Commentary

# Carbon dioxide monitoring and evidence-based practice – now you see it, now you don't

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## Abstract

Carbon dioxide has been monitored in the body using a variety of technologies with a multitude of applications. The monitoring of this common physiologic variable in medicine is an illustrative example of the different levels of evidence that are required before any new health technology should establish itself in clinical practice. End-tidal capnography and sublingual capnometry are two examples of carbon dioxide monitoring that require very different levels of evidence before being disseminated widely. The former deserves its status as a basic standard based on observational data. The latter should be considered investigational until prospective controlled data supporting its use become available. Other applications of carbon dioxide monitoring are also discussed.

**Keywords** biomedical technology assessment, capnography, critical care, evidence-based medicine, physiologic monitoring

## Introduction

The technology required to perform capnography on expired gas is not new and its use has been considered a standard in basic anaesthetic monitoring by the American Society of Anesthesiologists since 1986 [1]. This contrasts with the use of sublingual capnometry as a detector of regional hypoperfusion [2], which is a recent application of carbon dioxide monitoring whose use should currently be considered investigational.

Evidence-based medicine, defined as the integration of best research evidence with clinical expertise and patient values [3], encourages us to use all appropriate sources of data to inform best practice. Using the example of carbon dioxide monitoring and its many applications, we compare the different kinds of evidence that were required or are needed before a health technology can earn its place in clinical practice.

## When controlled clinical trials are unnecessary

Measurement of the magnitude and severity of adverse outcomes following undiagnosed esophageal intubation in anesthesia helped create the demand for an effective way to prevent this important problem. The use of capnography to confirm endotracheal tube placement is founded on a simple and widely understood physiologic rationale, and the appropriate level of evidence required before recommending the use of a device designed to perform this function is a demonstration that the device is safe, sensitive, and specific. The debate has long since moved on to other aspects of end-tidal capnography such as its use in prehospital settings and to the inadequate dissemination of this practice throughout critical care [4].

Colorimetric indicators of end-tidal carbon dioxide are much simpler devices than gas analyzers, and rely on visible color

$P_{CO_2}$ = partial carbon dioxide tension.

changes in a chemical indicator that is housed within a disposable connector. As with a gas analyzer, prospective users of these devices need only see evidence that the device is safe, sensitive, and specific. Clinical experience tells us that these devices may have real additional benefits in terms of ease of use, cost, and applicability in a wide range of situations.

Applications of capnography that do not require controlled clinical trials before their use can be recommended share similar features. They address an important clinical problem that can easily be described using observational methods. There is a simple rationale for monitoring a well known physiologic variable as a way to solve the problem, and a safe and effective device is available to carry out the function.

## When controlled clinical trials might be needed

There are other applications of carbon dioxide monitoring that may fulfil these criteria. The key difference is the nature of the inference that is drawn from the use of the technology in these situations. If a capnograph or capnometer were available, then there is no reason not to use it when transporting patients within or between hospitals. A simple trial might confirm that this reduces the incidence of hypoventilation during transport [5], but a complex one would be required to conclude, for example, that it improved outcome when used in the prehospital period for patients suffering from traumatic brain injury.

Capnography would surely assist in the placement of a needle in the trachea [6] during percutaneous tracheostomy, but if a claim were made that this was superior to an existing method, such as bronchoscopy, then a controlled clinical trial would be necessary to test this hypothesis [7]. As a final example of an application that may or may not require a controlled clinical trial before it could be disseminated, in an interesting role reversal capnography has been used to diagnose tracheal placement of enteral feeding tubes. Evaluating the properties of capnography as a diagnostic test in this setting can be done by comparing it with the 'gold standard' of chest radiography [8]. Clinical experience tells us that using this method may have a real advantage by detecting misplacement of the tube during the insertion itself, but we would still require a very high level of evidence to justify replacing the existing gold standard rather than using capnography as an adjunct to it.

## When controlled clinical trials are required

Carbon dioxide is produced in the body as a product of metabolism and transported to the lungs by the cardiovascular system. Hence, a simple physiologic rationale exists for using carbon dioxide monitoring to obtain information about cellular metabolism and global perfusion. Clinical experience and research shows that gross disturbances in global perfusion may be reflected by end-tidal carbon dioxide, and this can have useful applications, for example as a prognostic marker during advanced cardiac life support [9].

It is also possible to monitor carbon dioxide 'upstream' from expired gases. Capnometry can measure partial carbon dioxide tension ($P_{CO_2}$) in a regional tissue bed, and the reason for monitoring this in critical care medicine is that hypoperfusion causes oxygen deficit and increases tissue carbon dioxide production. Furthermore, hypoperfusion is not always clinically apparent. There is large body of literature examining the significance of splanchnic hypoperfusion. Despite research supporting the use of gastric tonometry, this technology never earned an established role in clinical practice. Sublingual capnometry has recently been proposed as a measure of regional hypoperfusion that is technically simpler and easier to apply than gastric tonometry [10,11].

Describing why occult splanchnic hypoperfusion is a clinical problem is much more difficult than describing why undiagnosed esophageal intubation is a problem. A clinician using sublingual capnometry is not being asked to accept a simple physiologic rationale but rather a complex and controversial paradigm. Does a sublingual capnometer reliably and accurately measure sublingual $P_{CO_2}$? Is lingual tissue hypercarbia a valid surrogate for splanchnic hypoperfusion? Most importantly, is it reasonable to infer that interventions arising from the monitoring of sublingual $P_{CO_2}$ will improve any clinically meaningful outcomes?

Sublingual capnometry fulfils none of the criteria required for a health technology to be recommended for widespread use before there are prospective, controlled clinical data to support it. Research and clinical expertise will always retain equally important roles in evidence-based practice. If research can show us that sublingual capnometry is a superior predictor of mortality in critically ill patients than the serum lactate concentration [2], then can it not also show us that it is superior to an experienced clinician?

## Conclusion

The level of evidence that is required before applying any health technology in critical care medicine is highly variable. Manufacturers and regulatory authorities are responsible for the safety of a device, but users must assess for themselves the clinical problem it addresses and the sturdiness of its underlying physiologic rationale. All inferences made when using a device should be supported by an appropriate combination of experience and data.

## Competing interests

None declared.

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