

Guideline

Transcutaneous CO₂ monitoring using the SenTec digital monitor system during neonatal transfers

1 Scope

For use within the Paediatric and Neonatal Decision Support and Retrieval Service (PaNDR) for the East of England

2 Purpose

To ensure safe and effective monitoring of carbon dioxide levels in babies receiving respiratory support.

3 Definitions and abbreviations

PaNDR	Paediatric and Neonatal Decision Support and Retrieval Service
pCO ₂	Partial pressure of Carbon Dioxide
CO ₂	Carbon Dioxide
TC	Transcutaneous
SDM	SenTec Digital Monitor
TcCO ₂	Transcutaneous Carbon Dioxide
ABG	Arterial Blood Gas
VBG	Venous Blood Gas
CBG	Capillary Blood Gas
Preterm	Born at less than 37 weeks gestation

4 Introduction

Severe hypercapnia and fluctuations in carbon dioxide levels have been linked to intraventricular/periventricular haemorrhage, especially in the first 2 weeks of life in ventilated preterm infants (1). To minimise such risks carbon dioxide levels should be targeted tightly during this time, with continuous monitoring. Hypocarbica causes cerebral vasoconstriction, thus reducing cerebral blood flow, and should be avoided due to an increased risk of periventricular leukomalacia and cerebral palsy (1).

CO₂ is a gas that readily diffuses through body and skin tissue and, therefore, can be measured by an adequate non-invasive sensor being applied at the skin surface. If the skin tissue beneath the sensor site is warmed up to a constant temperature local capillary blood flow increases, metabolism stabilises, gas diffusion improves and, hence, reproducibility and accuracy of CO₂ measurements at the skin surface improves.

The following clinical situations or factors may limit the correlation between transcutaneous and arterial blood gas tensions:

- hypo-perfused skin tissue beneath the sensor site due to low cardiac output
- hypothermia
- use of vasoactive drugs
- mechanical pressure exercised on measurement site
- inadequate (too low) sensor temperature

Indications for carbon dioxide monitoring will include all ventilated babies and can be assessed on an individual basis for neonates requiring non-invasive respiratory support. Blood gas monitoring is also required as directed by clinical condition, endotracheal or transcutaneous carbon dioxide levels or on medical advice.

5 Management

Values of pCO₂ recorded between 4.6 – 6.0 kPa.

Values outside this range to be discussed with the clinical team.

Preterm infants: 4.5 kPa – 8.5 kPa on days 1-3.

4.5 kPa – 10 kPa from day 4 onwards (2).

CO₂ monitoring does not replace the need for blood gas measurement but reduces the frequency of blood gas sampling. Correlation of transcutaneous CO₂ monitoring can be assessed by ensuring it is in situ prior to blood gas sampling.

All ventilated babies should receive continuous CO₂ monitoring. Transcutaneous monitoring is preferred as end tidal cannot be used in conjunction with HFOV or closed suction systems (2).

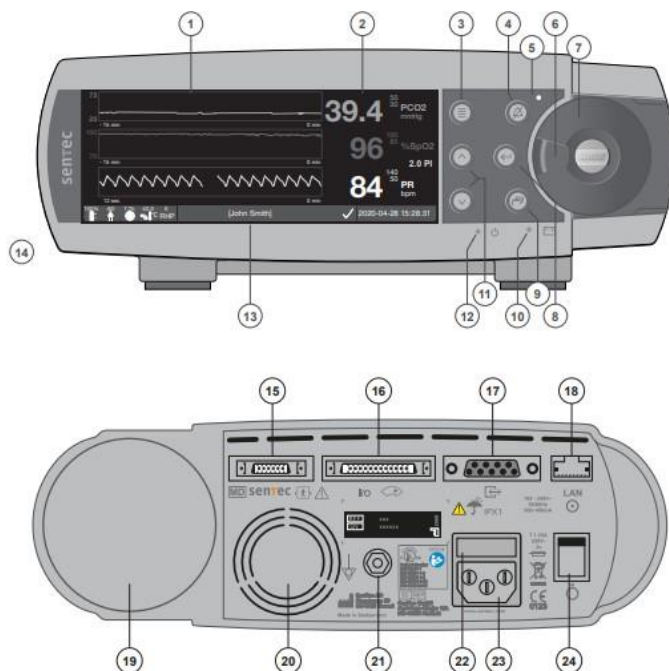
All ventilated infants will require an ABG, VBG or CBG during stabilisation and arrival at the receiving unit. This will need to be documented.

A rising CO₂ may be an indicator of:

- Pneumothorax
- Deterioration (collapse, consolidation, oedema, sepsis)
- Accidental extubation
- Need for endotracheal suction (3)
- Consider DOPES – displacement, obstruction, pneumothorax, equipment and Stomach aspiration

6 SenTec transcutaneous CO₂ monitor

The SenTec Digital Monitoring system consists of the SDM, the sensors, connecting cables, accessories and disposables for sensor application / maintenance and a PC based software (V-STATS™) indicated for continuous, non-invasive PCO₂ infant monitoring.



- | | |
|---|--|
| 1. Trend Display Area | 2. Numerical Display Area |
| 3. Menu/Previous Level Button | 4. AUDIO PAUSED/OFF Button |
| 5. AUDIO PAUSED/OFF Indicator (yellow LED) | 6. Door Handle |
| 7. Docking Station Door | 8. Enter Button |
| 9. Display Button | 10. AC Power/Battery Indicator (green/yellow LED) |
| 11. UP/DOWN Buttons | 12. ON/OFF Indicator, (green LED) |
| 13. Status Bar | 14. Speaker (on the side) |
| 15. Sensor Connection Port | 16. Multipurpose I/O-Port (Nurse Call/Analog output) |
| 17. Serial Data Port (RS-232) | 18. Network Port (LAN) |
| 19. Gas Bottle Slot | 20. Fan |
| 21. Equipotential Terminal Connector (ground) | 22. Fuse Holder |
| 23. AC Power Connector | 24. ON/OFF Switch |

The SenTec monitor will give both numerical and trend CO₂ data on the main monitoring screen. It is useful to look at the figure and this will be recorded on the observation chart, but the trend allows 'real time' graphics of rises or falls in CO₂ values.

When not in use the monitor can be turned off to preserve gas supply, but it is useful to leave it turned on when on the transport system, as this will decrease initial stabilisation time.

Once the monitor is turned on and the automatic calibration is complete a message on the screen will read 'Ready for use'. Additional information available will be monitoring time and when the next membrane change is due. Once the Docking Station door is opened, the percentage of gas remaining will be displayed along with the temperature setting and alarm limits.

A longer site time is acceptable if only CO₂ is being monitored which requires a lower site temperature and therefore the likelihood of skin damage is reduced.

Turn on the SDM by pushing the ON/OFF switch on the rear panel. The SDM will automatically perform a 'Power On Self-Test'. Check the date/time settings of the SDM and adjust if necessary.



Changing the gas bottle

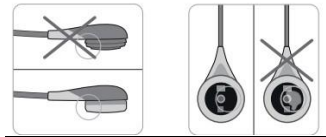


The gas bottle slot is located on the rear of the SDM. Remove the old gas bottle by turning it anti-clockwise. Insert the new gas bottle by turning it clockwise approx. 4.5 turns and thoroughly tighten it (without applying undue force).

Failure to properly insert the gas bottle may result in incorrect sensor calibrations and may cause increased gas consumption. The status icon 'Gas' indicates the

remaining capacity of the gas bottle in %. It is only displayed if a SenTec TC sensor is connected to the SDM and is in the Docking Station.

7 Check SDM settings, system readiness and sensor condition before use



Checking a SenTec TC sensor: Check the condition of the sensor membrane and the integrity of the sensor before, after each use, and after changing the membrane.

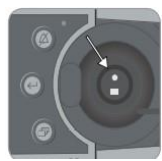
Change the sensor membrane if it is damaged or missing, has a loose fit, or if there is trapped air or dry electrolyte under the membrane.

Do not touch the delicate optical/glass components embedded in the sensor's surface should the membrane be missing.

Do not use a dry gauze or wipe, as this may damage the sensor membrane or sensor cable.

To calibrate the sensor:

Open the Docking Station Door by pulling the door handle.



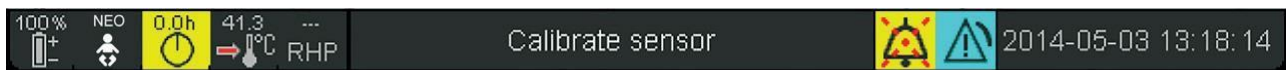
Check the gasket (arrow) in the docking station. If necessary, clean the docking station and gasket using a cotton swab moistened with 70% isopropanol.



Hang the sensor into the holder on the inside of the door. Ensure that the sensor's red light is visible. **Caution:** Incorrect orientation of the sensor in the docking station

may cause damage to the sensor, the Docking Station, or parts thereof when closing the Docking Station Door.

Close the Docking Station Door. The SDM will check the sensor and, if necessary, start the sensor calibration (message 'Calibration in progress'). The message 'Ready for use' will display once calibration is finished.



If a sensor calibration is mandatory, the SDM displays the message 'Calibrate sensor', a low priority alarm sounds and PCO₂ is marked as 'invalid' (values replaced by '---'). Calibration intervals for SenTec TC sensors can last up to 12 hours.

Once the 'Calibration Interval' has elapsed, sensor calibration is recommended (message 'Sensor calibration recommended') and monitoring is possible for another 4 to 6 hours with PCO₂ marked as 'questionable'.

Check SDM settings and system readiness.

Ensure current SDM settings and SDM profile are appropriate for the infant, for the selected site and the skin condition/skin tissue perfusion at the selected measurement site.

Verify system readiness (message 'Ready for use') and check the 'Available Monitoring Time'.

If the connected sensor is in the docking station, the 'Ready for use' or 'Calibration' screen (summarising important system information (see diagram below) displays.



When removing the sensor from the docking station check the condition of its membrane and its integrity before applying it to the infant. Change the membrane if necessary. Do not use the sensor if any problems are noted.

8 Sensor attachment

Clean the skin with a swab wetted with 70% isopropanol or sterile water.

Take a Multi-site Attachment Ring out of the package and pull off the liner protecting the adhesive tape of the ring.

Remove the sensor from the Docking Station and inspect the membrane. Clean with an alcohol wipe between patients and between calibrations (including the Docking Station).

Attach the ring to the measurement site (see diagram below), checking skin condition when choosing an appropriate site. Ensure there is no skin wrinkling when the adhesive ring is attached.

Apply **one drop** of contact gel to the area of skin in the centre of the ring.

Holding the sensor at its neck approach the attachment ring from the flap side, first insert the nose of the sensor into the ring. Click the sensor into the ring by applying gentle pressure to the sensor neck.

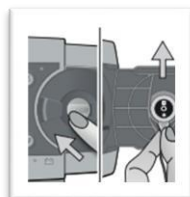
Rotate the sensor to the best position for the comfort of the baby and press gently on top of the sensor to ensure even spread of contact gel.

Check sensor application. Ensure that air gaps are eliminated between the skin and the sensor.

Verify that the SDM detects that the sensor was placed on the patient, initiates monitoring and that the enabled parameters stabilise. If necessary, readjust sensor application or reposition the sensor.



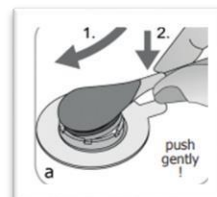
1.



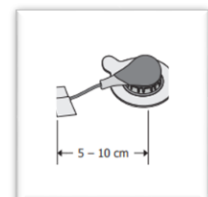
2.



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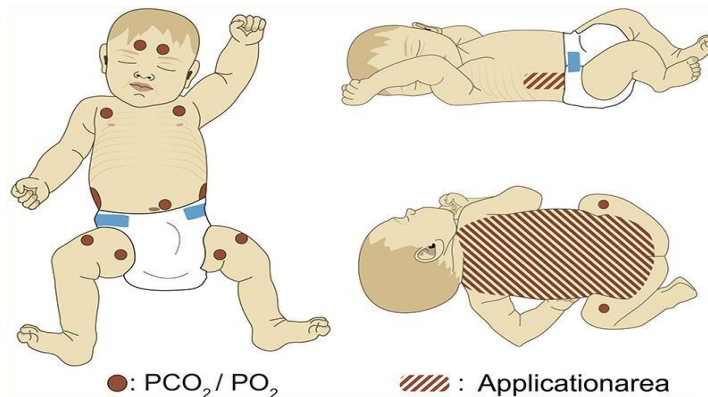


4.



5.

9 Measurement sites



10 TCO2 wraps

TCO2 wraps should be used for all extreme preterm infants' of 22 week and 23 week gestation. The wraps can be used on babies of 24 weeks if there are clinical concerns with skin integrity. The use of Cavilion on TCO2 rings for ring attachment for infants 24 weeks gestation and over to be considered prior to use of wraps. The use of the wraps can be considered on other infants that have poor skin integrity that require TCO2 monitoring.

Step One

- Choose a measurement site on the right or left upper thigh.
- Consider how the patient will be positioned to ensure there will be no external pressure on the sensor.
- Clean the skin with 70% isopropanol or water, according to hospital policy.



Step Two

- Measure the wrap around the upper thigh and cut the wrap to avoid overlap of the two ends.
- Ensure that the closure tab will not contact patient skin.
- **TIP!** Always make your first cut a little long (vs short) in case you need to adjust. You can always trim more length to make the wrap shorter.
- **TIP!** You may find a measuring tape helpful for cutting to the correct size. Measure the thigh and add half a centimetre for your first cut. Adjust fit as needed.



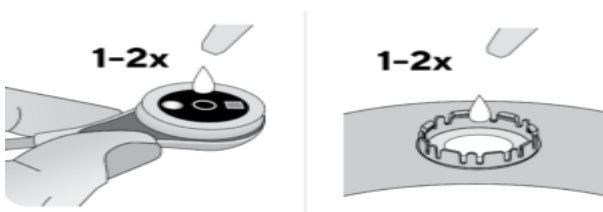
Step Three

- Once cut to size, apply the wrap and fasten with the closure tab.
- Check the site after applying the wrap to ensure that circulation is adequate.
- When the monitor is 'Ready for use', remove the sensor from the Docking Station.
- Do not use the product for longer than 24 hours.
- **TIP!** Aim for a gentle but secure application. Avoid over-tightening the wrap which may decrease local perfusion and impact correlation.
- **TIP!** While a "nose to nose" fit is preferred to prevent exposing the skin to the Velcro, it is *most* important that the wrap is not too tight (which may decrease local perfusion and impact correlation.)



Step Four

- Apply 1-2 drops of Contact Gel to the centre of the sensor surface.
- Keep the sensor horizontal (membrane facing upwards) so that the contact liquid does not run off the membrane.
- Flip over the sensor just before inserting it into the ring.
- You may also apply 1-2 drops of Contact Gel directly into the centre of the attachment ring if the patient is positioned so the gel does not roll off to the side.



Step Five

- Holding the sensor at its neck, approach the attachment ring and first insert the nose of the sensor into the retainer ring.
- Then apply slight downward pressure on its neck.
- Rotate the sensor in the ring and press the sensor gently against the skin to spread the contact liquid.

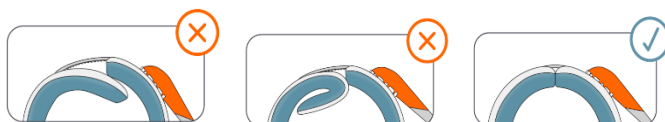


Step Six

- Verify that the SDM detects that the sensor was placed on the patient and the PCO₂ value begins to stabilize (PCO₂ value in grey).
- Stabilization can take between 2-10 minutes.
- If the values do not stabilize or are not rising, check the sensor application for good contact between the skin and sensor.
- **TIP!** Continuously assess the fit of the wrap in case a change in patient condition has caused the fit to tighten (which may decrease local perfusion and impact correlation.)

Best Practices and Tips

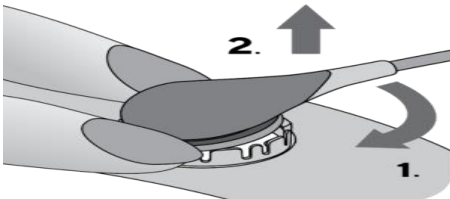
- **TIP!** Aim for a gentle but secure application. Avoid over-tightening the wrap that may decrease local perfusion and impact correlation.
- **TIP!** Continuously assess the fit of the wrap in case a change in patient condition has caused the fit to tighten (which may decrease local perfusion and impact correlation.)
- **TIP!** Always make your first cut a little long (vs short) in case you need to adjust. You can always trim more length to make the wrap shorter.
- **TIP!** You may find a measuring tape helpful for cutting to the correct size. Measure the thigh and add half a centimetre for your first cut. Adjust fit as needed.
- **TIP!** While a “nose to nose” fit is preferred to prevent exposing the skin to the Velcro, it is *most* important that the wrap is not too tight (which may decrease local perfusion and impact correlation.)



Instructions to remove the Sentec Non-Adhesive Wrap

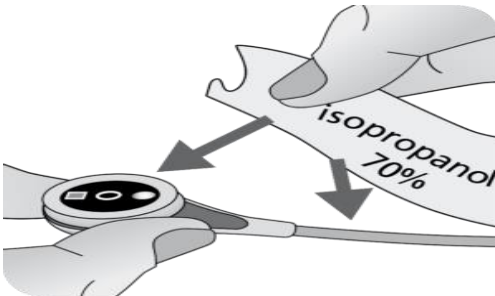
Step One

- Remove the sensor from the ring.



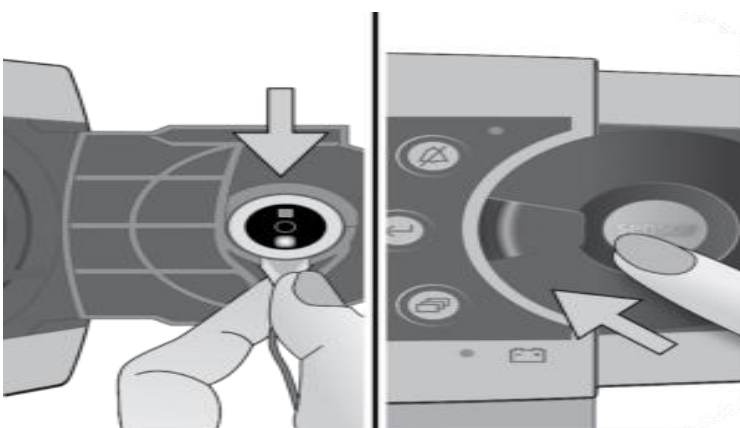
Step Two

- Clean the sensor using 70% isopropanol.



Step Three

- Place in the Docking Station and calibrate.



Step Four

- The wrap can be removed after site time has elapsed and reapplied to the opposite leg or may be adjusted to alternate the sensor position.
- The wrap may be used on one patient for up to 24 hours, at which time it should be discarded.

11 Site times

The recommended (and default) 'Sensor Temperature' and 'Site Time' for SenTec TC Sensors depends on the selected patient type and the enabled parameters, as summarised in the following table. The recommended site time for a preterm is 4 hours and an extreme preterm is 2 hours (4).

Patient Type	PO ₂ enabled	Recommended Sensor Temperature [°C]	Recommended Site Time [hrs]
Neonatal (if younger than term birth + 12 months)	No	41.0	8.0
	Yes	43.0	2.0
Adult/ Pediatric	No	42.0	8.0
	Yes	44.0	2.0

12 Patient monitoring 'Sensor-On-Patient' detection

Once the sensor is correctly applied to the infant, the SDM usually detects that the sensor is applied on the infant and initiates monitoring for the enabled parameters.

Sensor-On-Patient is typically detected within a few seconds, otherwise within less than 2 minutes. After sensor application verify that the SDM detects 'Sensor-On Patient', initiates monitoring, and the enabled parameters stabilise. If necessary, readjust sensor application or reposition the sensor.

A good sealed contact between the TC Sensor and the skin provided a TC reading stabilises within 2 to 10 minutes after sensor application (the time required to warm up the measurement site and to achieve equilibrium between the gas concentrations in the skin tissue and the gas concentrations on the sensor surface).

Once the sensor has been applied, there will be a few minutes with no number on the screen whilst the sensor temperature is achieved. A number will then appear in grey and once the reading has stabilised this will turn green and can then be documented as appropriate.

Various preconfigured measurement screens are available. Press the Display Button to cycle between the available screens.

Press the Enter Button to open a 'Quick Access Menu' to set a baseline.

13 Sensor removal

When monitoring is completed or monitoring time has elapsed, remove the sensor from the infant and clean/inspect the skin. Document skin integrity.

Clean sensor after use. Check condition of membrane and integrity of sensor prior/after use. To maintain monitor readiness and minimise PCO₂ drift potential keep SDM switched on and store sensor in Docking Station in between monitoring.

Inspect condition of membrane and integrity of sensor before inserting it into the Docking Station.

14 Membrane change

The sensor membrane needs to be changed at a 28-day interval or sooner if the readings become inaccurate (when there has been previous correlation) or if necessary due to a system error or when damage is evident. If air dry electrolyte solution is evident under the existing membrane, this may also be an indication for a membrane change. A membrane changer & spare membrane is located in a pouch on each incubator if membrane requires changing during transfers. The membrane only needs to be changed between infants if there are infection control concerns.

The following steps are to be followed to successfully change the sensor (this must be done on a flat surface):

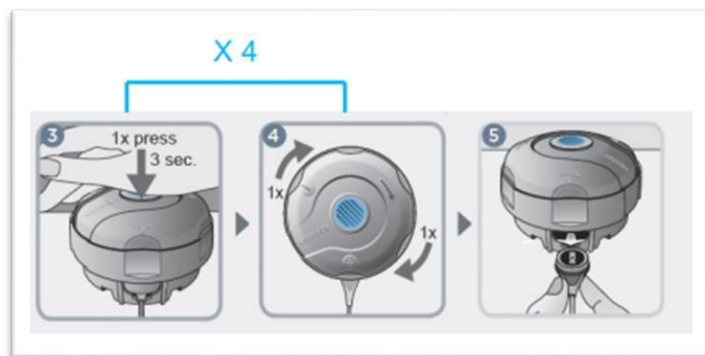


Verify that the sensor is clean before changing its membrane. If necessary, carefully wipe off any residue from the sensor's surface (including membrane, housing, groove, and cable) with 70% isopropanol.



Place the Membrane Changer on a horizontal, dry surface with the coloured dot facing up.

Insert the sensor into the Membrane Changer with the sensor side facing up. The insert receiver 1 is designed so that improper alignment of the sensor is difficult, if not impossible.



Press down slowly but firmly with palm of the hand and hold for 3 seconds.

Turn the top portion one click clockwise to the next stop. Keep the Membrane Changer horizontal. Hold the changer's bottom half in place while turning the top half.

The membrane change procedure consists of four identical press-and-turn steps. To provide better guidance, these steps are marked with the corresponding numbers on the Membrane Changer.

Step 1 removes the old sensor membrane: Press down slowly but firmly with palm of hand and hold for three seconds. Release the top. Carry out a visual check to ensure that the membrane is removed. Turn the top portion one click clockwise to the next step. Keep the Membrane Changer horizontal.

Step 2 cleans the sensor surface from old electrolyte: As in step 1, press the membrane changer slowly but firmly, release the top and turn clockwise to the next step.

Step 3 applies new electrolyte on the sensor surface: Press the membrane changer slowly but firmly for three seconds, release the top and turn clockwise to the next step.

Step 4 places a new membrane on the sensor: Press the membrane changer top down slowly but firmly for three seconds, release the top and turn clockwise to the ✓ symbol.



Press one last time or lift the sensor and remove it from the Membrane Changer. The ✓ symbol indicates that the membrane change is completed.

Once the membrane has been changed place it back into the Docking Station with the door open and then in the membrane change menu confirm 'membrane change done'. The number of days until membrane due will then reset to 28. The door must then be shut to calibrate the sensor. Stabilisation time will be longer immediately after a membrane change.

15 References

1. Thorne U.H. et al. PHELBI Study Group. (2018) Influence of PCO₂ Control on Clinical and Neurodevelopmental Outcomes of Extremely Low Birth Weight Infants. *Neonatology*. 113(3):221-230.
2. National Institute for Health and Care Excellence (2019) Specialist neonatal respiratory care for babies born preterm (NICE guideline NG124), Available at <https://www.nice.org.uk/guidance/ng124>.
3. Thome U.H. et al. PHELBI Study Group. (2015) Permissive hypercapnia in extremely low birthweight infants (PHELBI): a randomised controlled multicentre trial.' *Lancet Respiratory Medicine*, July; 3(7):534-43.
4. Aly S., El-Dib., M. Mohammed, M., & Aly. H. (2016) Transcutaneous Carbon Dioxide Monitoring with Reduced Temperature Probes in Very Low Birth Weight Infants. *American Journal of Perinatology*. Vol 34, p480-485

16 Associated documents

Boxwell Neonatal Intensive Care Nursing. Routledge. London. [IV]

SenTec Digital Monitoring System – Continuous non-invasive ventilation monitoring in NICU Quick Reference Guide.

SenTec Digital Monitoring System – Manual.

Diagrams and Instructions from SenTec Digital Monitoring System Quick Reference Guide and Manual with permission.

17 Monitoring compliance with and the effectiveness of this document

The PaNDR team will monitor compliance with this document by undertaking regular audits and results will be reported back to the PaNDR Governance meeting.

Equality and diversity statement

This document complies with the Cambridge University Hospitals NHS Foundation Trust service equality and diversity statement.

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Document management

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