

WORKSHEET for Evidence-Based Review of Science for Emergency Cardiac Care**Worksheet author(s)**

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Date Submitted for review: 2009 06 17**Clinical question.**

"In adult cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of physiological feedback regarding CPR quality (e.g. End-tidal CO2 monitoring) (I) compared with no feedback (C), improve any outcomes (eg. ROSC, survival) (O)?"

Is this question addressing an intervention/therapy, prognosis or diagnosis? Intervention/therapy

State if this is a proposed new topic or revision of existing worksheet: New Worksheet

Conflict of interest specific to this question

Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet? No.

Search strategy (including electronic databases searched).Pubmed

"Heart Arrest"[Mesh] AND "Cardiopulmonary Resuscitation"[Mesh]
AND ("Capnography"[Mesh] OR "Monitoring, Physiologic"[Mesh] OR "Oximetry"[Mesh] OR "Carbon Dioxide"[Mesh] OR
"Continuous SVO2 monitoring" OR "CPP" OR "Cerebral Perfusion Pressure" OR "Aortic Diastolic Pressure") AND ("Survival
Analysis"[Mesh] OR "Outcome Assessment (Health Care)"[Mesh]) OR "Survival/statistics and numerical data"[Mesh]) OR
"Mortality"[Mesh]

Results: 56

Embase

'heart arrest'/exp AND 'resuscitation'/exp AND ('capnography'/exp OR 'monitoring'/exp OR 'oximetry'/exp OR 'carbon dioxide'/exp
OR 'Continuous SVO2 monitoring' OR 'CPP' OR 'Cerebral Perfusion Pressure' OR 'Aortic Diastolic Pressure') AND
('survival'/exp OR 'mortality'/exp OR 'outcome assessment'/exp)

Results: 96

Cochrane

cardiopulmonary resuscitation AND (heart arrest OR cardiac arrest) AND (survival OR mortality OR outcomes) AND (capnography
OR capnograph OR physiologic monitoring OR carbon dioxide OR co2 OR Continuous SVO2 monitoring OR CPP OR Cerebral
Perfusion Pressure OR Aortic Diastolic Pressure)

Results: 7

- State inclusion and exclusion criteria

Include human studies

Exclude all case reports (<3 subjects)

Exclude all animal studies

Exclude all studies using physiologic monitoring for termination rules

Exclude studies that do not include outcomes

Exclude pediatric studies

- Number of articles/sources meeting criteria for further review:

Pubmed: 56

Embase: 96

Cochrane: 7

Author/ILCOR nominated: 3

17 Full Text studies were classified as Evidence Neutral LOE 4 (6 Good, 7 Fair, 4 Poor) and were included in the review.

Summary of evidence

Evidence Supporting Clinical Question

Good					
Fair					
Poor					
	1	2	3	4	5
Level of evidence					

A = Return of spontaneous circulation
 B = Survival of event

C = Survival to hospital discharge
 D = Intact neurological survival

E = Other endpoint
Italics = Animal studies

Evidence Neutral to Clinical question

Good				Wayne, 1995, 764 A, B, C, E Levine, 1997, 303 A, B, C, O Grmec, 2001, 263 A, B, C, D, E Grmec, 2003, 142 A, E Chollet-Xemard, 2009, 215 A, B, C, D Grmec, 2007, 408-9 A, B, C, E	
Fair				Grmec, 2003, 92 A Callaham, 1990, 358 A, B Cantineau, 1996 A Salen, 2001, 612 A B Varon, 1991, 291 A, B, C, E Ornato, 1994, 521 A, E Kolar, 2008, 117 A, B, E	
Poor				Paradis, 1990, 1106 A, B, C Steedman, 1990, 131 A Rivers, 1994, 1093 A, B, C, D Sehra, 2003, 516 A, E	
	1	2	3	4	5
Level of evidence					

A = Return of spontaneous circulation
 B = Survival of event

C = Survival to hospital discharge
 D = Intact neurological survival

E = Other endpoint
Italics = Animal studies

Evidence Opposing Clinical Question

Good					
Fair					
Poor					
	1	2	3	4	5
Level of evidence					

A = Return of spontaneous circulation
 B = Survival of event

C = Survival to hospital discharge
 D = Intact neurological survival

E = Other endpoint
Italics = Animal studies

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

The question asked, "In adult cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of physiological feedback regarding CPR quality (e.g. End-tidal CO₂ monitoring) (I) compared with no feedback (C), improve any outcomes (e.g. ROSC, survival) (O)?" This question is specifically referring to a physiologic monitoring intervention such as the use of ETCO₂ feedback and how the use of these interventions would improve outcomes. Of the 17 chosen for this worksheet, none specifically looked at physiologic feedback as an intervention for improving outcome although some of the studies did look at using physiologic feedback in relation to ROSC.

ETCO₂ was the physiologic measure reported most frequently. Nine studies demonstrated an increase in ETCO₂ values when ROSC occurred (Callahan, 1990, 358-362; Cantineau, 1996, 791-796; Grmec, 2003, 92; Grmec, 2003, 142; Grmec, 2001, 264; Kolar, 2008, 117; Ornato, 1992; 521; Shera, 2003, 516; Steedman, 1990, 131). It was also shown that ETCO₂ rose in those patients who obtained ROSC before it was shown by vitals signs (Grmec, 2007, pg 207). Sehra, 2003, 516 found that ETCO₂ fell during VF and then rose significantly after ROSC. Grmec 2008, 408 also found that initial PetCO₂ was higher not only for those who achieved ROSC but also for those who survived.

Cantineau, 1996, 791; Kolar, 2008, 117; Levine, 1997, 303; Varon, 1991, 291; Wayne, 1995, 765, found that ETCO₂ was accurate to predict patients who were not able to be resuscitated, some gave a time frame for that prediction of 20 minutes. Grmec, 2001, pg 284; Grmec, 2003, pg 92; Grmec, 2003, 142 and Grmec, 2006, 409 showed when ETCO₂ rose above 10 mm Hg, all patients in their studies had ROSC and in the Grmec 2003 study those patients survived. Similarly, Levine, 1997, 303 and Wayne, 1995, 765 showed that if the ETCO₂ did not rise above 10 mmHg, survival was zero. Another study cited within Levine's paper showed that "Although an end-tidal carbon dioxide level of at least 10 mm Hg did not guarantee successful resuscitation, no patient with a value of less than 10 mm Hg was resuscitated" (Sanders, 1989).

Other physiologic measures have been reported in the literature. Rivers et al (1992, 1098) found that patients with ROSC had higher mean and maximal central venous oxygen saturations than those with no ROSC. Similarly, this trend can be seen when looking at Coronary Perfusion Pressure as shown in the manuscript by Paradis 1990, 1107. Conversely, Chollet-Xemard, 2009, 215 found the using BIS during cardiac arrest played no significant role in predicting ROSC or outcomes. Rivers, 1994, 1093 found similar ROSC predictions with central venous oxygen saturation, "No patient attained return of spontaneous circulation without reaching a central venous oxygen saturation of at least 30%." A central venous oxygen saturation of greater than 72% was 100% predictive of return of spontaneous circulation." Paradis, 1990, 1106 also found that no patient with an initial coronary perfusion pressure of zero had ROSC.

Acknowledgements:

Dr. Laurie Morrison and Dr. Steven Brooks for guidance.
Co-reviewer Marion Leary and I worked closely on the final CoSTAR.

Citation List

1. Callahan M, Barton C. (1990). Prediction of outcome of cardiopulmonary resuscitation from end-tidal carbon dioxide concentration.[see comment]. *Critical Care Medicine*, 18(4): 358-362.

Summary: LOE 4 (No control group, prospective study), Fair, Evidence Neutral, ETCO₂ for prediction of ROSC

Abstract summary taken directly from manuscript and edited: Fifty-five patients were included in the study. PetCO₂ was initiated in the emergency department and monitored throughout the resuscitation. Fourteen patients achieved ROSC and forty-one patients did not. Patients who achieved ROSC had a mean PetCO₂ of 19 +/- 14 (SD) torr at the start versus 5 +/- 4 (SD) for those who did not achieve ROSC. An initial PetCO₂ of 15 torr predicted ROSC with a sensitivity of 71% and a specificity of 98%.

2. Cantineau, J. P., Lambert, Y., Merckx, P., Reynaud, P., Porte, F., Bertrand, C., et al. (1996). End-tidal carbon dioxide during cardiopulmonary resuscitation in humans presenting mostly with asystole: A predictor of outcome. *Critical Care Medicine*, 24(5), 791-796.

Summary: LOE 4 (No control group, prospective study), Fair, Evidence Neutral, ETCO₂ for prediction of ROSC

Abstract summary taken directly from manuscript and edited: 120 nontraumatic prehospital cardiac arrests. Eight patients were successfully resuscitated. ROSC was associated with significant increase in ETCO₂. An initial ETCO₂ of more than 10 torr predicted ROSC with a sensitivity of 87% and a specificity of 74%. A maximal end-tidal CO₂ during the first 20 mins after tracheal intubation predicted ROSC with a sensitivity of 100% and a specificity of 66%.

3. Grmec S, Krizmaric M, Mally S, Kozelj A, Spindler M, & Lesnik B. (2007). Utstein style analysis of out-of-hospital cardiac arrest--bystander CPR and end expired carbon dioxide. *Resuscitation*, 72(3), 404-405-414.

Summary: LOE 4 (No control group, prospective cohort study), Good, Evidence Neutral, ETCO₂ for prediction of ROSC and prognostication

Abstract summary taken directly from manuscript and edited: 389 patients, 237 with ROSC, 195 had ROSC at hospital admission. Eighty-two had survival to discharge. Initial petCO₂ were significantly higher in patients with ROSC on admission to hospital and in those who survived. Final petCO₂ were significantly higher in the group of patients with ROSC on admission to hospital compared with those without ROSC and in those who survived. In 158 of all 195 ROSC the first sign of ROSC was a rise in petCO₂ before palpable pulse or blood pressure was detected.

4. Grmec S, & Kupnik D. (2003). Does the mainz emergency evaluation scoring (MEES) in combination with capnometry (MEESc) help in the prognosis of outcome from cardiopulmonary resuscitation in a prehospital setting? *Resuscitation*, 58(1), 89-90-96.

Summary: LOE 4 (No control group, prospective study), Good, Evidence Neutral, ETCO₂ for prediction of ROSC and prognostication

Abstract summary taken directly from manuscript and edited: 246 patients who had normothermic nontraumatic cardiac arrest. 130 had ROSC, 39 survived to discharge and 10 were alive at one year. Initial petCO₂ were significantly higher in patients with ROSC compared with the group of patients without ROSC. The initial values of petCO₂ were also significantly higher in those who survived compared with those who did not survive. The final values of petCO₂ were significantly higher in the group of patient with ROSC compared with those without ROSC and the final values were significantly higher in those who survived compared with those who died.

5. Grmec, S., Lah, K., & Tusek-Bunc, K. (2003). Difference in end-tidal CO₂ between asphyxia cardiac arrest and ventricular fibrillation/pulseless ventricular tachycardia cardiac arrest in the prehospital setting. *Critical Care (London, England)*, 7(6), R139-44.

Summary: LOE 4 (No control group, prospective observational study), Fair, Evidence Neutral, ETCO₂ for prediction of ROSC

Abstract summary taken directly from manuscript and edited: 141 patients with primary cardiac arrest and 44 patients with cardiac arrest due to asphyxia. In the group of patients who presented with VF/VT there was a significant difference in the initial values of PetCO₂ between patient who had ROSC and without ROSC. In all patients with ROSC the initial PetCO₂ was higher than 10mmHg. In both groups significantly higher values were achieved in patient with ROSC than in those without ROSC. The values of the final PetCO₂ in both groups were significantly higher in patients with ROSC than in the patient without ROSC.

6. Grmec, S., & Klemen, P. (2001). Does the end-tidal carbon dioxide (EtCO₂) concentration have prognostic value during out-of-hospital cardiac arrest?. *European Journal of Emergency Medicine*, 8(4), 263-269.

Summary: LOE 4 (No control group, prospective study), Good, Evidence Neutral, ETCO₂ for prediction of ROSC and prognostication

Abstract summary taken directly from manuscript and edited: 139 adult patients of out-of-hospital non-traumatic cardiac arrest. The initial, final, average, minimal and maximal ETCO₂ was found to be significantly higher in resuscitated patients than in non-resuscitated patients. Using an initial, average and final ETCO₂ value of 10 mmHg, 100% of resuscitated patients were correctly identified with a specificity of 74.1%, 90%, 81.4%.

7. Kolar, M., Krizmaric, M., Klemen, P., & Grmec, S. (2008). Partial pressure of end-tidal carbon dioxide successful predicts cardiopulmonary resuscitation in the field: A prospective observational study. *Critical Care (London, England)*, 12(5), R115.

Summary: LOE 4 (prospective, observational study), Fair, Evidence Neutral, ETCO₂ for prediction of ROSC and prognostication.

Abstract summary taken directly from manuscript and edited: Seven hundred and thirty seven out-of-hospital arrest patients. It was hypothesized that an end-tidal of 1.9 kPa or more after 20 minutes of standard advanced cardiac life support would predict ROSC. End-tidal carbon dioxide of 1.9 kPa or less discriminated between the 402 patients who had ROSC and the 335 who did not have ROSC. When a 20-minute end-tidal carbon dioxide value of 1.9 kPa (14.3 mmHg) or less was used as a screening test to predict ROSC, the sensitivity, specificity, positive predictive value, and negative predictive value were all 100%.

8. Levin, P. D., & Pizov, R. (1997). End-tidal carbon dioxide and outcome of out-of-hospital cardiac arrest. *New England Journal of Medicine*, 337(23), 1694-1695.

Summary: LOE 4 (No control group, prospective, observational study), Good, Neutral, ETCO₂ for prediction of ROSC and prognostication

Abstract summary taken directly from manuscript and edited: One-hundred and fifty out-of-hospital cardiac arrest patients who had electrical activity but no pulse. At 20-minutes, an ETCO₂ value of 10 mmHg or less successfully discriminated between the 35 patients who survived to hospital admission and the 115 nonsurvivors. When a 20-minute end-tidal carbon dioxide value of 10 mmHg or less was used as a screening test to predict death, the sensitivity, specificity, positive predictive value, and negative predictive value were all 100 percent.

9. Ornato, J., Shipley, J., Racht, E., Slovis, C., Wrenn, K., P., PE, et al. (1992). Multicenter study of a portable, hand-size, colorimetric end-tidal carbon dioxide detection device. *Annals of Emergency Medicine*, 21(5), 518-519-523.

Summary: LOE 4 (prospective study), Evidence Neutral, ETCO₂ for prediction of ROSC and adequacy of CPR.

Abstract summary taken directly from manuscript and edited: Two-hundred and twenty-seven patients were enrolled in the study, 144 of which had a cardiopulmonary arrest. In the cardiac arrest patients, a longer period of arrest appeared to be associated with a lower ETCO₂ reading. All patients who survived to hospital admission had an initial ETCO₂ measurement signifying more than 0.5%. ROSC was usually accompanied by an improved ETCO₂. Mechanical CPR always produced an ETCO₂ value that was as high or higher than that produced by manual CPR.

10. Paradis, N., Martin, G., Rivers, E., Goetting, M., Appleton, T., Feingold, M., Nowak, R (1990). Coronary Perfusion Pressure and the Return of Spontaneous Circulation in Human Cardiopulmonary Resuscitation. *JAMA*, 263(8), 1106-1114.

Summary: LOE 4, Evidence Neutral, Poor, CPP for prediction of ROSC.

Abstract summary taken directly from manuscript and edited: One hundred cardiac arrest patients had Coronary Perfusion Pressure (CPP) measured. Twenty-four patients had ROSC. Initial CPP was 1.6 +/- 8.5 mm Hg in patients without ROSC and 13.4 +/- 8.5 mm Hg in patients with ROSC. No patient with an initial CPP less than 0 mm Hg had ROSC.

11. Rivers, E., Martin, G., Smithline, H., Randy, M., Schultz, CH., Goetting, M., Appleton, T., Nowark, R (1994). The Clinical Implications of Continuous Central Venous Oxygen Saturation During Human CPR. *Annals of Emergency Medicine*, 21 (9), 73-80.

Summary: LOE 4, Evidence Neutral, Poor, Continuous Central Venous Oxygen Saturation for prediction of ROSC.

Abstract summary taken directly from manuscript and edited: One hundred patients who suffered a cardiac arrest had Continuous Central Venous Oxygen Saturation measured. The patients with ROSC had initial and statistically higher mean and maximal central venous oxygen saturation than those without ROSC. No patients achieved ROSC without a central venous oxygen saturation of at least 30%. A central venous oxygen saturation of greater than 72% was 100% predictive of ROSC.

12. Salen, P., O'Connor, R., Sierzenski, P., Passarello, B., Pancu, D., Melanson, S., et al. (2001). Can cardiac zoography and capnography be used independently and in combination to predict resuscitation outcomes?[see comment]. *Academic Emergency Medicine*, 8(6), 610-615.

Summary: LOE 4 (No control group, prospective study), Fair, Neutral, ETCO2 for prognostication

Abstract summary taken directly from manuscript and edited: One hundred two patients all underwent cardiac sonography during cardiac arrest. Fifty-three had capnography measurements as well. Higher median ETCO2 levels, 35 torr, were associated with improved chances of survival than the median ETCO2 levels for nonsurvivors, 13.7 torr ($p > 0.01$) No patient with an ETCO2 less than 16 torr survived.

13. Sehra, R., Underwood, K., & Checchia, P. (2003). End tidal CO2 is a quantitative measure of cardiac arrest. *Pacing & Clinical Electrophysiology*, 26(1 Pt 2), 515-517.

Summary: LOE 4 (No control group, observational study), Poor, Evidence Neutral, ETCO2 for prediction of ROSC

Abstract summary taken directly from manuscript and edited: Thirty-one cardiac arrest/VF episodes that underwent defibrillation for ICD implant for ventricular tachycardia or previous cardiac arrest were evaluated with continuous ETCO monitoring during defibrillation threshold testing. Significant difference ($p > 0.001$) were noted between ETCO values prior versus during VF and during VF versus return of spontaneous circulation. ETCO2 decreased from pre-VF to during VF. It increased during VF to ROSC.

14. Steedman, D. J., & Robertson, C. E. (1990). Measurement of end-tidal carbon dioxide concentration during cardiopulmonary resuscitation. *Archives of Emergency Medicine*, 7(3), 129-134.

Summary: LOE 4 (No control group, prospective study), Poor, Evidence Supporting, ETCO2 for prediction of ROSC and adequacy of CPR.

Abstract summary taken directly from manuscript and edited: Twelve cardiac arrest patients undergoing cardiopulmonary resuscitation. Return of spontaneous circulation occurred in five patients. Changes in end-tidal CO2 were often the first indication of return of spontaneous cardiac output. ETCO2 provides a simple and non-invasive method of measuring blood flow during CPR and can indicate ROSC.

15. Varon, A., Morrina, J., & Civetta, J. (1991). Clinical utility of a colorimetric end-tidal CO₂ detector in cardiopulmonary resuscitation and emergency intubation. *Journal of Clinical Monitoring and Computing*, 7(4), 289-290-293.

Summary: LOE 4 (No control group, prospective study), Fair, Neutral, ETCO₂ for prediction of ROSC, prognostication and adequacy of CPR.

Abstract summary taken directly from manuscript and edited: One-hundred and ten patients requiring emergency intubation, 57 of which were intubated for cardiac arrest. A low ETCO₂ color range in 19 patients undergoing CPR was interpreted as low cardiac output and prompted the physicians to attempt to increase perfusion. No patients whose ETCO₂ level remained less than 2% was successfully resuscitated. Those who had an ETCO₂ greater than or equal to 2% had a significantly higher incidence of successful resuscitation.

16. Wayne, M. A., Levine, R. L., & Miller, C. C. (1995). Use of end-tidal carbon dioxide to predict outcome in pre-hospital cardiac arrest. *Annals of Emergency Medicine*, 25(6), 762-767.

Summary: LOE 4 (No control group, prospective, observational study), Good, Neutral, ETCO₂ for prediction of ROSC and prognostication.

Abstract summary taken directly from manuscript and edited: Ninety subjects were enrolled. Using ETCO₂ of 10 mmHg or less as a theoretical threshold to predict death in the field successfully discriminated between 16 survivors to hospital admission and 75 pre-hospital deaths. Of the 16 survivors, 9 died in hospital and 7 were discharged from the hospital alive. In 13 of 16 survivors, the first evidence of return of spontaneous circulation, before a palpable pulse or blood pressure, was a rising ETCO₂.

17. Chollet-Xemard, C, Combes, X, Soupizet, F, Jabre, P, Penet, C, Bertrand, C Margenet & A, Marty, J (2009). Bispectral index monitoring is useless during cardiac arrest patients' resuscitation. *Resuscitation*, 80, 213-216.

Summary: LOE 4 (No control group, prospective, observational study), Good, Neutral, BIS for prediction of ROSC and survival to discharge.

Abstract summary taken directly from manuscript and edited: Ninety-two out-of-hospital cardiac arrest patients were included in the study. Sixty-two died on-scene and thirty had ROSC and were admitted to the hospital. Of the thirty patients twenty-seven died and three were discharged neurologically intact. There were no significant differences in BIS values for those who had ROSC and those who did not. There was also no significant difference between those who survived and those who expired.