Carbon Dioxide - It's not just a gas

Part 3: Applications for the non-intubated patient

In this final article in a series of three, Martin Betzer of Falck Denmark explains how end tidal carbon dioxide monitoring might guide you in your clinical assessment of critically ill, non-intubated patients.

Summary

In the previous editions of Ambulance Today, the basic physiological principles of capnography and the application possibilities during resuscitation were discussed. This article will review the usability of capnography in the spontaneously breathing, non-intubated cohort, starting with a summary of the basics.

End tidal carbon dioxide (EtCO2) monitoring is the measurement of the partial pressure of expired carbon dioxide gas in the end of an exhalation. The CO2 gas itself emerges as a by-product of cellular metabolism, diffusing into circulation and eliminating through ventilation. Therefore, EtCO2 sampled through a nasal cannula gives you a visual, continuous and real-time, breath-to-breath insight to your patient's airway, respiratory, circulatory and metabolic state.

The graphic capnogram curve and the numeric EtCO2 value known as the capnometer gives you the information you need for interpretation. Normal EtCO2 values lies within 4.0-5.7 kPa or 35-45 mmHg[1], values that, as this article will show, might reveal way more about your patient than your regular assessment.

In previous articles we have established, that in the intubated patient capnography monitoring is no doubt the gold standard for ventilation monitoring; furthermore we found that during resuscitation you might gain several benefits from capnography. But what about those patients who are not intubated or in cardiac arrest? Read on...

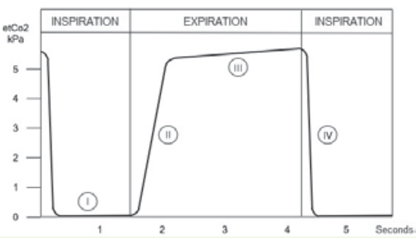

Figure 1: The normal capnogram curve. I: pause/inspiration, II: expiration of dead-space mixed gasses, III: expiration of CO2, IV: inspiration/pause.

The background

Alongside the emerging use of pre-hospital capnography in later years, its application possibilities in the non-intubated patient have evolved. Clinicians have made their own personal experiences with its use and in some areas capnography is now a standard alongside more common monitoring equipment such as blood pressure and oxygen saturations [1 p. 15].

But does capnography for the non-intubated patient make a difference in your clinical decision making process, compared to standard monitoring alone? Do you obtain any need-to-know information that your clinical examination does not reveal? Not necessarily.

In 2015, Falck conducted a systematic review of available literature to reveal when (or if) we should use capnography for the non-intubated patient [2]. Our conclusion was, that routine use of capnography should be discouraged, as we found no scientific study that evaluated the benefits in clinical decision-making, when adding capnography

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to standard monitoring. In certain circumstances however, capnography might make a difference in your clinical evaluation, which is why it should be used on special indications based on an reflectory clinical judgement.

What we also found, was that to use capnography correctly the clinician should be well-educated within respiratory physiology and capnography interpretation. Especially the so-called ventilation/perfusion mismatch (V/Q mismatch) originating from inequalities within ventilation and perfusion might influence readings and further challenge interpretation [3].

The basics of interpretation start with your patient having tidal volumes large and regular enough for the capnograph to make a reading, otherwise the gas sample will be inadequate leading to falsely low and unreliable EtCO2 levels [1 p. 58]. From here, basically the faster and deeper your patient breathes, the lower the EtCO2 levels, and vice versa. But this is not always the case as to why EtCO2 levels cannot stand alone, and should be interpreted as a part of a multimodal patient assessment. This also involves capnogram evaluation – the ventilations should be graphically pictured on the monitor, just as you are confirming correct oxygen saturations by looking at the plethysmograph curve, right?

Your patient assessment and your working diagnosis should furthermore be set before evaluating the capnography readings; thus you can use capnography as a means of confirming your working diagnosis and tailoring your treatment. In the following, some scenarios will be discussed where pre-hospital capnography monitoring could make a difference to your everyday patient care. Furthermore, the V/Q phenomenon will be exemplified and hopefully also demystified!

Continuous monitoring

In the pre-hospital environment, a variety of factors might affect our ability to adequately assess and monitor our patients during transport which is why capnography in some cases might have a place as a continuous monitoring form. Commonly, ventilation is evaluated through a combination of clinical parameters such as ventilation frequency, depth, labor and oxygen saturations. Evaluation of these parameters are however subjective and they have been shown to be inadequate even for experienced health care personnel [4]. Used as a means of continuous ventilation monitoring, capnography has been found superior to common clinical and medico-technical monitoring [5].

Think about it: You are treating and transporting a young gentleman who might have drank too much, and currently he is lying on his side on your stretcher; sleeping. A low-risk common pre-hospital case, right? Are you able to evaluate his airway and breathing in this position? The pulse oximeter is showing 99%, but does this mean that he is breathing? Using capnography, you will identify significantly more cases of inadequate ventilation and hypoxia than using standard assessment and monitoring alone [6]. It is commonly said that we should not utilise capnography just to get the ventilation frequency which the capnograph is kind enough to calculate for us. But why not? You are alone back there with your patient, and you have a lot of tasks en route to hospital. Ventilation frequency is known to be the first parameter to change in almost every medical emergency, but to realise that there is a change, you will need to identify it through a trend first! How many of your patients have a ventilatory rate of 14? Using capnography enables you to monitor and document the true trend.

Also, if there is no ventilation at all, an apnea alert is built into the capnograph ensuring your immediate attention compared to the several minutes it would take for the oxygen saturations to drop [7].

Shortness of breath

The normal "box-shaped" capnogram pictured in figure 1 shows the ventilation cycle under normal circumstances. Comparing this with the pathological "shark-fin"-like appearance of the capnogram in figure 2, it is obvious that the exhalation phase of the ventilation cycle is prolonged, reflecting bronchospasm such as in anaphylaxis or exacerbation of asthma or chronic obstructive pulmonary disease (COPD) [8].

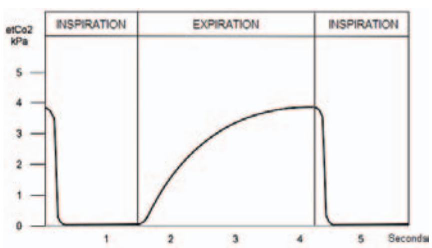

Figure 2: Pathological capnogram curve reflecting prolonged expiration – the "shark-fin".

The more the exhalation phase is sloping, the more severe the bronchospasm is [9]. This also means, that you can use capnography as a means of evaluating the effect of medical treatment, as the capnogram slowly should return to normal.

You are of course never in doubt as to whether your patient has COPD exacerbation or pulmonary edema, but your colleague might be. Tell your colleague that the shape of the capnogram might come in handy in distinguishing between the two. Bronchospasm will be reflected in a "shark-fin" appearance as displayed in figure 2, and pulmonary edema should be reflected as a normal shaped capnogram as in figure 1 [9]. Additionally, severe cases of asthma and COPD tend to have higher EtCO2 levels than those of pulmonary edema [8]. Ultimately, inclining EtCO2 levels in asthma or COPD despite aggressive treatment has been described to serve as an accompanying tool in the decision to intubate [10].

When applying capnography to the patient in respiratory distress, you once again should use clinical judgement. Ask yourself: "What do I expect to find, and how will the findings change my treatment?". Picture a 67-year old patient suffering from COPD in a tripod position, wheezing with cyanotic lips and rapid, shallow breathing. This should ring a bell even without capnography. Do yourself and your patient a favor - prepare yourself by evaluating your reasons for applying capnography.

It might make a difference in respiratory distress, and it might serve as the "the full picture" – but before using capnography – ask yourself why! We do not want to waste our patient's time fiddling with useless, rubber-smelling gear.

Low-flow states

As capnography indirectly reflects circulation, it might make sense to use the EtCO2 levels when assessing patients in hypovolemia and other low-flow-states. Oxygen is carried to the tissue through the circulation and likewise circulation is carrying the waste product CO2 back to the lungs. If the circulation in some way is compromised, lower amounts of CO2 is delivered to the lungs – hence you will get a low EtCO2 reading [1 p.313]. Furthermore, if your patient is having a pulmonary embolism or is suffering from hypovolemia due to trauma – the ventilations might be rapid on top of that – further decreasing EtCO2 [1 p.313].

Interpreting your readings in this setting is where clinical experience, reflection capabilities and education is a must – and why capnography interpretation should always be accompanied by a multimodal patient assessment. Low-flow states are a classic example of a V/Q mismatch. There is not enough perfusion (Q) to transport the present amounts of CO2 to the ventilation (V). In another configuration, there is too much ventilation (V) relative to the present amount of perfusion (Q). Furthermore, this serves as an example of the difference between EtCO2 and an arterial blood gas analysis – PaCO2. Both parameters are evaluating CO2 levels, but the sampling point makes a great difference in the reading [1 p.313]!

Another example of a low-flow state and thereby a V/Q mismatch is septic shock. Here, the body tries to eliminate large amounts of lactate through an increase in ventilation. Simultaneously, there is likely a drop in blood-pressure leading to a decrease in perfusion. Both mechanisms are resulting in low EtCO2 levels, and thereby a possible benefit for the clinician when assessing and evaluating patients in septic shock. In the future when further studies are available, we might see EtCO2 levels as a part of early warning scores in sepsis [11].

The bottom line

Know about respiratory physiology and the V/Q phenomenon to use capnography with a critical approach. The EtCO2 value itself is not of particular interest. On the other hand changes in trends or extremely low or high patient specific values are [12]. There are many other application possibilities than those mentioned in this and the earlier articles, the clinical bottom line is however, that if you ensure that you are capable of interpreting the readings and the EtCO2 level is accompanied by a trustworthy capnogram, capnography can be used to assess sudden changes and trends which might aid you in your clinical assessment.

The summary

We do not want to waste our patients' time. We are able to perform a lot of assessments, monitoring and treatments – but every single one of our actions should be considered useful. This goes for capnography in particular. This article series underpins that the clinician analysing the EtCO2 data must possess a certain amount of knowledge within respiratory physiology, as well as establishing that capnography should be utilised for monitoring a trend rather than identifying an instant value.

In the literature, there are some indications of possible benefits in clinical decision-making when applying capnography to the spontaneously breathing non-intubated patient. The scientific large-scale study evaluating the impact on clinical decision-making when adding capnography to the non-intubated pre-hospital patient cohort is however yet to be performed, thus a true benefit is not yet fully established.

This sums up the background of this three-article series on capnography - and "treat the patient, not the monitor" remains the recurrent punch-line. Thank you for reading!

Take home box

- Capnography should not be used routinely

- Interpreting capnography calls for knowledge within respiratory physiology

- Capnography in the non-intubated cohort might make a difference in clinical decision-making.

Conversion table

mmHg	kPa	mmHg	kPa
5	0.67	45	6.00
10	1.33	50	6.67
20	2.67	60	8.00
30	4.00	70	9.33
35	4.67	80	10.67
40	5.33	90	12.00

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