**WORKSHEET for Evidence-Based Review of Science for Emergency Cardiac Care**

**Worksheet author(s)**

| Marion Leary, RN, BSN | Date Submitted for review: |

**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? Minor: have received $750 honorarium from Philips for a lecture on CPR quality; vetted by Dr Morrison (10/08)

**Search strategy (including electronic databases searched). Last search 09/09/09**

Searched OVID and PUBMED and Cochrane and EMBASE and AHA End Note databases using the following terms:

(cardiac arrest OR cardiopulmonary resuscitation OR CPR)

AND

(capnography OR end-tidal CO2 OR ETCO2 AND Feedback)

AND

(Quality AND Feedback)

AND

(Outcomes OR ROSC OR Return of Spontaneous Circulation OR Survival)

AND

(In-hospital OR Pre-hospital OR Out-of-Hospital)

AND

(Physiologic Monitoring AND CPR OR cardiopulmonary resuscitation)

AND

(Continuous SVO2 monitoring AND CPR OR cardiopulmonary resuscitation)

AND

(CPP OR Cerebral Perfusion Pressure AND CPR OR cardiopulmonary resuscitation)

AND

(Aortic Diastolic Pressure AND CPR OR cardiopulmonary resuscitation)

**State inclusion and exclusion criteria**

Include human adult studies

Exclude all case reports (<3 subjects)

Exclude all studies using physiologic monitoring for termination rules

Exclude studies that do not include outcomes

Exclude pediatric studies and animal studies
• Number of articles/sources meeting criteria for further review:

Pubmed:
- ("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 ETCO2[All Fields] = 37

- ("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 (End[All Fields] AND Tidal[All Fields] AND CO2[All Fields]) = 84

- ("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 (End[All Fields] AND Tidal[All Fields] AND CO2[All Fields]) AND Outcome[All Fields] = 20

CPR or Cardiopulmonary resuscitation AND Physiologic Monitoring = 93
CPR or Cardiopulmonary resuscitation AND Continuous SVO2 monitoring = 0
CPR or Cardiopulmonary resuscitation AND Aortic Diastolic Pressure monitoring = 17
Cardiac Arrest AND Physiologic Monitoring AND CPR or Cardiopulmonary resuscitation = 117

Ovid:
- Cardiac Arrest or Heart Arrest AND Capnography/ or Monitoring or Physiologic/ or Carbon Dioxide AND ETCO2 = 28
- Cardiac Arrest or Heart Arrest AND Capnography/ or Monitoring or Physiologic/ or Carbon Dioxide AND ETCO2 OR End Tidal CO2 = 67
- Cardiac Arrest or Heart Arrest AND Capnography/ or Monitoring or Physiologic/ or Carbon Dioxide AND ETCO2 AND CPR or Cardiopulmonary Resuscitation = 47
  - CPR’ or ‘Cardiopulmonary resuscitation AND ‘Physiologic Monitoring’ = 148
  - CPR’ or ‘Cardiopulmonary resuscitation AND ‘Cardiac Arrest’ or ‘heart arrest’ AND ‘Continuous SVO2 monitoring’ or ‘Swanz-Ganz Catheter’ AND ‘Physiologic Monitoring’ = 71
  - CPR’ or ‘Cardiopulmonary resuscitation AND ‘Cardiac Arrest’ or ‘heart arrest’ AND ‘Aortic Diastolic Pressure monitoring’ = 7
  - CPR’ or ‘Cardiopulmonary resuscitation AND ‘Cardiac Arrest’ or ‘heart arrest’ AND ‘Cerebral Perfusion Pressure monitoring’ = 17
  - ‘Cardiac Arrest’ or ‘heart arrest’ AND ‘Physiologic Monitoring’ = 71
  - ‘Cardiac Arrest’ AND ‘Physiologic Monitoring’ AND ‘CPR’ OR ‘Cardiopulmonary resuscitation’ = 168

Cochrane:
- ‘Cardiac Arrest’ AND ‘ETCO2’ = 8
- ‘Cardiac Arrest’ AND ‘ETCO2’ AND ‘Outcomes’ = 2
- ‘Cardiopulmonary Resuscitation’ AND ‘Capnography’ = 3
- ‘CPR’ AND ‘ETCO2’ = 12
- ‘Cardiopulmonary Resuscitation’ OR ‘CPR’ AND ‘Capnography’ OR ‘ETCO2’ = 12
- ‘CPR’ OR ‘Cardiopulmonary resuscitation AND ‘Physiologic Monitoring’ = 3
- ‘CPR’ OR ‘Cardiopulmonary resuscitation AND ‘Continuous SVO2 monitoring’ = 3
- ‘CPR’ OR ‘Cardiopulmonary resuscitation AND ‘Aortic Diastolic Pressure monitoring’ = 3
- ‘CPR’ OR ‘Cardiopulmonary resuscitation AND ‘Cerebral Perfusion Pressure monitoring’ = 3
- ‘Cardiac Arrest’ AND ‘Physiologic Monitoring’ = 4
- ‘Cardiac Arrest’ AND ‘Physiologic Monitoring’ AND ‘CPR’ OR ‘Cardiopulmonary resuscitation’ = 3

EMBASE:
- ‘cardiac arrest’ AND ‘etco2’ OR ‘end-tidal CO2’ OR ‘capnography’ AND ‘cardiopulmonary resuscitation’ or ‘CPR’ = 73
- ‘cardiac arrest’ AND ‘etco2’ AND ‘rosc’ = 2
- ‘cardiac arrest’ AND ‘etco2’ AND ‘cardiopulmonary resuscitation’ = 4
- ‘CPR’ OR ‘Cardiopulmonary resuscitation AND ‘Physiologic Monitoring’ = 93
- ‘CPR’ OR ‘Cardiopulmonary resuscitation AND ‘Continuous SVO2 monitoring’ = 0
- ‘CPR’ OR ‘Cardiopulmonary resuscitation AND ‘Aortic Diastolic Pressure monitoring’ = 17
- ‘CPR’ OR ‘Cardiopulmonary resuscitation AND ‘Cerebral Perfusion Pressure monitoring’ = 4
- ‘cardiac arrest’ AND ‘Physiologic Monitoring’ = 0

AHA Endnote:
- ‘cardiac arrest’ AND ‘end-tidal CO2’ AND ‘return of spontaneous circulation’ = 5
- ‘cardiopulmonary resuscitation AND ‘end-tidal CO2’ OR ‘etco2’ OR ‘capnography’ AND ‘return of spontaneous circulation’ OR ‘ROSC” = 183
- ‘cardiopulmonary resuscitation AND ‘end-tidal CO2’ AND ‘return of spontaneous circulation’ = 9
- ‘Physiologic monitoring’ AND ‘CPR’ AND ‘Cardiac Arrest’ = 0
- ‘Coronary Perfusion Pressure’ AND ‘CPR’ AND ‘Cardiac Arrest’ = 0
- ‘Aortic Diastolic Pressure’ AND ‘CPR’ AND ‘Cardiac Arrest’ = 0

17 Full Text studies met criteria for further review.

17 studies were classified as Evidence Neutral LOE 4 (6 Good, 7 Fair, 4 Poor)
## Summary of evidence

### Evidence Supporting Clinical Question

<table>
<thead>
<tr>
<th>Level of evidence</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>Good</td>
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<td>Fair</td>
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<td>Poor</td>
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### 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

<table>
<thead>
<tr>
<th>Evidence</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
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</thead>
<tbody>
<tr>
<td>Cantineau, 1996 A</td>
<td>Salen, 2001 B</td>
<td>Grmec, 2003 A</td>
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</tbody>
</table>

### 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

<table>
<thead>
<tr>
<th>Evidence</th>
<th>Good</th>
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<th>Poor</th>
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<tr>
<td>Sehra, 2003 A, E</td>
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</table>

### 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 many papers found on physiologic feedback, most had to do with using ETCO2. 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. Many found that ETCO2 values increased when ROSC was obtained: Callaham, 1990, 358-362, LOE 4 Fair; Cantineau, 1996, 791-796, 4 Fair; Grmec, 2003, 92, 4 Fair; Grmec, 2003, 142, 4 Good; Grmec, 2001, 264, 4 Good; Kolar, 2008, 117, 4 Fair; Ornato, 1992; 521, 4 Fair; Shera, 2003, 516, 4 Poor; Steedman, 1990, 131, 4 Poor; Rivers et al, 1098, 1992, 4 Poor; LoE 4 Fair. Similarly, this trend can be seen when looking at Coronary Perfusion Pressure as shown in the manuscript by Paradis et al (1990, 1107, 4 Poor). It was also shown that ETCO2 rose in those patients who obtained ROSC before it was shown by vitals signs (Grmec, 2007, 207, 4 Good). Sehra, 2003, 516, 4 Poor found that ETCO2 fell during VF and then rose significantly after ROSC. Grmec et al (2008, 408, 4 Good) also found that initial PetCO2 was higher not only for those who achieved ROSC but also for those who survived. Conversely, Chollet-Xemard (2009, 215, 4 Good) et al found the using BIS during cardiac arrest played no significant role in predicting ROSC or outcomes. Cantineau, 1996, 791, 4 Fair; Kolar, 2008, 117, 4 Fair; Levine, 1997, 303, 4 Good; Varon, 1991, 291, 4 Fair; Wayne, 1995, 765, 4 Good, 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, 4 Good; Grmec, 2003, pg 92, 4 Fair; Grmec, 2003, 142, 4 Good and Grmec, 2006, 409, 4 Good 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, 4 Good and Wayne, 1995, 765, 4 Good 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).

Rivers et al 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.” (1992, 1094, 4 Poor). Paradis et al also found that no patient with an initial coronary perfusion pressure of zero had ROSC (1990, 1106, 4 Good).

Acknowledgements:

Citation List


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%.


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%.


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.


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.


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.


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.


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%.


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%.


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 predicative value were all 100 percent.


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.


**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.


**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.


**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.


**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.

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.


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.


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.