Editorial

Utility of end-tidal carbon dioxide monitoring in critically ill children

Balagangadhar R. Totapally[1,2]

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Carbon dioxide is produced in the tissues as a byproduct of aerobic metabolism, then transported to the lungs by the venous circulation and is finally eliminated during the expiratory phase of ventilation. End-tidal CO_2 ($ETCO_2$) is defined as the peak CO_2 value during expiration and is dependent on adequate pulmonary blood flow to the ventilating areas of the lung. $ETCO_2$ in healthy subjects differs normally by <5 mmHg from the arterial CO_2 ($PaCO_2$). An increased $ETCO_2$-$PaCO_2$ gap can be found in association with a decreased pulmonary blood flow and/or increased dead-space.

Capnometry is the measurement of CO_2 concentration of tidal gas at the airway opening. Capnography is the graphic display of the measured CO_2. Capnography is an important non-invasive technique that can monitor CO_2 production, pulmonary perfusion and alveolar ventilation as well as respiratory patterns.[1] Capnography has been shown to be effective as a tool for early detection of complications during anesthesia including, hypoventilation, esophageal intubation and circuit disconnection. Tinker *et al*.[2] concluded after a closed claim analysis for the American Society of Anesthesiology that the application of capnography and pulse oximetry together could have helped prevent 93% of avoidable anesthesia mishaps identified in their study. Capnometry is now a standard of care during administration of general anesthesia, for confirmation of placement of endotracheal tube after intubation and during transportation of an intubated patient. It has been increasingly used in intubated ventilated patients in intensive care units to safely wean patients, decrease the number of arterial blood gases, detect endotracheal displacement and prevent hypercarbia. Nasal $ETCO_2$ monitoring is useful during procedural sedation and post-operative monitoring in the recovery room. In addition, volumetric capnography can be used as a non-invasive method to measure cardiac output.

In this journal, Mehta and colleagues presented their data showing good correlation between $ETCO_2$ and $PaCO_2$ in neonates and children.[3] As expected correlation between $ETCO_2$ and $PaCO_2$ was weaker when P/F ratio was <200 in neonates as well as children compared to when P/F ratio was >200. Although, the mean bias with the Bland-Altman plot was low in neonates as well as children the limits of agreement is large suggesting variability of PaCO2-$ETCO_2$ gap in their sample. Their findings confirm previously published data in neonates.

The gradient between $PaCO_2$ and $ETCO_2$ depends upon the amount of dead space during ventilation.[4] Many variables influence the percentage of dead space to total minute ventilation. Decreased pulmonary blood flow, pulmonary disease or hyperinflation of lungs can lead to increased dead space and consequently high $PaCO_2$-$ETCO_2$ gap. An important limitation of using $ETCO_2$ as a surrogate for $PaCO_2$ measurement is that the $PaCO_2$-$ETCO_2$ gap changes from patient to patient based on underlying pulmonary and cardiovascular conditions and ventilation strategies and within the same patient with significant changes in the cardiopulmonary

From:
[1]Division of Critical Care Medicine, Miami Children's Hospital, Miami, FL 33155, [2]Herberth Wertheim College of Medicine, Florida International University, Miami, FL 33199, USA

Correspondence:
Dr. Balagangadhar R. Totapally, Division of Critical Care Medicine, Miami Children's Hospital, 3100 SW, 62nd Avenue, Miami, FL 33165, USA.
E-mail: bala.totapally@mch.com

condition. In a stable patient $ETCO_2$ monitoring can be used as trending tool during weaning or after the change in ventilator setting. Periodic measurement of $PaCO_2$ is necessary to make sure the $PaCO_2$-$ETCO_2$ gap is not significantly altered.

Mehta *et al*.[3] confirmed previous reports of $ETCO_2$ monitoring as a valid tool in sick, mechanically ventilated neonates and children. In addition to monitoring ventilation status, continuous $ETCO_2$ is useful in early detection of dislodgement of endotracheal tube. Waveform of capnography may be useful in detecting certain type of pulmonary pathology, such as obstructive airway disease. $ETCO_2$ monitoring is a valuable tool during cardiopulmonary resuscitation (CPR). $ETCO_2$ levels fall to low levels at the onset of cardiac arrest, increases with effective CPR and returns to normal levels at return of spontaneous circulation.

Although there are no absolute contraindications of use of $ETCO_2$ monitoring there few limitations for its use.[5] Large main stream capnometers can add dead space and may cause kinking of endotracheal tubes. Fortunately, most modern capnometers add a small amount dead space and are of light weight. Gas sampling rate from a side stream capnometer can lead to auto triggering and sometimes inadequate tidal volume delivery in very small neonates. Secretions and condensation in the tubing and leaks in the ventilator circuit can affect the accuracy of $ETCO_2$.

End-tidal carbon dioxide monitoring is a useful tool in the management of acutely ill and is becoming a standard of care in many clinical situations. In ventilated patients, $ETCO_2$ monitoring is best used as a trending device for ventilation in addition to detecting endotracheal position.

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