Non-Invasive Carbon Dioxide Monitoring During Neonatal Transport

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Contents

Key points:

- Transcutaneous CO2 monitoring is recommended for infants requiring respiratory support (invasive and non-invasive) and end tidal monitoring for ventilated patients (except for high frequency oscillation).
- The shape of capnography waveform can provide useful clinical information during transport
- Blood gas may not be necessary at the end of transfer for stable transfers if non-invasive monitoring is in place and the criteria detailed in the tables were met.
- End tidal sensor will increase dead space – this may be significant for smaller infants
- Therapeutic hypothermia, poor peripheral perfusion, acidosis, and inotropic support may lead to falsely high reading therefore results should be interpreted with caution

1. Introduction

The purpose of this document is to provide practical guidance for staff of CenTre Neonatal Transport Team on non-invasive carbon dioxide monitoring.

Wide fluctuation of carbon dioxide leads to changes in cerebral and pulmonary blood flow and is associated with neurological and pulmonary morbidities in neonates. Blood gas measurement is the gold standard for assessing gas exchange, but it is intermittent, invasive and contributes to iatrogenic blood loss. Non-invasive CO_2 monitoring has the potential to reduce the number of blood gases needed to manage ventilation, alert medical and nursing staff to a change in baby's condition or support clinical decision when adjusting ventilation during transport. Two common methods of non-invasive CO_2 monitoring are end-tidal and transcutaneous, and both are used by CenTre Neonatal Transport Team.

2. Basic principles

2.1 End-tidal CO2 monitoring (EtCO2, capnography)

This method is used for ventilated patients and measures the expiratory CO_2 with infrared spectroscopy. It has increasingly become the gold standard of ETT placement confirmation. The actual measured value tends to be **lower than the blood gas CO_2**, though this difference can be increased due to certain conditions, such as ventilation-perfusion mismatch. The shape of the waveform can provide very useful clinical information during transport. Normal capnography is shown in Figure 1.

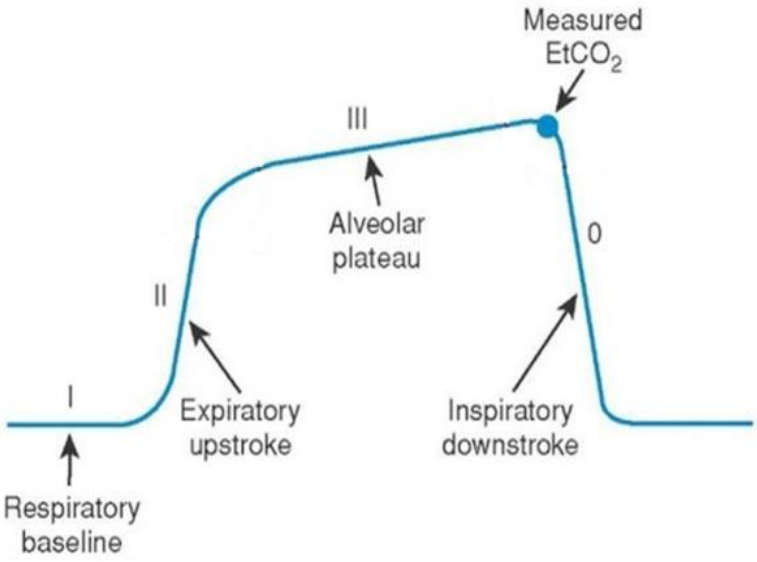
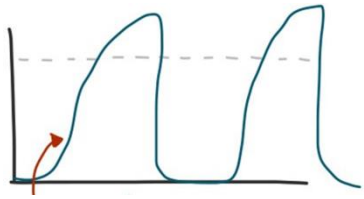
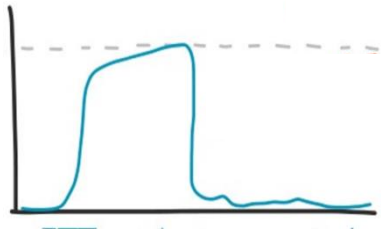
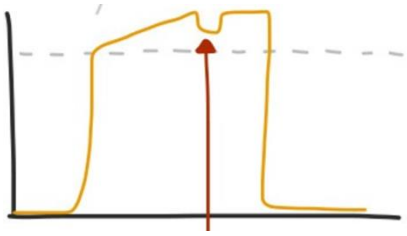
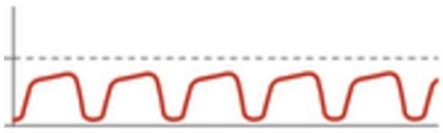


Figure 1. Normal capnography.
I: respiratory baseline and reflects inspired air**, II**: expiratory upstroke which is the transition between the dead space to alveolar gas, **III**: the alveolar plateau

$EtCO_2$ is only one component of capnography. It is measured at the end-peak of each waveform and reflects alveolar CO_2 content (ie. the maximum value of PCO_2 at the end of

the breath). This is affected by alveolar ventilation, pulmonary perfusion, and CO_2 production.

Factors contributing to ***increased EtCO₂***	Factors contributing to ***reduced EtCO₂***
• Pain • Pyrexia • Shivering • Sedation / respiratory depression • Increased cardiac output • Sodium bicarbonate	• Hypothermia • Metabolic acidosis • Hyperventilation • Mucus plugging • Hypotension • Sudden hypovolaemia • Leak around ETT

Capnography	**Common cause, description**
	Shark fin appearance is due to delayed exhalation, often seen in airway obstruction. Beaking of the plateau is also observed in lungs with poor compliance such as RDS.
	Sudden loss of waveform means ETT dislodged, disconnection or sudden loss of cardiac output.
Capnography	**Common cause, description**
	This capnography shows asynchronous breathing. The cleft represents the patient breathing in between ventilator-delivered breaths.
	Hypoventilation on capnography shows low respiratory rate and high $EtCO_2$.
	Hyperventilation on capnography shows high respiratory rate and relatively low $EtCO_2$

2.2 Transcutaneous CO2 monitor

The principle of transcutaneous monitoring is based on the ability of CO_2 to diffuse through body tissues and skin and be detected by a sensor on the surface of the skin. The transcutaneous sensor heats the skin underneath and induces local hyperaemia, which increases the supply of arterial blood to the dermal capillary bed. Recent studies have shown that transcutaneous reading correlates better with blood gas CO_2 compared to end tidal[8]. Both methods of monitoring are suggested to be used as a complementary tool to blood gas sampling to allow trending of CO_2 levels. There should be a high level of suspicion whenever the non-invasive measurement does not fit the clinical scenario.
The monitor also measures relative heating power (RHP) [9]. This is the power required to maintain the sensor at the set temperature. A well-perfused baby will require a higher RHP than a poorly perfused baby to keep the sensor temperature stable to provide an accurate reading. The trend in RHP may be an indicator of the local blood flow which affects $TcCO_2$ reading, hence the two should be interpreted together.

2.3 CO_2 monitoring for ventilated babies

Non-invasive CO_2 monitoring for ventilated infants is particularly useful: end tidal sensor gives valuable information about ET position, transcutaneous CO_2 sensor can give clinical information on ventilation and also supports clinical decision for adjusting ventilation during transport. This needs to be documented in the transport record. The readings should be interpreted with caution if baby is requiring inotropic support, actively cooled or if peripheral perfusion has changed.
It is a national requirement to record end of transfer blood gas. However, after short distance journeys (<30 minutes), the pain and stress of performing a repeat blood gas within a short period of time may outweigh its benefits. The omission of an end of transfer blood gas in these cases should be clearly documented, provided **all the following applies**:

Characteristic of **ventilated transfers** when post transfer blood gas can be omitted (this should be reviewed on a case-by-case basis provided **ALL these applies**)	
Blood gas parameter	• pH>7.3 before leaving referring unit
$TcCO_2$ reading	• Good correlation with blood gas CO_2 before leaving referring unit (≤1 kPa difference) • Continuous $TcCO_2$ reading during transfer with ≤2 kPa change in reading • $TcCO_2$ reading ≥4 and ≤ 8 on arrival
Infant's condition during transfer	• Stable oxygen requirement (≤10% change) • No changes were made to ventilator settings during journey • No events during transfer requiring intervention • Normal cardiovascular observation during transfer
Journey time	• ≤ 30 minutes

2.4 CO_2 monitoring for babies requiring non-invasive respiratory support

Although, this patient group is usually deemed more stable, it is not unusual to have CO_2 fluctuations during transport, hence the use of transcutaneous CO_2 monitoring is recommended. It is not a national requirement to perform post transfer blood gas for these patients. For stable infants, continuous $TcCO_2$ monitoring may replace the need for post transfer blood gas provided **all the following applies**:

Main characteristics of stable **NIV transfers** when post transfer blood gas may be omitted (this should be reviewed on a case-by-case basis provided **ALL these applies**)	
Blood gas parameter	• pH>7.3 before leaving referring unit
$TcCO_2$ reading	• Good correlation with blood gas CO_2 before leaving referring unit (≤1 kPa difference) • Continuous $TcCO_2$ reading during transfer with ≤2 kPa change in reading • $TcCO_2$ reading ≥4 and ≤ 8 on arrival
Infant's condition during transfer	• Stable oxygen requirement (≤10% change) • No changes were made to ventilator settings during journey • No events during transfer requiring intervention • Normal cardiovascular observation during transfer
Journey time	• ≤ 2 hrs

3. Safety considerations

3.1 End-tidal monitoring

The conventional neonatal adapter represents 1.8 ml dead space which can be significant for ELBW infants (e.g. over 3 ml/kg for a 500 g infant). This can impact both on the accuracy of measurement and the volume ventilation for infants weighing < 2kg[1]. The smallest neonatal sensor's dead space is 0.5 ml.
$EtCO_2$ monitoring can't be used in infants requiring high frequency oscillation (HFOV) or non-invasive respiratory support. It is also unreliable with large leak and in infants with severe lung disease or ventilation-perfusion mismatch.

3.2 Transcutaneous monitoring

Gestation itself is not a contraindication to use transcutaneous monitor and ELBW infants are particularly susceptible to hypocarbia and hypercarbia which are associated with lung and brain morbidities [5]. A large multi-centre study, looking at ELBW infants, showed no burns or skin breakdowns related to the sensor [5]. Extra caution is required though with changing sensor every 4 hours. Skin condition resulting in fragile skin (eg. epidermolysis bullosa) is a contraindication to use transcutaneous monitoring. Therapeutic hypothermia, poor peripheral perfusion, acidosis, and inotropic support may lead to falsely high reading therefore results should be interpreted with caution [6]

4. Troubleshooting

4.1 End-tidal monitoring

Issue	Possible cause
No capnography seen on monitor display.	Monitor not connected to sensor. Ensure that brown CO2 monitoring module is connected to patient monitor and near-patient sensor is connected to the ETT adapter.
Very abnormal reading displayed.	Ensure that sensor is calibrated.

4.2 Transcutaneous monitoring (9)

Issue	Possible cause
The site timer doesn't revert to a full 4-hour period.	This generally occurs when a calibration is required within the next 4 hours. Calibrate the sensor now or leave the sensor on and calibrate when calibration is due.
The reading doesn't stabilise within 10 minutes.	Check if attachment ring is attached properly. Check if contact gel was used. Check perfusion of the patient.
Both transcutaneous measurement and RHP have changed significantly in a short period of time.	This may reflect a change in local skin perfusion.
Transcutaneous measurement has changed significantly but RHP is stable.	This may reflect a true change in the blood pCO_2, consider adjusting ventilator setting.

5. Education and Training

All CenTre clinical staff should have completed training on using both carbon dioxide monitors.

6. Monitoring Compliance

What will be measured to monitor compliance	How will compliance be monitored	Monitoring Lead	Frequency	Reporting arrangements
Documentation of blood gas and non-invasive CO2	CenTre data collection sheet			
Babies with pH< 7.2 and pCO_2> 7 kPa	CenTre dashboard			To National Neonatal Transport Group

7. References

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9. Sentec Digital Monitoring System; Instruction Manual

8. Key Words

Blood gas, Capnography, End-tidal CO_2 monitoring, Transcutaneous CO_2, Ventilation

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The Trust recognises the diversity of the local community it serves. Our aim therefore is to provide a safe environment free from discrimination and treat all individuals fairly with dignity and appropriately according to their needs.
As part of its development, this policy and its impact on equality have been reviewed and no detriment was identified.

Contact and review details			
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Details of Changes made during review:			
Date	**Issue Number**	**Reviewed By**	**Description Of Changes (If Any)**
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