiac sonography and capnography to predict survival of cardiac arrest patients in the emergency department (ED).
METHODS:
Nonconsecutive cardiac arrest patients prospectively underwent either cardiac ultrasonography alone or in conjunction with capnography during cardiopulmonary resuscitation at two community hospital EDs with emergency medicine residency programs. Cardiac ultrasonography was carried out using the subxiphoid view during pauses for central pulse evaluation and end-tidal carbon dioxide (ETCO(2)) levels were monitored by a mainstream capnograph. A post-resuscitation data collection form was completed by each of the participating clinicians in order to assess their impressions of the facility of performance and benefit of cardiac sonography during nontraumatic cardiac resuscitation.
RESULTS:
One hundred two patients were enrolled over a 12-month period. All patients underwent cardiac sonographic evaluation, ranging from one to five scans, during the cardiac resuscitation. Fifty-three patients also had capnography measurements recorded. The presence of sonographically identified cardiac activity at any point during the resuscitation was associated with survival to hospital admission, 11/41 or 27%, in contrast to those without cardiac activity, 2/61 or 3% ($p < 0.001$). Higher median ETCO(2) levels, 35 torr, were associated with improved chances of survival than the median ETCO(2) levels for nonsurvivors, 13.7 torr ($p < 0.01$). The multivariate logistic regression model, which evaluated the combination of cardiac ultrasonography and capnography, was able to correctly classify 92.4% of the subjects; however, of the two diagnostic tests, only capnography was a significant predictor of survival. The stepwise logistic regression model, summarized by the area under the receiver operator curve of 0.9, furthermore demonstrated that capnography is an outstanding predictor of survival.
CONCLUSIONS:
Both the sonographic detection of cardiac activity and ETCO(2) levels higher than 16 torr were significantly associated with survival from ED resuscitation; however, logistic regression analysis demonstrated that prediction of survival using capnography was not enhanced by the addition of cardiac sonography.

**Stauffer JL, Fayter NA, Graves B, Cromb M, Lynch JC, Goebel P.**
Chest. 1993 Oct;104(4):1222-9.
**Survival following mechanical ventilation for acute respiratory failure in adult men.**
Veterans Administration Medical Center, Fresno, Calif.
Abstract
STUDY DESIGN:
Survival following mechanical ventilation for acute respiratory failure has important implications for medical decision-making and allocation of expensive resources for critical care.

PROCEDURE:
We reviewed a 5-year experience with mechanical ventilation in 383 men with acute respiratory failure and studied the impact of patient age, cause of acute respiratory failure, and duration of mechanical ventilation on survival. Survival rates were 66.6 percent to weaning, 61.1 percent to ICU discharge, 49.6 percent to hospital discharge, and 30.1 percent to 1 year after hospital discharge. When our data were combined with 10 previously reported series, mean survival rates were calculated to be 62 percent to ventilator weaning, 46 percent to ICU discharge, 43 percent to hospital discharge, and 30 percent to 1 year after discharge. Of 255 patients weaned from mechanical ventilation, 44 (17.3 percent) required an additional period of mechanical ventilation during the same hospitalization.
RESULTS:
Age had a significant influence on survival to hospital discharge and on that to 1 year after hospital discharge, and the cause of acute respiratory failure had a significant influence on survival only to weaning. Survival was best in younger patients and those with COPD or postoperative respiratory failure and worst in patients resuscitated after cardiac or respiratory arrest. Increased duration of mechanical ventilation significantly reduced survival only to hospital discharge. Overall survival was significantly affected by age and cause of acute respiratory failure, but not by duration of mechanical ventilation.
CONCLUSION:
We conclude that age, cause of acute respiratory failure, and duration of mechanical ventilation have specific influences on the generally poor outcome of mechanical ventilation for acute respiratory failure.

**Sunde K, Pytte M, Jacobsen D, Mangschau A, Jensen LP, Smedsrud C, Draegni T, Steen PA.**
Resuscitation. 2007 Apr;73(1):29-39. Epub 2007 Jan 25.
**Implementation of a standardised treatment protocol for post resuscitation care after out-of-hospital cardiac arrest.**
Department of Anaesthesiology, Ulleval University Hospital, Oslo, Norway. kjetil.sunde@medisin.uio.no
Abstract
BACKGROUND:
Mortality among patients admitted to hospital after out-of-hospital cardiac arrest (OHCA) is high. Based on recent scientific evidence with a main goal of improving survival, we introduced and implemented a standardised post resuscitation protocol focusing on vital organ function including therapeutic hypothermia, percutaneous coronary intervention (PCI), control of haemodynamics, blood glucose, ventilation and seizures.
METHODS:
All patients with OHCA of cardiac aetiology admitted to the ICU from September 2003 to May 2005 (intervention period) were included in a prospective, observational study and compared to controls from February 1996 to February 1998.
RESULTS:
In the control period 15/58 (26%) survived to hospital discharge with a favourable neurological outcome versus 34 of 61 (56%) in the intervention period (OR 3.61, CI 1.66-7.84, p=0.001). All survivors with a favourable neurological outcome in both groups were still alive 1 year after discharge. Two patients from the control period were revascularised with thrombolytics versus 30 (49%) receiving PCI treatment in the intervention period (47 patients (77%) underwent cardiac angiography). Therapeutic hypothermia was not used in the control period, but 40 of 52 (77%) comatose patients received this treatment in the intervention period.

CONCLUSIONS:
Discharge rate from hospital, neurological outcome and 1-year survival improved after standardisation of post resuscitation care. Based on a multivariate logistic analysis, hospital treatment in the intervention period was the most important independent predictor of survival.

**Todd MM, Tommasino C, Shapiro HM.**
Crit Care Med. 1985 Sep;13(9):720-3.
**Cerebrovascular effects of prolonged hypocarbia and hypercarbia after experimental global ischemia in cats.**
Abstract
Hyperventilation therapy is often recommended after an episode of global cerebral ischemia (cardiac arrest), even though several workers have shown that under such circumstances the cerebral vasculature is unresponsive to changing PaCO2. However, no study has examined the effects of prolonged PaCO2 changes. We therefore studied the cerebrovascular effects of a 3-h period of continuous hypercarbia (40 to 45 torr) or hypocarbia (15 to 20 torr) in cats resuscitated from 12 min of electrically induced ventricular fibrillation. There were no differences in postresuscitation cerebral blood flow (CBF) or EEG, but intracranial pressure was lower in the hypocapnic animals. Furthermore, hypocapnic cats retained some CBF responsiveness to varying PaCO2 levels, while no such response was noted in previously hypercapnic animals. These findings suggest that some measurable changes in postarrest cerebrovascular behavior can result from prolonged hypocapnia (possibly related to tissue pH alterations). Whether such changes will have clinical utility is unclear.

**Vanicky I, Marsala M, Murár J, Marsala J.**
Neurosci Lett. 1992 Feb 3;135(2):167-70.
**Prolonged postischemic hyperventilation reduces acute neuronal damage after 15 min of cardiac arrest in the dog.**
Institute of Neurobiology, Slovak Academy of Sciences, Kosice.
Abstract
Hyperventilation is commonly used as a constituent of antiedematous therapy after global cerebral ischemia. The effect of hyperventilation on brain functions, however, is complex, and a number of mechanisms involved remains unclear. In this study, we attempted to determine whether postischemic hyperventilation influences acute neuronal changes developing during recirculation. Two groups of dogs underwent 15 min of cardiac arrest and cardiopulmonary resuscitation with an 8 h survival. After resuscitation, in group A the internal environment was maintained in the physiological ranges. In group B the animals were artificially hyperventilated maintaining a high level of respiratory alkalosis during recirculation. Histopathological examination of the vulnerable structures was performed using the Nauta degenerating method and the argyrophilic neurons were counted. Statistically significant amelioration in group B suggests that postischemic hyperventilation may act as a neuroprotective factor.