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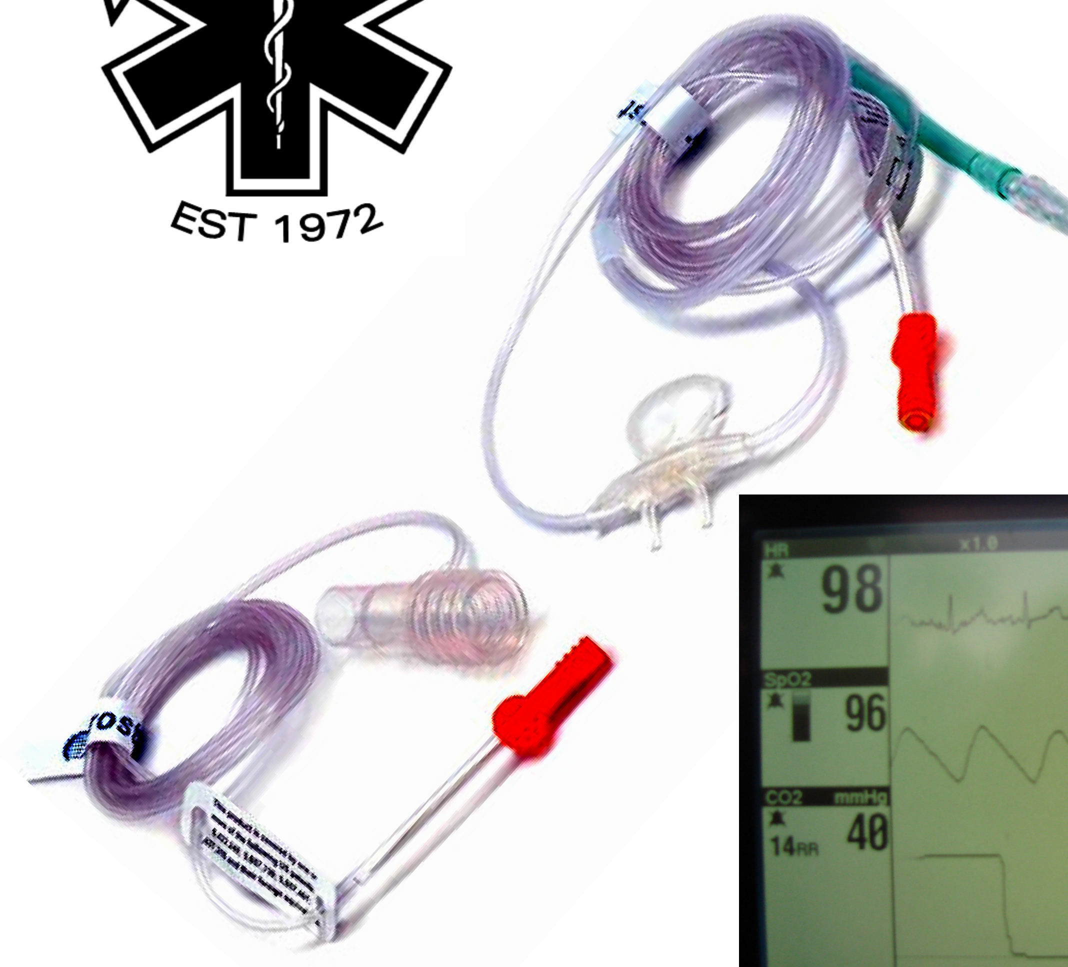
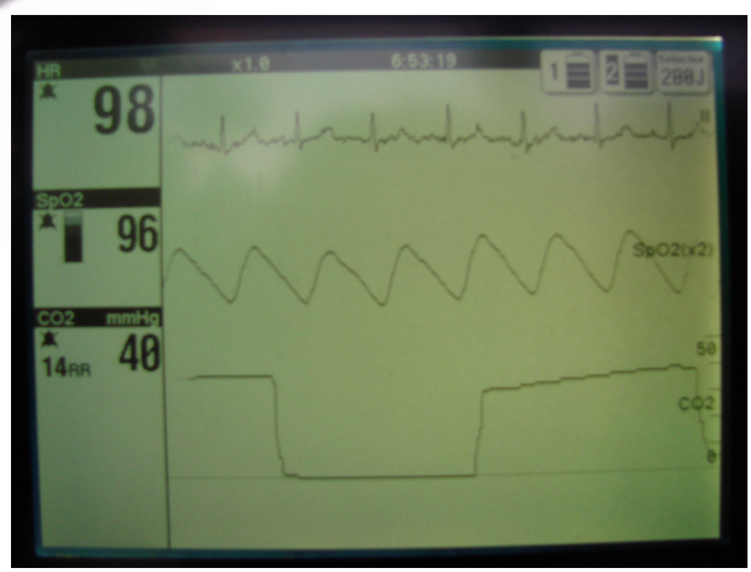
Capnography Review & Case Studies





Questions/Comments on this module are welcome & should be directed to:
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NWC EMSS In-Field Coordinator
dneubecker@nch.org or 847 618 4488

Upon successful completion of this module the participant will be able to:

1. Describe the difference between pulse oximetry and capnography.
2. Discuss how carbon dioxide is produced in the body.
3. Describe information displayed on capnography devices.
4. State normal ETCO2 levels.
5. Describe factors which affect ETCO2 levels.
6. Identify physiologic components of a capnogram.
7. Recognize normal and abnormal capnograms.
8. Defend situations when capnography should always be used.
9. Describe situations when capnography can assist with pt care.
10. Identify how metabolic factors may affect ETCO2 values.
11. Identify how perfusion status may affect ETCO2 values.
12. Identify how ventilation may affect ETCO2 values.
13. Describe the effects of hypo and hyperventilation on capnography.
14. Defend the role of capnography related to advanced airway use.
15. Demonstrate how capnography is used in the spontaneously breathing pt.
16. Demonstrate how capnography is used in the pt receiving assisted ventilation.
17. Demonstrate capnography use with RQP/ITD, oxygen masks, CPAP, and nebulizers.
18. Explain the components of capnography equipment.
19. Support how capnography equipment should be stored.
20. Describe benefits and limitations of capnography.
21. Explain and value capnography use during management of the pt in cardiac arrest.
22. Describe capnography use in the following clinical situations: asthma, COPD, HF, AMS, DAI, shock, and TBI.

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HEART BEAT | MAY 17, 2011

96 Minutes Without a Heartbeat

New Strategies to Revive Victims of Cardiac Arrest; Improving Odds of Survival Without Brain Damage

By RON WINSLOW

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Neurologic Recovery Following Prolonged Out-of-Hospital Cardiac Arrest With Resuscitation Guided by Continuous Capnography

Roger D. White, MD, **Bruce W. Goodman, CCEMT-P, and Mary A. Svoboda, RN**

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This Article

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Abstract

A 54-year-old man with no known cardiac disease collapsed outdoors

Review of Basic Concepts

A How do pulse oximetry and capnography differ?

i) Where does the ETCO2 come from?

B When using capnography, what 3 parameters will be shown on the monitor?

C What VS do you think is least accurately recorded on PCR's? Why?

D What is a normal ETCO2 value?

i) What is an elevated ETCO2 level called?

ii) What is a decreased ETCO2 level called?

E What 3 things affect ETCO2 values?

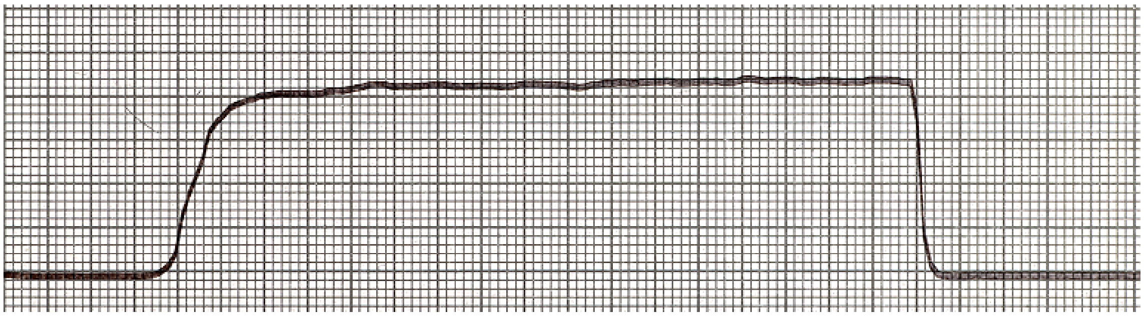
i) Metabolism

(a) List metabolic factors that will increase ETCO2

(b) List metabolic factors that will decrease ETCO2

F What is the shape of a normal capnogram?

G Label the following components on the capnogram below.



Baseline
Expiration
Alpha angle
Plateau
ETCO2 value
Inspiration

Note: Two different types of capnography devices exist (time & volume). EMS devices are time capnograms. Pulmonary function testing often utilizes volume capnograms.

H Under what circumstance must capnography <u>always</u> be used?

i) Should capnography always be used even when just bagging w/ a BVM & OP/NPA?

(a) Why should capnography always be used in that situation?

(b) How will the ETCO2 change if the pt is HYPERventilated (rate or depth)?

(c) How will the ETCO2 change if the pt is HYPOventilated (rate or depth)?

ii) Should capnography always be used after advanced airway (ET, KLT) placement?

(a) Why?

- Are misplaced advanced airways a concern for EMS? If yes, why?
  - Can even initially correctly placed advanced airways become dislodged?
    - When are advanced airways most likely to become dislodged?
    - Are EMS pts often moved after placement of advanced airways?

(b) Why auscultate breath sounds - when using capnography to confirm correct ET tube placement?

I List 2 general situations/pt presentations when capnography <u>may</u> be useful?

J Why is it important where capnography sensors are stored?

i) Where should assisted ventilation capnography sensors be stored?

ii) Where should spontaneous breathing capnography sensors be stored?

● HANDS-ON DEMO – place oral-nasal capnography cannula & pulse ox on volunteer PM and have PM:

Hold breath as long as possible - note
- Immediate loss of waveform
- Delay in change of RR & $ETCO_2$ value (device averages 30 sec for readings)
- No change in pulse ox

Hyperventilate – note
- Immediate decrease in waveform height and closer distance between waveforms

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23. PM's are called to a pt in cardiac arrest, compressions have been initiated and combo-defib pads are being applied. List 4 pieces of equipment the PM managing the airway will immediately/first need?

A Should capnography be used prior to placement of an advanced airway?

i) If using ZOLL monitor what is needed to connect capnography sensor to RQP/ITD or mask?

B When using both RQP/ITD and capnography, is the placement order critical? If yes, what's the correct order?

● HANDS-ON DEMO – 1st w/ with RQP & <u>mask</u> – pass around room (all take apart & put together)

● HANDS-ON DEMO – 2nd w/ with RQP & <u>ET/KLT</u> – pass around room (all take apart & put together)

C Cardiac arrest is often due to either a cardiac or respiratory cause. Can capnography readings help determine which it is?

D What is the relationship between ETCO2 readings and CPR?

i) How will poor quality chest compressions affect ETCO2 values?

ii) How will good quality chest compression affect ETCO2 values?

iii) What will happen to ETCO2 values as compressor gets tired?

(a) What will happen to ETCO2 values when a compressor who is tired is relieved by someone doing better compressions?

E During CPR what other capnography value (besides ETCO2 value) should be monitored?

i) Why?

ii) Why is hyperventilation harmful during CPR?

F Should pulse oximetry be monitored during CPR? Why?

i) How should oxygenation be assessed during CPR?

G What ETCO2 values are associated with a patient who is unlikely to be resuscitated?

i) What is an exception to the “less than 10 mmHg for 20 minutes”?

H Can ETCO2 be used to determine the viability of a pt receiving CPR?

i) Why?

Well published case, in Goodhue, MN, a 54-male survived, neurologically intact & able to return to work, a documented 69 minutes of prehospital CPR. OLMC (cardiologist Dr. Roger White) continued resuscitation for that duration - due to the pts ETCO2 values.

I Can ETCO2 predict when ROSC will occur?

i) Why?

J If ROSC occurs and the pts ETCO2 remains high (>45 mmHg) should the ventilator increase the rate/depth of ventilations to decrease the ETCO2 reading?

(a) Why

K How will therapeutic hypothermia after cardiac arrest affect ETCO2 values?

L In cardiac arrest, what 2 things should be assessed & documented every 2 minutes?

24. PM's called for 10/F having an asthma attack. Pts mom states she has been coughing for past hour, and she has been sick with URI for the past week. PMH asthma; Meds advair & albuterol; Allergies denies. Exam: P 126, ST, R 34, coughing, lungs poor air movement but no wheezing heard, O2 sat 96% RA, BP 114/72, skin warm & dry, no rash or urticaria. Senior PM feels pt is not having an asthma attack since no wheezing is heard and she should be transported with no further treatment. What can treating PM do to help diagnose the asthma attack?

A How can capnography help diagnose an asthma attack?

B How may the waveform shape change during an asthma attack?

C List 2 things, other than an asthma attack, can also cause that shape?

D If the pts ETCO2 value is increased, what should a PM consider?

E Can a pt have a normal O2 sat and an elevated ETCO2?

F PM's decide to treat the pt w/ an albuterol nebulizer, can capnography be used simultaneously?

i) How?

⬣ HANDS-ON DEMO – use manikin apply oral-nasal capnography cannula - under neb mask

25. PM's are called for a 60/M c/o SOB which began 3 days ago and has been getting worse. Pt states he was diagnosed with pneumonia yesterday, but has not been able to get antibiotic Rx filled. PMH COPD, HTN, smoker 2 ppd x 40 yrs; Meds Combivent & Lotrel; Allergies peanuts. Exam: BP 174/92, P 108, ST, 12L normal ECG, R 28, labored, lungs wheezes bilaterally, O2 sat 84% RA. What should a PM expect this pts ETCO2 value to be?

A Why?

B If the pts ETCO2 value is normally increased, how can ETCO2 help assess the pts response to treatment?

C What should a PM expect this pts capnogram shape to be?

i) Why?

26. PM's called for a 72/F pt c/o SOB (rates distress as 8/10) which began ~12-hrs ago, and has gotten worse since she went to bed. Denies any pain/discomfort, n/v, diaphoresis, or syncope. PMH MI, HTN, high cholesterol. Meds Captopril, ASA & Zocor. Allergies denies. Exam: BP 186/94, P 108, ST, 12L ECG LVH & old anterior wall MI, R 28, labored, lungs inspiratory crackles bilat bases, O2 sat 82% RA, skin pale & warm. What SOP should a PM use to treat this pt?

A What should a PM expect this pts capnogram shape to be?

B The pts ETCO2 is low - 30, what may be causing this?

C What treatment should be initiated for this pt?

D Can capnography be used with CPAP?

i) How?

NOTE: published research demonstrates this to be most accurate method

HANDS-ON DEMO – on manikin apply capnography oral-nasal cannula under CPAP mask

E How may the pts ETCO2 values change during treatment?

i) What should be considered if during CPAP treatment ETCO2 values do not stabilize and continue increasing above normal levels?

F If pt in HF deteriorates into cardiogenic shock & becomes hypotensive, how may this affect ETCO2 values?

i) Why?

27. PM's called for 76/F c/o SOB which began yesterday, getting progressively worse. Denies any pain/discomfort, n/v, diaphoresis, or syncope. PMH MI, HTN, COPD. Meds , Vasotec, ASA, Lipitor, Combivent. Allergies denies. Exam: BP 172/88, P 102, ST, 12L ECG old anterior wall MI, R 26, labored, lungs wheezes bilat, O2 sat 88% RA, skin pale & warm. What can help determine if this pt should be treated according to HF or COPD SOP?

A How?

B If the waveform is square/rectangular, what should be suspected?

C If waveform is sharkfin, with increased alpha angle, what should be suspected?

D If the pts COPD exacerbation, also caused an exacerbation of her HF, how will the waveform appear?

i) Why is this important to know?

28. List causes of AMS

29. PM's are called for a 40/M pt found, lying on couch, unresponsive by his wife. Denies recent illness, injury, PMH, meds or allergies. Exam: GCS 3, BP 150/70, P 72, SR, R 8 & shallow, unlabored, lungs clear, O2 sat 94%, glucose 84, skin warm & dry, no signs of apparent injury. Nearest hospital ETA is normally 20 minutes, but a severe snowstorm will extend that to at least 30 minutes. A senior PM states that the pt should be intubated because the GCS is "8 or less," the resps are slow and shallow, and the transport will be prolonged. What additional information may help the PM's & OLMC with decision making regarding intubation of this pt?

A What is a severely elevated ETCO2 value an indication of?

30. PM's are called for a combative 18/male. Parent's state pt had seizure-like activity while they were driving home from a restaurant, so they pulled over and called 911. Denies any PMH, meds, allergies, recent illness or injury. Multiple PM's and PD are attempting to restrain pt. Nasal secretions are noted, so the decision is made to administer midazolam IM. After ~3 minutes the pt is sedated enough to allow transfer to the stretcher. VS BP 160/90, P 84, R 10, O2 sat 96% RA, lungs clear, glucose 96, PERL, no apparent injuries.

While enroute to pts respirations become more slow & shallow; however, O2 sat remains $\geq$94%. Consideration is given to assisting ventilations w/ BVM but there is concern about causing gastric distention, vomiting & aspiration (esp. since the pt just ate). What can help with decision making regarding the need for assisted ventilation?

A What can be used to continuously monitor the pts spontaneous respiratory rate & ventilation effectiveness?

B Can pulse oximetry be used to monitor pts respiratory status?

31. PM's called to a MVC for unresponsive 20/M pt. Exam: GCS 6, BP 82/50, P 130, ST, R 4 & agonal, O2 sat 68%. Pt has obvious face & head injury, with bruising on chest & abdomen. Blood & vomit is noted in pts mouth, so the decision is made to intubate the pt prior to beginning transport to a level-I trauma center. Lidocaine, midazolam, etomidate & benzocaine are administered, and the pt is successfully intubated using in-line technique.

Capnography is attached to the ET tube and the ETCO2 value is 28. What may be causing this?

A Should the PM bag the pt at a slower rate or with less volume?

32. PM's are called to a MVC for an unresponsive 20/M pt. Exam: GCS 6, BP 186/70, P 60, SR, R 4 & agonal, O2 sat 68%. Pt has obvious face & head injury. Blood & vomit is noted in pts mouth, so the decision is made to intubate the pt prior to beginning transport to a level-I trauma center. Lidocaine, midazolam, etomidate & benzocaine are administered, and the pt is successfully intubated using in-line technique.

Capnography is attached to the ET tube and the ETCO2 value is 28. What may be causing this?

A Should the PM bag the pt at a slower rate or with less volume?

B What is the harm of hyperventilating a pt with head injury?

i) How?

C Should the pt with a head injury be hypoventilated?

INDEPENDENT STUDY MATERIAL

While entire abstracts included, PM's responsible for _underlined italic content only_.

NOTE:

- ***Following study shows why we should not ventilate a HYPOTENSIVE pt to a specific ETCO2 number, but should ventilate at the appropriate rate & depth.***
- ***Shock / hypotension may decrease ETCO2 even when pt is ventilated at the correct rate.***
- ***In hyPOtensive pts - a low ETCO2 does not automatically mean the pt is being hypERventilated.***

J Trauma. 2009 Jan;66(1):26-31.
The utility of early end-tidal capnography in monitoring ventilation status after severe injury.
Warner KJ, Cuschieri J, Garland B, Carlbom D, Baker D, Copass MK, Jurkovich GJ, Bulger EM. Dept of Trauma, Harborview, Seattle, WA
BACKGROUND: An arterial CO2 (Paco2) of 30 to 39 mm Hg has been shown to be the ideal target range for early ventilation in trauma pts; however, this requires serial arterial blood gases. The use of end-tidal capnography (EtCO2) has been recommended as a surrogate measure of ventilation in the prehospital arena. This is based on the observation of close EtCO2 Pa(CO2) correlation in healthy pts, yet trauma pts frequently suffer from impaired pulmonary ventilation/perfusion. Thus, we hypothesize EtCO2 will demonstrate a poor reflection of actual ventilation status after severe injury.
METHODS: Prospective observational study on consecutive intubated trauma pts treated in our Emerg Dept (ED) during 9 months. Arterial blood gas values and concomitant EtCO2 levels were recorded. Regression was used to determine the strength of correlation among all trauma pts and subgroups based on injury severity (Abbreviated Injury Score and Injury Severity Score) and physiologic markers of perfusion status (lactate, shock index, and arterial base deficit).
RESULTS: During 9 months, 180 pts were evaluated. The EtCO2 Paco2 correlation was poor at R2 = 0.277. Pts ventilated in the recommended EtCO2 (range, 35 to 40) were likely to be under ventilated (Pa(CO2) > 40 mm Hg) 80% of the time, and severely under ventilated (Pa(CO2) > 50 mm Hg) 30% of the time. _Correlation was_ best for pts with isolated traumatic brain injury and _worst for those with evidence of poor tissue perfusion_.
CONCLUSION: EtCO2 has low correlation with Pa(CO2), and therefore should not be used to guide ventilation in intubated trauma pts in the ED.

Acad Emerg Med. 2011 Jun;18(6):590-6.
A randomized controlled trial of capnography in the correction of simulated ET dislodgement.
Langhan ML, Ching K, Northrup V, Alletag M, Kadia P, Santucci K, Chen L. Yale Univ.
OBJECTIVES: _Unrecognized dislodgement of an endotracheal tube (ETT) during the transport of an intubated pt can have life-threatening consequences. Standard methods to monitor these pts, such as pulse oximetry and physical examination, are both subject to inaccuracies with patient movement and ambient noise. Capnography provides a continuous and objective measure of ventilation that can alert a provider immediately to an airway problem_. The objective of this study was to determine through simulation if capnography decreases time to correction of dislodged ETTs during the transport of intubated pts, in comparison to standard monitoring.
METHODS: Paramedics and paramedic students were randomized as to whether or not they had capnography available in addition to standard monitoring during a simulated scenario. In the scenario, subjects monitored an intubated baby who subsequently experiences a dislodgement of ETT during transport. Time to correction of ETT dislodgement was the primary outcome. The secondary outcome was correction of dislodgement prior to decline in pulse oximetry.
RESULTS: Fifty-three subjects were enrolled in the study, with complete data on 50 subjects. Median time to correction of ETT dislodgement was 2.02 minutes (95% confidence interval [CI] = 1.22 to 4.12 minutes) for the capnography group versus 4.00 minutes (95% CI = 3.35 to 5.50 minutes) in the standard monitoring group (p = 0.05). Forty-eight percent of subjects using capnography corrected the ETT dislodgement prior to decline in pulse oximetry compared with 12% of controls (p = 0.01). There were no differences in time to correction of dislodgement based on years of experience, perceived comfort, reported adequacy of teaching, or past use of capnography.
CONCLUSIONS: _The addition of capnography to standard monitoring significantly improves recognition of ETT dislodgement and reduces the time to correction of dislodged ETTs by prehospital providers_ in a simulated pediatric transport setting.

Emerg Med J. 2007 Sep;24(9):614-7.
Capnometry in the prehospital setting: are we using its potential?
Kupnik D, Skok P.
Capnometry is a non-invasive monitoring technique which allows fast and reliable insight into ventilation, circulation, and metabolism. In the prehospital setting it is mainly used to _confirm correct tracheal tube placement_. In addition it is a useful _indicator of efficient ongoing CPR due to its correlation with cardiac output, and successful resuscitation_. It helps to confirm the diagnosis of pulmonary thromboembolism and to _sustain adequate ventilation in mechanically ventilated pts_. In pts with haemorrhage, capnometry provides improved continuous haemodynamic monitoring, insight into adequacy of tissue perfusion, optimisation within current hypotensive fluid resuscitation strategy, and prevention of shock progression through controlled fluid administration.

Emerg Med Australas. 2006 Jun;18(3):221-8.

Paramedic intubation of pts with severe head injury: a review of current Australian practice and recommendations for change.

Bernard SA. Melbourne, Victoria, Australia.

Secondary brain injury may occur early after severe traumatic brain injury due to hypoxia and/or hypotension. Prehospital care by ambulance paramedics has the goal of preventing and treating these complications and, thus, improving outcomes. In Australia, most ambulance services recommend paramedics attempt endotracheal intubation in pts with severe head injury. Even though most pts with severe head injury retain airway reflexes, most states do not allow the use of appropriate drugs to facilitate intubation. In contrast, recent evidence from trauma registries suggests that this approach may be associated with significantly worse outcomes compared with no intubation. Two states allow intubation facilitated by sedative (but not relaxant) drugs, but this has a low success rate and could worsen brain injury because of a decrease in cerebral perfusion pressure. For road-based paramedics, the role of rapid sequence intubation is uncertain. Given the risks of this procedure and the lack of proven benefit, this procedure should not be introduced without supportive evidence from randomised, controlled trials. In contrast, for safety reasons, comatose pts transported by helicopter should undergo rapid sequence intubation prior to flight. However, this is not authorised in most states, despite good supportive evidence that this can be safely and effectively undertaken by paramedics. Finally, there is *evidence that inadvertent hyperventilation is associated with adverse outcome*, yet only two ambulance services use waveform capnography in head injury pts who are intubated. Overall, current paramedic airway practice in most states of Australia is not supported by the evidence and is probably associated with worse patient outcomes after severe head injury. For road-based paramedics, rapid transport to hospital without intubation should be regarded as the current standard of care. Rapid sequence intubation should be limited to use within appropriate clinical trials, or pts transported by helicopter. *For pts who are intubated, waveform capnography is essential to confirm tracheal placement and to prevent inadvertent hyperventilation*.

J Trauma. 2004 Jul;57(1):65-8.

Prehospital end-tidal carbon dioxide concentration and outcome in major trauma.

Deakin CD, Sado DM, Coats TJ, Davies G.

BACKGROUND: End-tidal carbon dioxide (Petco2) concentration is a marker of the pathophysiologic state because it is a reflection of cardiac output. Petco2 correlates with outcome after prehospital primary cardiac arrest, but association with outcome from prehospital trauma has not been established.

METHODS: Between 1998 and 2001, Petco2 was recorded in 191 blunt trauma pts requiring prehospital intubation. Rapid sequence intubation was performed using suxamethonium (1 mg/kg) and etomidate (0.2-0.3 mg/kg). Initial Petco2 after endotracheal intubation (t0) and Petco2 at 20 minutes after endotracheal intubation (t20) were recorded, together with survival to discharge.

RESULTS: Median Petco2 at t20 was 4.10 kPa in survivors and 3.50 kPa in nonsurvivors (95% confidence interval of difference between medians, 0.40 to 0.90 kPa; $p < 0.0001$). Petco2 at t20 was a better predictor of outcome than at t0.

CONCLUSION: Only 5% pts with Petco2 < 3.25 kPa survived to discharge. *Petco2 at t20 is of value in predicting outcome from major trauma.*

Emerg Med J. 2004 Jul;21(4):518-20.

Prehospital determination of tracheal tube placement in severe head injury.

Grmec S, Mally S.

OBJECTIVES: The aim of this prospective study in the prehospital setting was to compare three different methods for immediate confirmation of tube placement into the trachea in pts with severe head injury: auscultation, capnometry, and capnography.

METHODS: All adult pts (>18 years) with severe head injury, maxillofacial injury with need of protection of airway, or polytrauma were intubated by an emerg physician in the field. Tube position was initially evaluated by auscultation. Then, capnometry and capnography was performed (infrared method). emerg physicians evaluated capnogram and partial pressure of end tidal carbon dioxide (EtCO(2)) in millimetres of mercury. Determination of final tube placement was performed by a second direct visualisation with laryngoscope. Data are mean (SD) and percentages.

RESULTS: There were 81 pts enrolled in this study (58 with severe head injury, 6 with maxillofacial trauma, and 17 politraumatised pts). At the first attempt eight pts were intubated into the oesophagus. Afterwards endotracheal intubation was undertaken in all without complications. The *initial capnometry* (sensitivity 100%, specificity 100%), capnometry after sixth breath (sensitivity 100%, specificity 100%), and *capnography after sixth breath* (sensitivity 100%, specificity 100%) *were significantly better indicators for tracheal tube placement than auscultation* (sensitivity 94%, specificity 66%, $p<0.01$).

CONCLUSION: *Auscultation alone is not a reliable method to confirm endotracheal tube placement in severely traumatised pts in the prehospital setting. It is necessary to combine auscultation with other methods like capnometry or capnography*.

Anesth Analg. 2004 Jan;98(1):206-10.

Capnography in non-tracheally intubated emerg pts as an additional tool in pulse oximetry for prehospital monitoring of respiration.

Kober A, Schubert B, Bertalanffy P, Gorove L, Puskas T, Gustorff B, Joldzo A, Hoerauf K.

Victims of minor trauma transported by paramedic-based rescue systems are usually monitored with pulse oximetry. Under the difficult surroundings of prehospital trauma care, pulse oximeters show considerable periods of malfunction. We tested the hypothesis that capnography is a good, easy to use tool for monitoring in nonintubated trauma victims. Seventy nonintubated trauma victims were included in this study. Vital variables and number and time of malfunctions were sampled for oximeter and capnometer recordings. Total number of alerts (63 versus 10), number of alerts per patient (3.3 [1.9] versus 0.3 [0.9]) (mean [SD]), total time of malfunction (191.5 [216.7] s versus 11.8 [40.2] s), time of malfunction per alarm (58.3 [71.4] s versus 5.5 [14.6] s), and the percentage of malfunction time during transport (13.2% [15.3%] versus 0.8% [2.8%]) differed significantly ($P <0.01$) between oximetry and capnography. Although pulse oximetry is a standard method of monitoring in emerg care, we found capnography to be helpful as a monitoring device. We consequently recommend the use of capnography on transport as an additional monitoring tool to reduce periods lacking supervision of the vital variables. IMPLICATIONS: *Capnography is a useful tool to improve respiratory monitoring in nonintubated trauma victims on emerg transport and an easy to use supplement to pulse oximetry.*

Crit Care. 2003 Dec;7(6):R139-44.
Difference in end-tidal CO2 between asphyxia cardiac arrest and ventricular fibrillation / pulseless ventricular tachycardia cardiac arrest in the prehospital setting.
Grmec S, Lah K, Tusek-Bunc K.
INTRODUCTION: There has been increased interest in the use of capnometry in recent years. During cardiopulmonary resuscitation (CPR), the partial pressure of end-tidal carbon dioxide (PetCO2) correlates with cardiac output and, consequently, it has a prognostic value in CPR. This study was undertaken to compare the initial PetCO2 and the PetCO2 after 1 min during CPR in asphyxial cardiac arrest versus primary cardiac arrest.
METHODS: The prospective observational study included two groups of pts: cardiac arrest due to asphyxia with initial rhythm asystole or pulseless electrical activity, and cardiac arrest due to acute myocardial infarction or malignant arrhythmias with initial rhythm ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT). The PetCO2 was measured for both groups immediately after intubation and then repeatedly every minute, both for pts with and without return of spontaneous circulation (ROSC).
RESULTS: We analyzed 44 pts with asphyxial cardiac arrest and 141 pts with primary cardiac arrest. The first group showed no significant difference in the initial value of the PetCO2, even when we compared those with and without ROSC. There was a significant difference in the PetCO2 after 1 min of CPR between those pts with ROSC and those without ROSC. The mean value for all pts was significantly higher in the group with asphyxial arrest. In the group with VF/VT arrest there was a significant difference in the initial PetCO2 between pts without and with ROSC. CONCLUSIONS: *The initial PetCO2 is significantly higher in asphyxial arrest than in VT/VF cardiac arrest*. Regarding asphyxial arrest there is also no difference in values of initial PetCO2 between pts with and without ROSC.

Br J Anaesth. 2003 Mar;90(3):327-32.
Tight control of prehospital ventilation by capnography in major trauma victims.
Helm M, Schuster R, Hauke J, Lampl L.
BACKGROUND: Tracheal intubation combined with controlled ventilation of the lungs is an important part of the prehospital management of major trauma victims, but gauging the adequacy of ventilation remains a major problem.
METHODS: Ninety-seven major trauma victims who underwent tracheal intubation in the field and controlled ventilation of the lungs during prehospital treatment by a Helicopter Emerg Medical Service were assigned randomly to one of two groups: (1) monitor group (n=57) and (2) monitor-blind group (n=40), according to whether the anaesthetist could or could not see an attached capnograph screen. In the monitor-blind group ventilation was set by using a tidal-volume of 10 ml kg(-1) estimated body weight and an age-appropriate ventilatory frequency. In the monitor group, ventilation was adjusted to achieve target end-tidal carbon dioxide values determined by the 'physiological state' of the trauma victim. Arterial blood gases were measured upon hospital admission while maintaining the ventilation initiated in the field and the Pa(CO(2)) value obtained was used as the determinant of the adequacy of prehospital ventilation.
RESULTS: The incidence of 'normoventilation' was significantly higher (63.2 vs 20%; P<0.0001) and the incidence of 'hypoventilation' upon hospital admission was significantly lower (5.3 vs 37.5%; P<0.0001) in the monitor group; pts with severe head and chest trauma and haemodynamically unstable pts and those with a high injury severity score were significantly more likely to be 'normoventilated' upon hospital admission in the monitor group than in the monitor-blind group.
CONCLUSIONS: The data support the *routine use of prehospital capnographic monitoring using target end-tidal carbon dioxide values adapted to the physiological state of the patient in major trauma victims requiring tracheal intubation in the field.*

Intensive Care Med. 2002 Jun;28(6):701-4.
Comparison of three different methods to confirm tracheal tube placement in emerg intubation.
Grmec S.
OBJECTIVES: *Verification of endotracheal tube placement is of vital importance, since unrecognized esophageal intubation can be rapidly fatal (death, brain damage).* The aim of our study was to compare three different methods for immediate confirmation of tube placement: auscultation, capnometry and capnography in emerg conditions in the prehospital setting.
DESIGN AND SETTING: Prospective study in the prehospital setting.
PTS AND INTERVENTIONS: All adult pts (>18 years) were intubated by an emerg physician in the field. Tube position was initially evaluated by auscultation. Then, capnometry was performed with infrared capnometry and capnography with infrared capnography. The examiners looked for the characteristic CO(2) waveform and value of end-tidal carbon dioxide (EtCO(2)) in mmHg. Determination of final tube placement was performed by a second direct visualization with laryngoscope. Data are mean +/- SD and percentages.
MEASUREMENTS AND RESULTS: Over a 4 yr period, 345 pts requiring emerg intubation were included. Indications for intubation included cardiac arrest (n=246; 71%) and non-arrest conditions (n=99; 29%). In nine (2.7%) pts, esophageal tube placement occurred. The esophageal intubations were followed by successful ET intubations without complications. The capnometry (sensitivity and specificity 100%) and *capnography* (sensitivity and specificity 100%) were *better than auscultation* (sensitivity 94% and specificity 83%) in *confirming endotracheal tube placement* in non-arrest pts (p<0.05).
CONCLUSION: *Capnography is the most reliable method to confirm ET tube placement in emerg conditions in the prehospital setting.*

Acad Emerg Med. 2011 May;18(5):468-75.
Mathematical modeling for prediction of survival from resuscitation based on computerized continuous capnography: proof of concept.
Einav S, Bromiker R, Weiniger CF, Matot I.
OBJECTIVES: The objective was to describe a new method of studying correlations between real-time end tidal carbon dioxide (ETCO2) data and resuscitation outcomes.
METHODS: This was a prospective cohort study of 30 pts who underwent 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 pt 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, pts 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 pts 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 pts 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 computerized ETCO(2) carries potential as a tool for early, real-time decision-making during some resuscitations.

Mayo Clin Proc. 2011 Jun;86(6):544-8.

Neurologic recovery following prolonged out-of-hospital cardiac arrest with resuscitation guided by continuous capnography.

White RD, Goodman BW, Svoboda MA. Mayo Clinic, Rochester, MN.

A 54-year-old man with no known cardiac disease collapsed outdoors in a small rural community. The cardiac arrest was witnessed, and immediate cardiopulmonary resuscitation was begun by a bystander and a trained first responder who was nearby. The patient was moved into a building across the street for continued resuscitation. First responders arrived with an automated external defibrillator, and ventricular fibrillation was documented. First responders delivered 6 defibrillation shocks, 4 of which transiently restored an organized electrocardiographic rhythm but with no pulse at any time. Additional emergency medical services personnel from nearby communities and an advanced life support (ALS) flight crew arrived. The flight crew initiated ALS care. The trachea was intubated, ventilation controlled, and end-tidal carbon dioxide tension continuously monitored. Antiarrhythmic and inotropic drugs were administered intravenously. An additional 6 shocks were delivered using the ALS defibrillator. *End-tidal carbon dioxide measurements confirmed good pulmonary blood flow with chest compressions, and resuscitation was continued until a stable cardiac rhythm was restored after 96 minutes of pulselessness*. The patient was transported by helicopter to the hospital. He was in cardiogenic shock but maintained a spontaneous circulation. Coronary angiography confirmed a left anterior descending coronary artery thrombotic occlusion that was treated successfully. After hospital admission, the patient required circulatory and ventilatory support and hemodialysis for acute renal failure. *He experienced a complete neurologic recovery to his pre-cardiac arrest state. To our knowledge, this is the longest duration of pulselessness in an out-of-hospital arrest with a good outcome. Good pulmonary blood flow was documented throughout by end-tidal carbon dioxide measurements.*

J Clin Anesth. 2011 May;23(3):189-96.

Capnography enhances surveillance of respiratory events during procedural sedation: a meta-analysis.

Waugh JB, Epps CA, Khodneva YA.

OBJECTIVE: To determine if capnography, in addition to standard monitoring, identified more respiratory complications than standard monitoring alone.
MEASUREMENTS: The electronic databases PubMed, CINAHL, Cochrane Library (Cochrane Reviews, CENTRAL) were searched for studies published between 1995-2009 reporting adverse respiratory events during procedural sedation and analgesia (PSA) with clearly defined end-tidal carbon dioxide threshold, adult population, clear study design, P-value calculation, similar outcome and predictor variable definitions, and binary independent and dependent variable raw data. Five such studies were evaluated independently. A meta-analysis was performed.
MAIN RESULTS: During PSA, *cases of respiratory depression were 17.6 times more likely to be detected if monitored by capnography than cases not monitored by capnography* (95% CI, 2.5-122.1; $P < 0.004$).
CONCLUSION: End-tidal carbon dioxide monitoring is an important addition in detecting respiratory depression during PSA.

Pediatr Neonatol. 2010 Dec;51(6):330-5.

Noninvasive capnometry for end-tidal carbon dioxide monitoring via nasal cannula in nonintubated neonates.

Tai CC, Lu FL, Chen PC, Jeng SF, Chou HC, Chen CY, Tsao PN, Hsieh WS.

BACKGROUND: Arterial blood gas analysis is the gold standard for assessing the adequacy of ventilation. However, arterial blood sampling may be associated with serious complications in neonates. The aim of the study was to utilize the side-stream capnometry measurement of end-tidal carbon dioxide ($PetCO_2$) via nasal cannula circuits and to verify the reliability of $PetCO_2$ in reflecting the arterial blood carbon dioxide($PaCO_2$) level in nonintubated neonates.
METHODS: A retrospective medical record review analysis was performed in nonintubated neonates admitted to the neonatal ward in a medical center. Simultaneous arterial $PaCO_2$ and $PetCO_2$ levels were evaluated. $PaCO_2$ and $PetCO_2$ levels were compared by paired t test and were correlated using Pearson's correlation. The $PetCO_2$ bias was defined as the difference between $PaCO_2$ and $PetCO_2$, and was assessed by Bland-Altman plot analysis.
RESULTS: A total of 34 neonates were recruited, and data of 54 pairs of $PaCO_2$ and $PetCO_2$ levels were available for comparison. The average (mean ± SD) gestational age was 32.5 ± 4.2 weeks, and the average birth weight was 1881 ± 1077 g. There was a good correlation between $PetCO_2$ and $PaCO_2$ levels among all paired samples ($r = 0.809$, $p < 0.001$). When the data were divided into those with respiratory disease (n = 34) and those without (n = 20), significant correlation between $PetCO_2$ and $PaCO_2$ levels were both noted in the former group ($r = 0.823$, $p < 0.001$) and the latter group ($r = 0.770$, $p < 0.001$). The overall average mean value of $PetCO_2$ was lower than that of $PaCO_2$ (39.4 ± 8.8 mmHg vs. 41.3 ± 9.2 mmHg, $p = 0.014$). The difference between $PetCO_2$ and $PaCO_2$ levels was significant only among those with respiratory disease (38.8 ± 9.8 mmHg vs. 41.2 ± 10.3 mmHg, $p = 0.027$), but not among those without (40.5 ± 7.0 mmHg vs. 41.6 ± 7.2 mmHg, $p = 0.289$).
CONCLUSIONS: *End-tidal CO_2 measurement by side-stream capnometry through nasal cannula could provide an accurate and noninvasive estimate of $PaCO_2$ levels in nonintubated neonates*.

J Int Med Res. 2010 Jul-Aug;38(4):1458-67.

Impact of modified treatment in echocardiographically confirmed pseudo-pulseless electrical activity in out-of-hospital cardiac arrest pts with constant end-tidal carbon dioxide pressure during compression pauses.

Prosen G, Križmarić M, Završnik J, Grmec S.

This study evaluated the ability of focused echocardiography (FE) and *capnography to differentiate between pulseless electrical activity (PEA) and pseudo-PEA in out-of-hospital cardiac arrest*, and the potential survival benefits with modified treatment. In PEA pts with stable end-tidal carbon dioxide pressure (P(et)CO(2)) during the compression pause and concomitant FE showing cardiac kinetic activity, the compression pause was prolonged for 15 s and an additional 20 IU vasopressin was administered. If pulselessness persisted, compressions were continued. Fifteen of the 16 pts studied (94%) achieved restoration of spontaneous circulation (ROSC); eight pts (50%) attained a good neurological outcome (Cerebral Performance Category 1 - 2). In an historical PEA group with stable P(et)CO(2) values (n = 48), ROSC was achieved in 26 pts (54%); four pts (8%) attained Cerebral Performance Category 1 - 2. Echocardiographical verification of the pseudo-PEA state enabled additional vasopressor treatment and cessation of chest compressions, and was associated with significantly higher rates of ROSC, survival to discharge and good neurological outcome.

Am J Emerg Med. 2011 Jan;29(1):65-9.
ETCO2: a predictive tool for excluding metabolic disturbances in nonintubated pts.
Kartal M, Eray O, Rinnert S, Goksu E, Bektas F, Eken C
OBJECTIVES: The purpose of this study is to examine the relation between end-tidal carbon dioxide ($ETCO_2$) measurement and bicarbonate (HCO_3) level reflecting the pt's metabolic status.
METHOD: This prospective cross-sectional study has been carried out during a 3-month period in a tertiary care university hospital's emergency department (ED). During the study period, every spontaneously ventilating ED patient requiring arterial blood gas analysis for any medical indication, regardless of presenting symptoms, had a simultaneous $ETCO_2$ measurement using a Medlab Cap 10 side stream capnograph. The demographics and clinical outcomes of the pts were recorded.
RESULTS: Of 399 eligible pts, 240 with possible metabolic disturbance were enrolled into the study. There was a statistically significant correlation between the value of $ETCO_2$ and HCO_3 levels (r = 0.506). The mean $ET(CO)_2$ level was statistically significantly lower in pts who died (26.5 ± 7.2, 95% confidence interval [CI], 24.2-28.6, vs 30 ± 7.5, 95% CI, 29-31; P = .007) and who had low bicarbonate levels (25.7 ± 6.7, 95% CI, 24.3-27.1, vs 31.6 ± 7.1, 95% CI, 30.4-32.8; P = .000). The value of $ET(CO)_2$ measurement to detect low bicarbonate level was found to be significant. The area under the receiver operating characteristic curve was 0.734, the (+) likelihood ratio for $ETCO_2$ less than or equal to 25 was 2.7, and the (-) likelihood ratio for $ETCO_2$ greater than or equal to 36 was 0.05.
CONCLUSION: *$ETCO_2$ values correlate moderately with HCO_3 levels and thus might predict mortality and metabolic acidosis.* Therefore, capnography can be used as a noninvasive diagnostic tool for ruling out suspected severe metabolic disturbance in the ED.

Curr Opin Anaesthesiol. 2010 Aug;23(4):500-6.
Anesthesia in prehospital emergencies and in the emergency department.
Braun P, Wenzel V, Paal P.
PURPOSE OF REVIEW: Recently, notable progress has been made in the field of anesthesia drugs and airway management.
SUMMARY: Preoxygenation should be performed with high-flow oxygen delivered through a tight-fitting face mask with a reservoir. Ketamine may be the induction agent of choice in hemodynamically unstable pts. The rocuronium antagonist sugammadex may have the potential to make rocuronium a first-line neuromuscular blocking agent in emergency induction. Experienced healthcare providers may consider prehospital anesthesia induction. Moderately experienced healthcare providers should optimize oxygenation, hasten hospital transfer and only try to intubate a patient whose life is threatened. When intubation fails twice, ventilation should be performed with an alternative supraglottic airway or a bag-valve-mask device. Lesser experienced healthcare providers should completely refrain from intubation, optimize oxygenation, hasten hospital transfer and ventilate pts only in life-threatening circumstances with a supraglottic airway or a bag-valve-mask device. Senior help should be sought early. In a 'cannot ventilate-cannot intubate' situation, a supraglottic airway should be employed and, if ventilation is still unsuccessful, a surgical airway should be performed. *Capnography should be used in every ventilated patient*. Clinical practice is essential to retain anesthesia and airway management skills.

Am J Emerg Med. 2010 May;28(4):460-5.
The diagnostic role of capnography in pulmonary embolism.
Kurt OK, Alpar S, Sipit T, Guven SF, Erturk H, Demirel MK, Korkmaz M, Hayran M, Kurt B.
The aim of this study was to evaluate the diagnostic contribution of alveolar dead space fraction (AVDSf) measured using capnography in pts admitted with suspected pulmonary embolism (PE). A total of 58 pts who were admitted to our hospital with suspected PE between Oct 2006 and Jan 2008 were included in this study. All pts were assessed using Wells clinical score, capnography, computed tomographic pulmonary angiography, D-dimer measurement, lower-extremity venous Doppler ultrasonography, and V/Q scintigraphy. Forty pts (69%) had PE based on computed tomographic pulmonary angiography findings. The AVDSf value with the highest sensitivity and specificity, at the same time statistically significant, was 0.09. This value was consistent with the AVDSf value obtained using receiver operating characteristic analysis. In our study, the *sensitivity of capnography was 70%, with a specificity of 61.1%, positive predictive value of 80%, and negative predictive value of 47.8%*. The use of AVDSf in combination with any of the several scoring systems that evaluate clinical likelihood of PE and D-dimer levels resulted in higher sensitivity and specificity rates for the diagnosis of PE.
Rev Esp Enferm Dig. 2010 Feb;102(2):86-9.

Capnography is superior to pulse oximetry for the detection of respiratory depression during colonoscopy.
Cacho G, Pérez-Calle JL, Barbado A, Lledó JL, Ojea R, Fernández-Rodríguez CM.
BACKGROUND: Pulse oximetry is a widely accepted procedure for ventilatory monitoring during gastrointestinal endoscopy, but this method provides an indirect measurement of the respiratory function. In addition, detection of abnormal ventilatory activity can be delayed, especially if supplemental oxygen is provided. Capnography offers continuous real-time measurement of expiratory carbon dioxide.
OBJECTIVE: We aimed at prospectively examining the advantages of capnography over the standard pulse oximetry monitoring during sedated colonoscopies.
PTS AND METHODS: Fifty pts undergoing colonoscopy were simultaneously monitored with pulse oximetry and capnography by using two different devices in each patient. Several sedation regimens were administered. Episodes of apnea or hypoventilation detected by capnography were compared with the occurrence of hypoxemia.
RESULTS: Twenty-nine episodes of disordered respiration occurred in 16 pts (mean duration 54.4 seconds). *Only 38% of apnea or*

hypoventilation episodes were detected by pulse oximetry. A mean delay of 38.6 seconds was observed in the events detected by pulse oximetry (two episodes of disturbed ventilation were simultaneously detected by capnography and pulse oximetry).
CONCLUSIONS: *Apnea or hypoventilation commonly occurs during colonoscopy with sedation. Capnography is more reliable than pulse oximetry in early detection of respiratory depression in this setting.*

Crit Care. 2010;14(1):110.
Splendors and miseries of expired CO2 measurement in the suspicion of pulmonary embolism.
Verschuren F, Perrier A.
Capnography has been studied for decades as a potential diagnostic tool for suspected pulmonary embolism. Despite technological refinements and its combination with other non-invasive instruments, *no evidence to date allows recommending the use of expired carbon dioxide measurement as a rule-out test for pulmonary embolism* without additional radiological testing.

Ann Emerg Med. 2010 Mar;55(3):258-64.
Does end tidal CO2 monitoring during emergency department procedural sedation and analgesia with propofol decrease the incidence of hypoxic events?
Deitch K, Miner J, Chudnofsky CR, Dominici P, Latta D.
STUDY OBJECTIVE: We determine whether the use of capnography is associated with a decreased incidence of hypoxic events than standard monitoring alone during ED sedation with propofol.
METHODS: Adults underwent ED propofol sedation with standard monitoring (pulse oximetry, cardiac and blood pressure) and capnography and were randomized into a group in which treating physicians had access to the capnography and a blinded group in which they did not. All pts received supplemental oxygen (3L/minute) and opioids greater than 30 minutes before. Propofol was dosed at 1.0 mg/kg, followed by 0.5 mg/kg as needed. Capnographic and SpO2 data were recorded electronically every 5 seconds. Hypoxia was defined as SpO2 less than 93%; respiratory depression, as end tidal CO2 (ETCO2) greater than 50 mm Hg, ETCO2 change from baseline of 10%, or loss of the waveform.
RESULTS: One hundred thirty-two subjects were evaluated and included in the final analysis. We observed hypoxia in 17 of 68 (25%) subjects with capnography and 27 of 64 (42%) with blinded capnography (P=.035; difference 17%; 95% confidence interval 1.3% to 33%). *Capnography identified all cases of hypoxia before onset* (sensitivity 100%; specificity 64%), with the median time from capnographic evidence of respiratory depression to hypoxia 60 seconds (range 5 to 240 seconds).
CONCLUSION: In adults receiving ED propofol sedation, the *addition of capnography to standard monitoring reduced hypoxia and provided advance warning for all hypoxic events.*

J Emerg Med. 2010 Jun;38(5):614-21.
A sudden increase in partial pressure end-tidal carbon dioxide (P(ET)CO(2)) at the moment of return of spontaneous circulation.
Pokorná M, Necas E, Kratochvíl J, Skripský R, Andrlík M, Franek O.
BACKGROUND: Previous studies established that a level of partial pressure end-tidal carbon dioxide (P(ET)CO(2)) of 10 mm Hg divided pts undergoing advanced life support (ALS) into those likely to be resuscitated (values > 10 mm Hg) and those likely to die during ALS (values < 10 mm Hg). Objective: The study tested the significance of a sudden increase in the P(ET)CO(2) in signaling the return of spontaneous circulation (ROSC) during ALS.
MATERIAL AND METHODS: P(ET)CO(2) values were continuously recorded during ALS in out-of-hospital pts with cardiac arrest. Constant ventilation was maintained by an automatic device. There were 108 pts, representing two extreme outcomes of ALS, who were subdivided into two groups. The first group included 59 pts with a single ROSC followed by a stable spontaneous circulation. The second group included 49 pts with no signs of ROSC. Results: ROSC was associated with a sudden increase in P(ET)CO(2) that remained significantly higher than before ROSC. P(ET)CO(2) did not rise during the entire ALS in the second group of pts without ROSC and was lower than in the first group of pts.
CONCLUSIONS: In constantly ventilated pts, P(ET)CO(2) is significantly higher (about 10 mm Hg) after ROSC than before ROSC. *A sudden increase in P(ET)CO(2) exceeding 10 mm Hg may indicate ROSC. Consequently, the rule of 10 mm Hg may be extended to include a sudden increase in continuously recorded P(ET)CO(2) by more than 10 mm Hg as an indicator of the possibility of ROSC*.

J Paediatr Child Health. 2007 Oct;43(10):677-80.
Predicting diabetic ketoacidosis in children by measuring end-tidal CO2 via non-invasive nasal capnography.
Gilhotra Y, Porter P.
AIM: To determine if nasal capnography can be used as a screening tool to predict diabetic ketoacidosis (DKA) in children with Type 1 diabetes mellitus (T1DM) presenting to the emergency department.
METHODS: Cross-sectional, prospective, observational study of children with T1DM who presented to the ED of Princess Margaret Hospital for Children, Western Australia, over a 12-month period from June 2003 to June 2004. Information on demographic data and T1DM was recorded. Nasal capnography, venous blood gases and urinary analysis were performed on pts. Data were analysed using chi(2) tests and receiver operating characteristic curve analysis. Sensitivities and specificities were calculated at different end-tidal carbon dioxide (ETCO(2)) levels to predict presence of DKA.
RESULTS: Fifty-eight pts aged 1-18 years (mean 10.7, SD 4.7) were analysed. Thirty-three (57%) were male and 30 (52%) presented with new onset of T1DM. Of the 58 cases, 15 (26%) had DKA, and 11 of these were new T1DM pts. *No pts with an ETCO(2) > 30 mmHg had DKA* (sensitivity 1.0, specificity 0.86). Six pts with an ETCO(2) < 30 mmHg did not have DKA.
CONCLUSIONS: Nasal capnography in conjunction with clinical assessment is predictive of DKA. Further research into this area with larger numbers could help validate ETCO(2) as a screening tool for DKA in the emergency department.

Prague Med Rep. 2006;107(3):317-26.
End tidal CO2 monitoring in condition of constant ventilation: a useful guide during advanced cardiac life support.
Pokorná M, Andrlík M, Necas E.
Success of advanced cardiac life support (ACLS) depends on several factors: character and severity of the primary insult, time interval between cardiac arrest and effective basic life support (BLS) and the ensuing ACLS, patient's general condition before the insult, environmental circumstances and efficacy of BLS and ACLS. From these factors, only the efficacy of ACLS is under control of emergency personnel. *The end tidal partial pressure of CO2 (P(ET)CO2) has been shown to be an indicator of the efficiency of ACLS and a general*

prognostic marker. In this study P(ET)CO2 was monitored during out-of hospital ACLS in three cases of cardiac arrest of different aetiology. The aetiology included lung oedema, tension pneumothorax and high voltage electric injury. P(ET)CO2 served for adjustments of ACLS. In these three cases the predictive value of P(ET)CO2 monitoring corresponded to previously reported recommendations.

Ann Emerg Med. 2007 Jan;49(1):1-8.
The utility of supplemental oxygen during emergency department procedural sedation and analgesia with midazolam and fentanyl: a randomized, controlled trial.
Deitch K, Chudnofsky CR, Dominici P.
STUDY OBJECTIVE: To determine whether supplemental oxygen reduces the incidence of hypoxia by 20% in study pts receiving midazolam and fentanyl for emergency department procedural sedation and analgesia.
METHODS: Pts were randomized to receive either supplemental O2 or compressed air by NC at 2 L per minute. Physicians were blinded to the gas used and end-tidal carbon dioxide (ETCO2) data. *Respiratory depression was defined a priori as oxygen saturation less than 90%, ETCO2 level greater than 50 mm Hg, an absolute change from baseline of 10 mm Hg, or loss of the ETCO2 waveform.*
RESULTS: Of the 80 pts analyzed, 44 received supplemental oxygen and 36 received compressed air. Twenty supplemental oxygen pts and 19 compressed air pts met at least 1 criterion for respiratory depression. Six supplemental oxygen pts and 5 compressed air pts experienced hypoxia (P=.97; effect size 0%; 95% confidence interval -15% to +15%). Fourteen pts in each group met ETCO2 criteria for respiratory depression but were not hypoxic. Physicians identified respiratory depression in 8 of 11 pts who became hypoxic and 0 of 28 pts who met ETCO2 criteria for respiratory depression but who did not become hypoxic. There were no adverse events.
CONCLUSION: Supplemental oxygen did not reduce (or trend toward reducing) the incidence of hypoxia in pts moderately sedated with midazolam and fentanyl. However, our lower-than-expected rate of hypoxia limits the power of this comparison. *Blinded capnography frequently identified respiratory depression undetected by the treating physicians.*

Resuscitation. 2006 Oct;71(1):10-8.
Available ventilation monitoring methods during pre-hospital cardiopulmonary resuscitation.
Terndrup TE, Rhee J.
High quality cardiopulmonary resuscitation (CPR) in the pre-hospital setting has been associated with improved survival rates during cardiopulmonary arrest (CPA). *Recent documentation of hyperventilation associated deterioration in hemodynamics during CPR, suggests that guided or controlled ventilation strategies may contribute to improved hemodynamics and increased survival*. This article briefly reviews the mechanical methods, advantages, and disadvantages of the available ventilation monitoring methods currently available for clinical use, with an emphasis on pre-hospital implementation. We recommend that more objective measurement of ventilation during CPR be performed, with emphasis on a strategy for measuring both attempted ventilation frequency (f) and delivered tidal volume (VT). The use of improved thoracic impedance pneumography and capnography are appealing for such monitoring because of the widespread availability, but modifications to existing software and clinical data compared to a clinical standard would be required before general acceptance is possible. Other methods listed may offer advantages over these in select circumstances.

Acta Anaesthesiol Scand. 2006 Sep;50(8):1033-6.
Capnography rapidly confirmed correct endotracheal tube placement during resuscitation of extremely low birthweight babies (< 1000 g).
Salthe J, Kristiansen SM, Sollid S, Oglaend B, Søreide E.
During neonatal resuscitation, the routine use of capnography to verify correct placement of the endotracheal tube is not an established international practice. We present four cases that illustrate the successful use of immediate capnography to verify correct tracheal tube placement even in extremely low birthweight (ELBW) prematures (< 1000 g) during resuscitation. Based on this limited experience, we reached institutional consensus among paediatricians and anaesthesiologists that *capnography should become standard monitoring during all endotracheal intubations in premature babies.*

Pediatr Diabetes. 2006 Aug;7(4):196-200.
Continuous non-invasive end-tidal CO2 monitoring in pediatric inpts with diabetic ketoacidosis.
Agus MS, Alexander JL, Mantell PA.
INTRODUCTION: Pediatric pts with diabetic ketoacidosis (DKA) are routinely subjected to frequent blood draws to closely monitor degree of acidosis and response to therapy. The typical level of acidosis monitoring is less than ideal, however, because of the high cost and invasiveness of frequent blood labs. Previous studies have validated end-tidal carbon dioxide (EtCO2) monitoring in the ED for varying periods of time. We extend these findings to the inpatient portion of the hospitalization during which the majority of blood tests are sent.
METHODS: All pts admitted to an intermediate care unit in (InCU) a large children's hospital were fitted with an appropriately sized oral/nasal cannula capable of sensing EtCO2. Laboratory studies were obtained according to hospital clinical practice guidelines. In a retrospective analysis, EtCO2 values were correlated with serum total CO2 (stCO2), venous pH (vpH), venous pCO2 (vpCO2), and calculated bicarbonate from venous blood gas (vHCO3-).
RESULTS: A total of 78 consecutive episodes of DKA in 72 pts aged 1-21 yr were monitored for 3-38 h with both capnography and laboratory testing, producing 334 comparisons. Initial values were as follows, reported as median (range): stCO2, 11 (4-22) mmol/L; vpH, 7.281 (6.998-7.441); vpCO2, 28.85 (9.3-43.3) mmHg; and vHCO3-, 14 (3-25) mmol/L. EtCO2 was correlated well with stCO2 ($r = 0.84$, $p < 0.001$), vHCO3- ($r = 0.84$, $p < 0.001$), and vpCO2 ($r = 0.79$, $p < 0.001$).
CONCLUSIONS: These data support the findings of previous studies limited to ED populations and suggest that non-invasive *EtCO2 monitoring is a valuable and reliable tool to continuously follow acidosis in the setting of the acutely ill pediatric pt with DKA*. Continuous EtCO2 monitoring offers the practitioner an early warning system for unexpected changes in acidosis that augments the utility of intermittent blood gas determinations.

Pediatrics. 2006 Jul;118(1):260-7.
End-tidal carbon dioxide as a measure of acidosis among children with gastroenteritis.
Nagler J, Wright RO, Krauss B.
OBJECTIVES: We aimed to determine the correlation between end-tidal carbon dioxide levels and serum bicarbonate concentrations among pts with gastroenteritis, to compare the end-tidal carbon

dioxide with other clinical parameters that might also be associated with the degree of acidosis, and to examine the relationship between end-tidal carbon dioxide levels and return visits.
METHODS: Our prospective sample included pts presenting to the emergency department with a chief complaint of vomiting and/or diarrhea. The association between end-tidal carbon dioxides and serum bicarbonate concentrations was determined with simple linear-regression analysis. Receiver operating characteristic curves were computed to determine the predictive ability of the end-tidal carbon dioxide to detect metabolic acidosis.
RESULTS: One hundred thirty of 146 subjects who were approached were included in the final analysis. For those for whom laboratory studies were performed, the mean serum bicarbonate concentration was 17.3 +/- 4.3 mmol/L and the mean end-tidal carbon dioxide level was 34.2 +/- 5.2 mm Hg. End-tidal carbon dioxide levels and serum bicarbonate concentrations were correlated linearly in bivariate analysis. Receiver operating characteristic curves were calculated for end-tidal carbon dioxide as a predictor of serum bicarbonate concentrations of < or = 13, <or = 15, and < or = 17 mmol/L, with areas under the curves of 0.94, 0.95, and 0.90, respectively. The relationship between end-tidal carbon dioxide levels and serum bicarbonate concentrations was independent of other potential predictors of acidosis in multivariable analysis. The mean end-tidal carbon dioxide level for pts who required an unanticipated return visit (33.0 +/- 4.0 mm Hg) was lower than the level for those who did not seek reevaluation (36.6 +/- 3.6 mmHg).
CONCLUSIONS: *End-tidal carbon dioxide levels were correlated with serum bicarbonate concentrations among children with vomiting and diarrhea, independent of other clinical parameters. Capnography offers an objective noninvasive measure of the severity of acidosis among pts with gastroenteritis*.

Pediatrics. 2006 Jun;117(6):e1170-8.
Microstream capnography improves patient monitoring during moderate sedation: a randomized, controlled trial.
Lightdale JR, Goldmann DA, Feldman HA, Newburg AR, DiNardo JA, Fox VL
BACKGROUND: Investigative efforts to improve monitoring during sedation for pts of all ages are part of a national agenda for patient safety. According to the Institute of Medicine, recent technological advances in pt monitoring have contributed to substantially decreased mortality for people receiving general anesthesia in operating room settings. Pt safety has not been similarly targeted for the several million children annually in the US who receive moderate sedation without ET intubation. Critical event analyses have documented that hypoxemia secondary to depressed respiratory activity is a principal risk factor for near misses and death in this population. Current guidelines for monitoring patient safety during moderate sedation in children call for continuous pulse oximetry and visual assessment, which may not detect alveolar hypoventilation until arterial oxygen desaturation has occurred. Microstream capnography may provide an "early warning system" by generating real-time waveforms of respiratory activity in nonintubated pts.
OBJECTIVE: This study was to determine whether intervention based on capnography indications of alveolar hypoventilation reduces the incidence of arterial O2 desaturation in nonintubated children receiving moderate sedation for nonsurgical procedures.
PARTICIPANTS AND METHODS: We included 163 children undergoing 174 elective GI procedures with moderate sedation in a pediatric endoscopy unit in a randomized, controlled trial. All of the pts received routine care, including 2-L supplemental oxygen via nasal cannula. Investigators, pts, and endoscopy staff were blinded to additional capnography monitoring. In the intervention arm, trained independent observers signaled to clinical staff if capnograms indicated alveolar hypoventilation for >15 seconds. In the control arm, observers signaled if capnograms indicated alveolar hypoventilation for >60 seconds. Endoscopy nurses responded to signals in both arms by encouraging pts to breathe deeply, even if routine patient monitoring did not indicate a change in respiratory status.
OUTCOME MEASURES: Our primary outcome measure was patient arterial oxygen desaturation defined as a pulse oximetry reading of <95% for >5 seconds. Secondary outcome measures included documented assessments of abnormal ventilation, termination of the procedure secondary to concerns for patient safety, as well as other more rare adverse events including need for bag-mask ventilation, sedation reversal, or seizures.
RESULTS: Children randomly assigned to the intervention arm were significantly less likely to experience arterial oxygen desaturation than children in the control arm. Two study pts had documented adverse events, with no procedures terminated for patient safety concerns. Intervention and control pts did not differ in baseline characteristics. Endoscopy staff documented poor ventilation in 3% of all procedures and no apnea. Capnography indicated alveolar hypoventilation during 56% of procedures and apnea during 24%. We found no change in magnitude or statistical significance of the intervention effect when we adjusted the analysis for age, sedative dose, or other covariates.
CONCLUSIONS: The results of this controlled effectiveness trial *support routine use of microstream capnography to detect alveolar hypoventilation and reduce hypoxemia during procedural sedation in children*. In addition, *capnography allowed early detection of arterial oxygen desaturation because of alveolar hypoventilation in the presence of supplemental oxygen*. The current standard of care for monitoring all pts receiving sedation relies overtly on pulse oximetry, which does not measure ventilation. Most medical societies and regulatory organizations consider moderate sedation to be safe but also acknowledge serious associated risks, including suboptimal ventilation, airway obstruction, apnea, hypoxemia, hypoxia, and cardiopulmonary arrest. The results of this controlled trial suggest that microstream capnography improves the current standard of care for monitoring sedated children by allowing early detection of respiratory compromise, prompting intervention to minimize hypoxemia. Integrating capnography into patient monitoring protocols may ultimately improve the safety of nonintubated pts receiving moderate sedation.

Acad Emerg Med. 2006 May;13(5):500-4.
Does end-tidal carbon dioxide monitoring detect respiratory events prior to current sedation monitoring practices?
Burton JH, Harrah JD, Germann CA, Dillon DC.
OBJECTIVES: The value of ventilation monitoring with end-tidal carbon dioxide (ETCO2) to anticipate acute respiratory events during ED procedural sedation and analgesia (PSA) is unclear. The authors sought to determine if ETCO2 monitoring would reveal findings indicating an acute respiratory event earlier than indicated by current monitoring practices.
METHODS: The study included a prospective convenience sample of ED pts undergoing PSA. Clinicians performed ED PSA procedures with generally accepted patient monitoring, including oxygen saturation (SpO2), and clinical ventilation assessment. A study

investigator recorded ETCO2 levels and respiratory events during each PSA procedure, with clinical providers blinded to ETCO(2) levels. Acute respiratory events were defined as SpO2 < or =92%, increases in the amount of supplemental oxygen provided, use of bag-valve mask or oral/nasal airway for ventilatory assistance, repositioning or airway alignment maneuvers, and use of physical or verbal means to stimulate pts with depressed ventilation or apnea, and reversal agent administration.
RESULTS: Enrollment was stopped after review of 20 acute respiratory events in 60 pt sedation encounters (33%). Abnormal ETCO2 findings were documented in 36 pts (60%). Seventeen pts (85%) with acute respiratory events demonstrated ETCO2 findings indicative of hypoventilation or apnea during PSA. Abnormal ETCO2 findings were documented before changes in SpO2 or clinically observed hypoventilation in 14 pts (70%) with acute respiratory events.
CONCLUSIONS: *Abnormal ETCO2 findings were observed with many acute respiratory events. A majority of pts with acute respiratory events had ETCO2 abnormalities that occurred before oxygen desaturation or observed hypoventilation*.

Eur J Anaesthesiol. 2006 Feb;23(2):160-4.
Checking the capnograph before anaesthesia: a survey of national practice in the UK.
Gauthama P, Morris EA.
BACKGROUND AND OBJECTIVE: Published guidelines for checking anaesthetic equipment do not contain specific advice on how to check correct functioning of capnograph before inducing anaesthesia.
METHODS: We undertook a postal survey of UK consultant (physician) anaesthetists to establish what methods for checking the capnograph are currently in use. Two hundred and two questionnaires were sent to consultants in different hospitals and 163 returned, a response rate of 81%.
RESULTS: *52.1% consultants of check the capnograph themselves. Of these, 55.3% use their own expired breath to confirm a response to carbon dioxide*. Other methods used by consultant anaesthetists to check capnograph function include the machine self-test (16.5%), visual checks of the capnograph and sampling tubing (10.3%), and sampling of patient expired carbon dioxide (7.1%).
CONCLUSION: The *most common method for testing capnograph function among consultant anaesthetists and their assistants in the UK is the direct measurement of exhaled breath*.

Ann Emerg Med. 2005 Oct;46(4):323-7.
Concordance between capnography and arterial blood gas measurements of carbon dioxide in acute asthma.
Corbo J, Bijur P, Lahn M, Gallagher EJ.
STUDY OBJECTIVE: We examine the concordance between end-tidal partial pressure of CO2 (PetCO2) measured by capnography and arterial partial pressure of carbon dioxide (PaCO2) obtained by arterial blood gas in acute asthmatic pts presenting to the ED.
METHODS: Prospective observational cohort study of acutely ill adult asthmatic pts undergoing an arterial blood gas measurement as part of their evaluation. PetCO2 was recorded during exhalation into a capnograph while arterial blood was pulsing in the arterial blood gas tubing. Concordance between PetCO2 and PaCO2 was displayed as a Bland-Altman matrix, using prespecified limits of agreement of +/-5 mm Hg difference between PetCO2 and PaCO2 in each patient.
RESULTS: The mean difference between the PetCO2 and PaCO2 levels was 1.0 mm Hg (95% confidence interval -0.1 to 2.0 mm Hg), with a median of 0 mm Hg. Of the 39 pts enrolled, 37 (95%) fell within the a priori limits of agreement.
CONCLUSION: *In adult asthmatic pts with acute exacerbations, concordance between PetCO2 measured by capnography and PaCO2 measured by arterial blood gas was high*. These findings must be validated before capnography replacement of arterial blood gas as an accurate means of assessing alveolar ventilation in acute asthma is recommended.

Pediatr Emerg Care. 2005 Sep;21(9):574-7.
Predicting the need for hospitalization in acute childhood asthma using end-tidal capnography.
Kunkov S, Pinedo V, Silver EJ, Crain EF.
OBJECTIVE: To explore the utility of end-tidal capnography for predicting hospitalization in acute childhood asthma.
DESIGN, SETTING, AND PARTICIPANTS: A prospective cohort study of a convenience sample of children 5-17 years presenting to a pediatric ED with an acute asthma exacerbation. Capnography was performed at baseline. The length of the plateau portion of the baseline capnograph waveform was measured in millimeters and divided by the respiratory rate at the time of the measurement to create a ratio. The sensitivity and specificity of the baseline capnography ratio for predicting hospitalization were assessed.
MAIN OUTCOME MEASURES: Hospitalization versus discharge from the pediatric emergency department.
RESULTS: Thirty-seven pts were enrolled. The hospitalized (n = 12) and discharged (n = 25) groups did not differ in terms of any demographic or baseline characteristics except for pulmonary score and the median baseline capnography ratio. The median ratio was 0.15. Ten (83.3%) of 12 of pts who were hospitalized had a baseline ratio less than 0.15 compared with 8 (32%) of 25 of pts who were discharged from pediatric emergency department (P < 0.05). Controlling for baseline asthma severity, the odds of being hospitalized if the baseline capnography ratio was less than 0.15 were 18.77 (95% confidence interval, 1.91-184.69).
CONCLUSION: This pilot study suggests that *baseline capnography may be useful as an objective effort-independent tool for identifying children with an asthma exacerbation who are at risk for hospitalization*.

Curr Opin Crit Care. 2005 Aug;11(4):326-32.
Recent developments in percutaneous tracheostomy: improving techniques and expanding roles.
Bardell T, Drover JW.
PURPOSE OF REVIEW: The purpose of this review is to provide an update of recent developments pertaining to the use of percutaneous tracheostomy. Percutaneous tracheostomy has been established as an alternative to open surgical tracheostomy, but many key questions about the optimal use of this procedure remain unanswered.
RECENT FINDINGS: Issues in percutaneous tracheostomy addressed in the recent literature include the optimal method, timing, use of percutaneous tracheostomy in emergencies, safety in high-risk populations, confirmation of tracheal puncture, and outcomes.
SUMMARY: Recent literature suggests that percutaneous tracheostomy is safe to use in an expanding population of pts, including pts with airway compromise and thrombocytopenia. Several methods seem to be safe alternatives to that originally described. *Capnography has arisen as an alternative to bronchoscopy for confirmation of tracheal puncture*. Recent evidence highlights that

although tracheostomy may improve short-term outcome, these critically ill pts have a significant long-term risk of poor outcome. This must be taken into consideration when this procedure is offered.

Pediatr Emerg Care. 2005 May;21(5):327-32.
End-tidal carbon dioxide monitoring in pediatric emergencies.
Sullivan KJ, Kissoon N, Goodwin SR.
End-tidal carbon dioxide (CO2) monitoring is useful in the prehospital setting, emergency department, intensive care unit, and operating room. *Capnography provides valuable, timely information about the function of both the cardiovascular and respiratory systems*. End-tidal CO2 monitoring is the *single most useful method in confirming endotracheal tube position*. It also provides information about dead space, cardiac output, and airway resistance. A thorough understanding of cardiopulmonary physiology and the technical nuances of capnometry is required for its optimal use in children. This review examines the basic physiology pertinent to end-tidal CO2 monitoring, its clinical applications, and evidence supporting its use in infants and children.

Ann Emerg Med. 2005 May;45(5):497-503.
The effectiveness of out-of-hospital use of continuous end-tidal carbon dioxide monitoring on the rate of unrecognized misplaced intubation within a regional emergency medical services system.
Silvestri S, Ralls GA, Krauss B, Thundiyil J, Rothrock SG, Senn A, Carter E, Falk J.
STUDY OBJECTIVE: We evaluate the association between out-of-hospital use of continuous end-tidal carbon dioxide (ETCO2) monitoring and unrecognized misplaced intubations within a regional emergency medical services (EMS) system.
METHODS: This was a prospective, observational study, conducted during a 10-month period, on all pts arriving at a regional Level I trauma center ED who underwent out-of-hospital ET intubation. The regional EMS system that serves the trauma service area is composed of multiple countywide systems containing numerous EMS agencies. Some of the EMS agencies had independently implemented continuous ETCO2 monitoring before the start of the study. The main outcome measure was the unrecognized misplaced intubation rate with and without use of continuous ETCO2 monitoring.
RESULTS: Two hundred forty-eight pts received out-of-hospital airway management, of whom 153 received intubation. Of the 153 pts, 93 (61%) had continuous ETCO2 monitoring, and 60 (39%) did not. Forty-nine (32%) were medical, 104 (68%) were trauma, and 51 (33%) were in cardiac arrest. *The overall incidence of unrecognized misplaced intubations was 9%. The rate of unrecognized misplaced intubations in the group for whom continuous ETCO2 monitoring was used was zero, and rate in the group for whom continuous ETCO2 monitoring was not used was 23.3%* (95% CI -13.4% to 36.0%).
CONCLUSION: No *unrecognized misplaced intubations were found in pts for whom paramedics used continuous ETCO2 monitoring. Failure to use continuous ETCO2 monitoring was associated with a 23% unrecognized misplaced intubation rate.*

Emerg Med Serv. 2005 Mar;34(3):65-9.
Capnography in sedation and pain management.
Hatlestad D.
Monitoring respiratory rate, effort and efficacy of ventilation during pain management and sedation can be difficult in the field. Capnography is an ideal monitor for use during the administration of narcotics and benzodiazepines. The addition of EtCO2 monitoring *enables earlier identification of respiratory depression* in this group of pts. Standard vital signs, oxygen saturation and EtCO2 must also be monitored continuously. End-tidal carbon dioxide monitoring, although not required on all pts, *provides an earlier indication of respiratory depression than pulse oximetry and respiratory rate alone*.

Anesth Analg. 2005 Mar;100(3):884-8.
Capnogram shape in obstructive lung disease.
Krauss B, Deykin A, Lam A, Ryoo JJ, Hampton DR, Schmitt PW, Falk JL
Small, preliminary studies have suggested that *capnograms of obstructive lung disease (OD) exhibit a characteristic shape* and this shape may be correlated to changes in forced expiratory volume in 1 s (FEV(1)). We evaluated the association between capnograms and spirometry from subjects with OD with normal and restrictive lung disease (RD) subjects. The study was conducted in a prospective, nonrandomized manner using a convenience sample of 262 subjects presenting to a pulmonary function laboratory. Capnograms were recorded before pulmonary function testing. Subjects with OD had capnograms that were significantly different from normal and RD subjects. These differences were progressive, increasing with disease severity. The average take-off angle of the ascending phase for severe OD was 7.2 degrees less (95% confidence interval [CI]:4.0, 10.4) than for normals. The average alveolar plateau elevation angle was 0.8 degrees more (95% CI: 0.14, 1.4) for moderate OD than for normals, whereas the average elevation angle was 3.6 degrees more (95% CI: 2.9, 4.3) for severe OD than for normals. Differences between OD capnograms and normal and RD capnograms,correlating to changes in FEV(1), were sufficiently large enough to suggest the capnogram could be used to discriminate between OD and normal.

Chest. 2004 Nov;126(5):1552-8.
Supplemental oxygen impairs detection of hypoventilation by pulse oximetry.
Fu ES, Downs JB, Schweiger JW, Miguel RV, Smith RA.
STUDY OBJECTIVE: This two-part study was designed to determine the effect of supplemental oxygen on detection of hypoventilation, evidenced by a decline in O2 saturation (Spo(2)) with pulse oximetry.
DESIGN: Phase 1 was a prospective, patient-controlled, clinical trial. Phase 2 was a prospective, randomized, clinical trial.
SETTING: Phase 1 took place in the OR. Phase 2 took place in the postanesthesia care unit (PACU). PTS: In phase 1, 45 pts underwent abdominal, gynecologic, urologic, and lower-extremity vascular operations. In phase 2, 288 pts were recovering from anesthesia.
INTERVENTIONS: In phase 1, modeling of deliberate hypoventilation entailed decreasing by 50% the minute ventilation of pts receiving general anesthesia. Pts breathing a fraction of inspired oxygen (Fio(2)) of 0.21 (n = 25) underwent hypoventilation for up to 5 min. Pts with an Fio(2) of 0.25 (n = 10) or 0.30 (n = 10) underwent hypoventilation for 10 min. In phase 2, spontaneously breathing pts were randomized to breathe room air (n = 155) or to receive supplemental oxygen (n = 133) on arrival in the PACU.
MEASUREMENTS AND RESULTS: In phase 1, ETCO2 and Spo(2) were measured during deliberate hypoventilation. A decrease in Spo(2) occurred only in pts who breathed room air. No decline occurred in pts with Fio(2)levels of 0.25 and 0.30. In phase 2, Spo(2) was recorded every min for up to 40 min in the PACU. Arterial

desaturation (Spo(2) < 90%) was four-fold higher in pts who breathed room air than in pts who breathed suppl. O2 (9.0% vs 2.3%, p = 0.02). CONCLUSION: Hypoventilation *can be detected reliably by pulse oximetry only when pts breathe room air*. In pts with spontaneous ventilation, supplemental oxygen often masked the ability to detect abnormalities in respiratory function in the PACU. Without the need for capnography and arterial blood gas analysis, pulse oximetry is a useful tool to assess ventilatory abnormalities, but only in the absence of supplemental inspired oxygen.

Emerg Med Serv. 2004 Aug;33(8):75-80.
Capnography as a predictor of the return of spontaneous circulation.
Hatlestad D.
EtCO2 monitoring is a valuable tool for clinical management of pts in cardiac arrest, near-arrest and post-arrest. *During cardiac arrest, EtCO2 levels fall abruptly at onset of cardiac arrest, increase after 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*. 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.

Acad Emerg Med. 2002 Dec;9(12):1373-8.
End-tidal carbon dioxide predicts the presence and severity of acidosis in children with diabetes.
Fearon DM, Steele DW.
BACKGROUND: Pts with diabetic ketoacidosis (DKA) hyperventilate, lowering their alveolar (PACO(2)) and arterial carbon dioxide (PaCO(2)). This ventilatory response lessens the severity of their acidemia in a predictable way. Because end-tidal CO(2) closely approximates PaCO(2), measured ETCO(2) levels should allow for predictions about presence and severity of acidosis in diabetic pts.
OBJECTIVES: 1) To evaluate the relationship between measured serum bicarbonate(HCO(3)) and ETCO(2) measured via nasal capnography in children with suspected DKA; and 2) to assess the ability of capnography to predict DKA.
METHODS: Children being evaluated in a pediatric emergency department for suspected DKA (known or suspected diabetes presenting with hyperglycemia with or without ketonuria) were enrolled in a cross-sectional, prospective, observational study. Prior to the availability of venous HCO(3) results, ETCO(2) values were measured using a Nellcor NPB-70 Handheld Capnograph.
RESULTS: Forty-two pts were enrolled. Linear regression analysis revealed a significant relationship between HCO(3) and ETCO(2) (R(2) = 0.80, p < 0.0001). Mean ETCO(2) was 37 torr (95% CI = 35.5 to 37.9 torr) in the children without DKA and 22 torr (95% CI = 17.4 to 26.9 torr) in the children with DKA (p < 0.0001). An ETCO(2) cut-point of <29 torr correctly classified the most pts (95%), with a sensitivity of 0.83 (95% CI = 0.52 to 0.98) and a specificity of 1.0 (95% CI = 0.88 to 1.0). *No patient with an ETCO(2) of > or =36 torr had DKA*, for a sensitivity of 1.0 (95% CI = 0.74 to 1.0).
CONCLUSIONS: *End-tidal CO(2) is linearly related to HCO(3) and is significantly lower in children with DKA*. If confirmed by larger trials, cut-points of 29 torr and 36 torr, with clinical assessment, may help discriminate between pts with and without DKA, respectively.

Acad Emerg Med. 2002 Apr;9(4):275-80.
End-tidal carbon dioxide monitoring during procedural sedation.
Miner JR, Heegaard W, Plummer D.
OBJECTIVE: To prospectively determine whether end-tidal carbon dioxide (ETCO2) monitors can detect respiratory depression (RD) and the level of sedation in emergency department (ED) pts undergoing procedural sedation (PS).
METHODS: This was a prospective observational study conducted in an urban county hospital of adult pts undergoing PS. Pts were monitored for vital signs, depth of sedation per the physician by the Observer's Assessment of Alertness/Sedation scale (OAA/S), pulse oximetry, and nasal-sample ETCO2 during PS. Respiratory depression was defined as an oxygen saturation <90%, an ETCO2 >50 mm Hg, or an absent ETCO2 waveform at any time during the procedure. The physician also determined whether protective airway reflexes were lost during the procedure and assisted ventilation was required, or whether there were any other complications. Rates of RD were compared with the physician assessment of airway loss and between agents using chi-square statistics. Spearman's rho analysis was used to determine whether there was a correlation between ETCO2 and the OAA/Sscore.
RESULTS: Seventy-four pts were enrolled in the study. Forty (54.1%) received methohexital, 21 (28.4%) received propofol, ten (13.5%) received fentanyl and midazolam, and three (4.1%) received etomidate. Respiratory depression was seen in 33 (44.6%) pts, including 47.5% of pts receiving methohexital, 19% receiving propofol (p = 0.008), 80% receiving fentanyl and midazolam, and 66.6% receiving etomidate. No correlation between OAA/S and ETCO2 was detected. Eleven (14.9%) pts required assisted ventilation at some point during the procedure, all of whom met the criteria for RD. Pulse oximetry detected 11 of 33 pts with RD. Post-hoc analysis revealed that all pts with RD had an ETCO2 >50 mm Hg, an absent waveform, or an absolute change from baseline in ETCO2 >10 mm Hg.
CONCLUSIONS: There was no correlation between ETCO2 and the OAA/S score. *Using the criteria of an ETCO2 >50 mm Hg, an absolute change >10 mm Hg, or an absent waveform may detect subclinical RD not detected by pulse oximetry alone. The ETCO2 may add to the safety of PS by quickly detecting hypoventilation during PS in the ED*.