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EDITORIAL

Use of Disposable End Tidal Carbon Dioxide Detector Device for Checking Endotracheal Tube Placement.

JAIN H, VARGESE C

ABSTRACT

End tidal carbon dioxide (ETCO2) monitoring is the non-invasive measurement of exhaled CO2. It is of particular use for verification of endotracheal tube placement. It is easy to apply to breathing circuits. This technology has the potential to become a very useful tool in the pre-hospital setting. It is a commercially available, disposable, colorimetric ETCO2 detector in which colour changes using a numerical scale semi-quantitatively measures carbon dioxide percentage in exhaled gases, and it has been proved useful in adults and children. End tidal CO2 detectors provide an objective evidence of the tube position in the trachea. In addition to quickly revealing the misplaced oesophageal intubations it can prevent unnecessary re-intubations. Other uses in the Emergency Department include monitoring CPR efforts and monitoring the ventilatory and haemodynamic status of intubated and nonintubated patients. In addition, future uses may include using PetCO2 as an adjunct when monitoring the status of asthma treatment, when making the diagnosis of pulmonary embolism, and when measuring cardiac output noninvasively.

Key words: End tidal carbon dioxide detector, neonates, emergency medicine, endotracheal intubation, cardiopulmonary resuscitation.

Introduction

Endotracheal intubation remains one of the critical skills for all concerned with emergency and intensive care. In life-threatening situations in the operating room, intensive care unit, emergency department and in the pre-hospital setting, endotracheal intubation is a commonly performed emergency procedure. It is not uncommon for young registrars to face this challenge in the delivery room. Bag and mask ventilation is an intervention that is performed in up to 10% of delivery room resuscitations in newborn infants [1]. Catastrophic situations like inadvertent, undetected oesophageal intubation can occur in the hands of the most experienced people [2][3][4]. Similarly, senior staff often needs reassurances with regards to intubation skills of the junior staff. Clinical methods of determining the tube placement are usually good enough for an experienced operator. However, there can be circumstances when opinions may vary between the nursing and medical staff regarding the tube placement. If the oxygen saturation increases quickly, there is little to doubt, though at times this may not happen soon. In those precious moments, lot of confusion can arise when the tube placement is in doubt. Similarly, it is difficult for a specialist on call who is contacted through the telephone, to judge whether the intubation has been correctly performed or not. End tidal CO2(ETCO2) detectors provide an objective evidence of tube position in the trachea. This can prevent unnecessary re-intubations, and can quickly reveal the misplaced oesophageal intubations.

Department of NEWBORN CARE, Liverpool Hospital, Liverpool, NSW 2170, Australia
Corresponding Author: Dr Hemant Jain
E-mail: drhemantjain@jcdr.net

Endotracheal Intubation

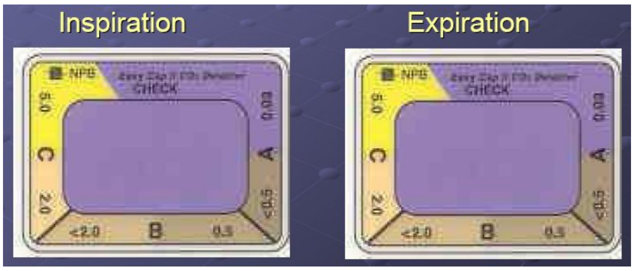
The usual clinical methods used for confirming endotracheal tube (ETT) position, such as bilateral breath sound auscultation, chest movement visualization, clouding of the ETT, auscultation over the stomach, etc., occasionally fail. Since CO2 which is exhaled through the trachea is not usually detected in the oesophagus, capnometry can distinguish between endo-tracheal and oesophageal intubation. In the early detection of oesophageal intubation measurement of ETCO2 has been shown to be superior to pulse oximetry, especially in patients who are pre-oxygenated with 100% oxygen [5].

Physiology

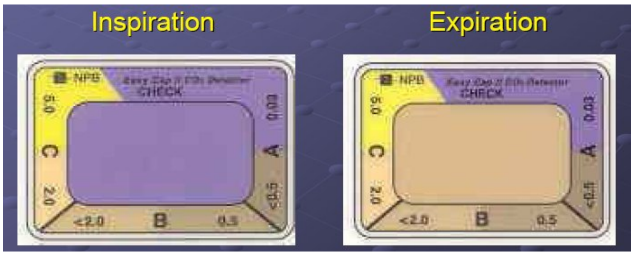
CO2 which is produced during cellular metabolism, is transported to the heart and exhaled via the lung, and so ETCO2 is a reflection of ventilation, metabolism and circulation. By keeping any two systems constant, changes in the third system are found to reflect changes in ETCO2. Hence, it is a non-invasive technique to evaluate these systems [3][4]. ETCO2 is increased in hyper-metabolic states such as sepsis, malignant hyperthermia, shock and pulmonary embolism. Decreased cardiac output and decreased pulmonary blood flow during cardiopulmonary resuscitation (CPR) cause decreased ETCO2[6]. In anaesthesia practice, ETCO2 monitoring is has become a standard of care. The normal ETCO2 is approximately 38 mm Hg (a 5% concentration at 760 mm of atmospheric pressure). In patients with normal perfusion and ventilation, ETCO2 measurement closely resembles arterial CO2 partial pressures[7][8].

Technology

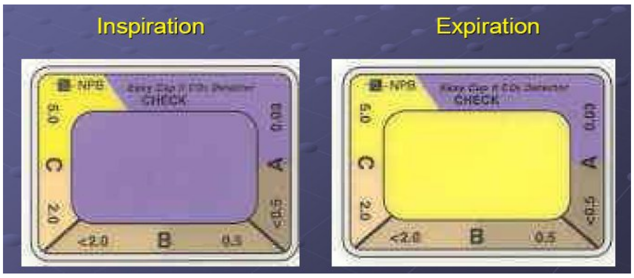
A non-toxic, pH-sensitive chemical indicator (metacresol purple) visible through a clear dome, detects CO2 in gas mixtures flowing through it. Concentrations of CO2 are indicated by reversible colour changes. The detector turns yellow during expiration and purple during inspiration, when it is attached to the ETT of a correctly intubated patient. When attached to an ETT placed in the oesophagus, it remains purple. Colour ranges are visible through the dome.



Purple = 0.03% -< 0.5% CO_2 (< 4 mm Hg); → ET tube position probably in Oesophagous or very poor perfusion leading to false negative results.



Tan= 0.5% - 2% CO_2 (4- 14 mm Hg): Deliver 6 more breaths, if the colour remains tan then most likely oesophageal intubation however sometimes poor perfusion can also give result in persistent tan colour.



Yellow = 2%-5% (15-38 mm Hg): →tube position in trachea (interpret after 6 breaths.)

[Table/Fig 1] Johnston E, Adams A, Steward M. Use of the Pedi-Cap® carbon dioxide detector in neonatal resuscitation and transport. In: NETS Education 2006 [9].

The device which works for about 2 hours, responds to breath-by-breath CO2 changes. Increased humidity can decrease the clinical lifespan of the detector. Only if there is reversible color change, the indicator colour is to be interpreted. This single-use device, which requires no sterilization, warm-up time or calibration. The detector has a shelf life of about 1 year and its use is easily learned [10].

[Table/Fig 2]: Types of device and its characteristics

	Easy Cap II ™	**Pedi-Cap™**
Recommended patient size	Weight over 15kg	Weight 1kg to 15kg
Internal volume (dead space)	25cc	3 cc
Resistance to flow	3.0cm H_20 ±1.0cm @ 60L/min flow	2.5cm H_20 ±0.5cm @ 10L/min flow
Connector ports:		
Patient end	22mm OD/15mm ID	18mm OD/15mm ID
Circuit end	15mm OD/13mm ID	15mm OD/5mm ID
Usage time	Up to 2 hours	Up to 2 hours

Source: Product information Nellcor (tyco) Health care. http://www.nellcor.com

Infants

It should not be continuously used in small infants because of the danger of re-breathing expired air.

Adults

Among adults, in order to avoid false positive readings (i.e. yellow colour despite oesophageal ETT position) caused by the presence of CO2 in the oesophagus, immediately after ingestion of carbonated beverages or after bag-valve-mask ventilation, readings should be obtained after six breaths, as per the manufacturer's recommendation [11].

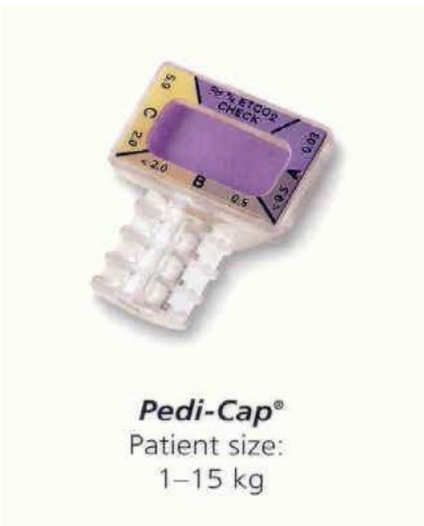
Caveats

Permanent yellow discolouration can occur due to direct contamination of the indicator from gastric contents, pulmonary oedema fluid, or intracheal drugs. Drugs such as epinephrine come in direct contact with the indicator membrane [12][13][14]
For colour change, the mean minimal CO2 concentration needed, has been shown to be 0.54% (4.1 mm Hg)][15].

USES

Neonates and Infants

After being first studied clinically by Smallhout and Kalenda in the 1970's, and in the late 1980's – 1990's, this methodology has been studied extensively in various clinical settings. Verifying endo-tracheal tube (ETT) position has been found to be the common use of ETCO2.[16]
Recommended evidence of effective assisted ventilation is the observation of adequate chest rise. However, chest rise can be difficult to identify by inexperienced personnel, may be confused with abdominal rise from stomach inflation, and is associated with increased ventilating pressures. The time spent in **verifying the endotracheal tube position** (trachea versus esophagus) in newborns, including premature babies with body weight < 1000 gm can be significantly reduced by the use of a disposable paediatric endotracheal CO2 detector . Direct visualization of the ETT going through the vocal cords and CO2 in the exhaled air, are the gold standards for verifying ETT position. Besides visualizing whether the ETT is going through the vocal cords, ETCO2 measurement has been found to be the most reliable method of **re-confirming ETT position** in an infant who is already on ventilator support [17][18]
At present many Neonatal units use this as a standard practice. It is recommended by the Australian Resuscitation Council (2006) neonatal Guidelines for verification of correct tube placement. **[19]**



[Table/Fig 3]

The author's personal experience suggests that it is a useful device that can be of great value where the skill of the operator is in doubt and senior staff are not on site. Another use is in infants who desaturate while being on respiratory support. Tube position can be confirmed by using this device. This can be of real value when the senior staff is not present on site and the confidence of the staff on site in re-intubation is limited. Thus, this avoids unnecessary re-intubation attempts. We found that the device is of high positive predictive value ie the colour yellow is very reassuring.

However, it is imperative to remember that if the perfusion of the infant is very poor, for example, in a newborn with very low heart rate especially if the infant is premature, the exhaled CO2 may be so less that the detector may not change colour in spite of correct tube placement. The detector quickly changes colour, once some perfusion is established, usually before the actual saturation increase is detected. We did not notice a similar problem while we being used for bigger babies.

[Table/Fig 4]: Johnston E, Adams A, Steward M. Use of the Pedi-Cap® carbon dioxide detector in neonatal resuscitation and transport. In: NETS Education 2006(1)

Infrequently, we found that this device to shows false negative results when the continuous gas flow through the device is high, probably resulting in dilution of exhaled CO2. We encountered this problem only while using neopuff. When we switched over to the resuscitator (lederal bag) the colour of the detector changed immediately [Table/Fig 4].

The cost of the device is around $ 8.80 Aus dollars (approx. 260 Indian rupees). We do not feel that it is necessary to use it in every intubation, but selected use is more cost effective.

The manufacturers recommend single use of the device. Once the device is removed from its packing it attracts moisture and hence looses its sensitivity with time. However, if immediately after use it is resealed in a plastic envelope it can be reused. Before the first and subsequent use it is important to take note of the original indicator colour. This should be purple; if it is already yellow then the device is no longer useful. We do not recommend its multiple use since there is no evidence to support it, however where resources are limited the intensivist can explore this possibility keeping in mind that reversible change of colour rather than static change, is more reliable.

Use of end tidal carbon dioxide in adults

ETCO2 monitoring has been strongly recommended in pre-hospital settings, and is the standard of care among anaesthesiologists . If experienced anaesthesiologists who perform intubations daily need to use ETCO2, the need is even more pressing for its use in the pre-hospital setting and in the Emergency Department where intubations are performed less frequently and in less favourable settings [20]. Pre-hospital transportation can dislodge ETT, and it can also take place because of rough road conditions and during interhospital transport, or because of patient movement or unsecured ETT

In the early detection of oesophageal intubation, especially if patients are preoxygenated with 100% O2, ETCO2 has been shown to be superior to pulse oximetry . This is because after the displacement of the ETT, the absence of CO2 is detected in the very next breath , while it takes a little while for drop of O2 saturations , and for the occurrence of physiological changes False positive readings (readings indicating tracheal placement) can be avoided by obtaining readings after 6 breaths, which may occur after ingestion of carbonated beverages or bag-valve-mask ventilation. True readings are obtained by the end of 6 breaths, when there is a CO2 wash out. Colorimetric detectors have shown good results in adults in the ICU, ED, OR, transport and pre-hospital settings False negative readings may occur during CPR, because of very limited pulmonary blood flow, i.e., the detector remains purple despite correct intratracheal placement.

ETCO2 monitoring is a valuable tool during **Cardio Pulmonary Resuscitation**. ETCO2 levels fall to abruptly to low levels at the onset of cardiac arrest, increases after the onset of effective CPR, and returns to normal levels at return of spontaneous circulation (ROSC). End-tidal CO2 has been shown to correlate with cardiac output, coronary perfusion pressure , efficacy of cardiac compression, ROSC, and even survival during effective CPR. In both adult and paediatric CPR, the colorimetric detectors which were shown to correlate with infrared capnometry in a paediatric canine arrest model, have been shown to have prognostic value. The initial value of ETCO2 was found to be proportional to the short term survival[21][22].

Conclusion

Using the portable device allows much faster detection of erroneous intubation and much earlier reintubation, and this is of particular benefit to babies who are erroneously intubated in the esophagus. It is useful where the operators are less experience, in pre-hospital setting and in reconfirmation of ET position on an infant on ventilatory support. It is a handy piece of equipment which should be a part of all resuscitation trolleys.

Conflict of Interest : None

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