

Transcutaneous CO₂ Monitoring

October, 2018

Summary:

A transcutaneous monitor (TCM) uses a noninvasive technique to measure the skin-surface partial pressure of carbon dioxide (PtcCO₂) and partial pressure of oxygen (PtcO₂) to provide an estimate of the partial pressure of arterial carbon dioxide (PaCO₂) and oxygen (PaO₂). The TCM induces arterialization of the capillaries by increasing the local temperature of the skin at the sensor site. The externally applied heat alters the solubility of carbon dioxide (CO₂) in the blood and increases the metabolic rate of the skin by approximately 4–5% for every degree Celsius, resulting in local production of CO₂. The sensor, usually a Severinghaus electrode, will calculate the PCO₂ electrochemically, usually by a change in pH of an electrolyte solution. Additionally, a temperature correction is used to address the epithelial CO₂ produced by heating the skin. A Clark electrode, which is composed of a platinum cathode and silver anode, measures the concentration of oxygen in the blood (PO₂). When a patient is under investigation for sleep related breathing disorders such as sleep apnea or obesity hypoventilation syndrome, this method can assist in documentation of diagnostic criteria and in determination of effective therapeutic responses (1). This guideline is primarily focused on the use of transcutaneous CO₂ monitoring equipment in the sleep center.

Key Definitions:

Severinghaus- An algorithm developed by J.W. Severinghaus that first corrects PCO₂ measured at the sensor temperature (T) to 37 °C by using an anaerobic temperature factor (A) and then subtracts an estimate of the local ‘metabolic offset’ (M) to estimate PaCO₂.

Transcutaneous Monitor - A transcutaneous monitor (TCM) is a noninvasive method that measures the skin-surface PCO₂ and PO₂ to provide an estimate of the PaCO₂ and PaO₂.

- PCO₂: Partial pressure of carbon dioxide; normal value is 35-45 mmHg
- PO₂: Partial pressure of oxygen; normal value is 80 to 100 mmHg (1)

Sleep Facility- Any sleep center whether it is hospital based or independent.

Sleep Technologist- Refers to a trainee, technician or technologist that is credentialed according to their state's requirements.

Clark Electrode - An electrode that measures ambient oxygen concentration in a liquid using a catalytic platinum surface according to the net reaction.

1.0 Scope

This technical guideline addresses the use of TCM during polysomnography to assess ventilation and oxygenation. A TCM measures the skin-surface PCO₂ and PO₂ to provide an estimate of the PaCO₂ and PaO₂. A sleep technologist can utilize transcutaneous PtcCO₂ to assist in detecting sleep hypoventilation and for assessing the efficacy of treatment for sleep related breathing disorders.

1.1 Indications for Transcutaneous Monitoring

TCM may be performed by trained personnel on pediatric and adult patients in a variety of settings that include, but are not limited to, sleep facilities. The use of TCM is indicated in patients with a need for continuous monitoring of carbon dioxide levels. Within a sleep facility TCM is used to determine the presence of hypoventilation or respiratory depression during both diagnostic and treatment sleep testing, specifically as follows:

- During the collection of diagnostic polysomnography where there is a need for continuous monitoring of carbon dioxide levels during sleep,
- To assess a patient's physiologic response to, and tailor treatment during therapeutic interventions (i.e., PAP therapy, including BiLevel, ASV and VAPS) during polysomnography.

The current *AASM Manual for the Scoring of Sleep and Associated Events* indicates the following recommendations and options for monitoring PtcCO₂:

- Monitoring and reporting hypoventilation in adults during a diagnostic study or PAP titration is optional and at the discretion of the clinician or investigator.
- Monitoring and reporting hypoventilation in children during a diagnostic study is recommended and during a PAP titration is optional.
- Arterial PCO₂, transcutaneous PCO₂, or end-tidal PCO₂ can be used for detecting hypoventilation during a diagnostic study in both adults and children.
- During PAP titration in both adults and children arterial or transcutaneous PCO₂ are the recommended methods to detect hypoventilation (2).

2.0 Recording Techniques and Sensor Application

2.0.1 Equipment



Figure 1 – A sampling of transcutaneous monitoring equipment, sensors, and application devices. (SenTec AG, Ringstrasse 39, CH-4106 Therwil, Switzerland, www.sentec.ch)

2.0.2 Sensor Placement

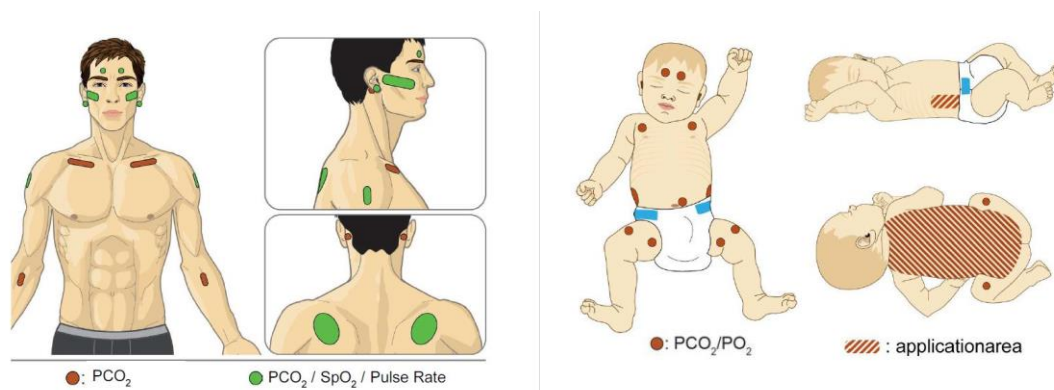


Figure 2 – One manufacturer's recommendations for sensor placement for TCM of CO₂. (SenTec AG, Ringstrasse 39, CH-4106 Therwil, Switzerland, www.sentec.ch)

After the sensor is calibrated, clean the skin of all oils, soaps, and dead skin. Once the site is cleaned, then a sensor fixation ring is placed in a highly vascularized area. The preferred location to obtain TC measurements in neonates and small pediatric patients is the upper chest. Alternative sites include the lateral chest, buttock, inside of the upper thigh, or forearm. In adults the upper chest, biceps, forearm, the zygomatic bone, the ear lobe, cheek, or the forehead may be used as recording sites (3). Once the fixation device is in place, place 1–2 drops of either contact gel or normal saline inside the ring. This improves the accuracy of the sensor and makes the diffusion of gases more efficient. Then place the sensor into the ring and secure. The sensor usually snaps into place. The ring must create enough of a seal to prevent leaks or formation of air bubbles, as ambient air reaching the sensor affects measured values (3).

In order to achieve accurate PtcCO₂ measurements the skin probe temperature is generally 43 °C for neonates and 44 °C in pediatric and adult patients. Caution is advised

in patients undergoing monitoring for long periods of time as the heat of the sensor may lead to injury or burning of the skin, particularly in neonates and patients with thin or damaged skin. Most TCM systems allow reduction of the probe temperature to minimize the risk of thermal injury.

Correlation with arterial blood gases is recommended to ensure accuracy of the values obtained by TCM. When monitoring PtcCO₂ using lower skin probe temperatures may allow for longer periods of contact time between the skin and the sensor; up to 8–12 hours. This option may be especially important for neonates and small infants. However; the location of the sensor may still need to be changed occasionally depending on the age of the patient and the type of transcutaneous device being used. Always follow the manufacturer's guidelines.

2.1 Calibration and Troubleshooting

Most transcutaneous monitoring equipment requires a “warm up” period of approximately 5 minutes before each recording. Follow the manufacturer's calibration protocol for the TCM sensor. Calibration requirements are defined by hours of use or cycles. As each device is unique, this process can vary based upon make and model of the unit. Always refer to the manufacturer guidelines for proper device and sensor calibration prior to use of a TCM.

- 2.1.1** The technologist verifies the calibration of the TCM according to the TCM device operation manual.
- 2.1.2** The technologist documents this information according to sleep center policies.
- 2.1.3** If the initial readings do not match the clinical setting or are incorrect as described in the TCM Operation Manual the technologist should check for a faulty sensor application, change the application site, or re-calibrate the monitor according to the TCM device operation manual.
- 2.1.4** If the TCM is re-calibrated repeat step 2.1.1.
- 2.1.5** The sleep recording should display the same values that the TC monitor displays. This must be verified initially and throughout the recording per sleep center protocol. Technologists should clearly document this verification on the PSG recording.
- 2.1.6** If the display on the sleep recording does not match that of the device, refer to the sleep system software User Manual in order to re-calibrate the sleep system to accurately display the TC monitor values.
- 2.1.7** Never open the TCM casing to repair internal components. Contact the manufacturer for instructions on repair.

2.1.8 If the sleep software is re-calibrated to the TCM monitor repeat step 2.1.1.

2.2 Recording

The technologist monitors the continuous transcutaneous trend of values throughout the night and ensures that quality signals are recorded. Interventions to correct signal quality are documented. Calibrate the TCM and change sensor membranes according to manufacturer specified cycle length. If TCM is used infrequently (i.e., once/month) perform a calibration and change sensor membranes before every recording.

2.2.1 The technologist monitors the continuous transcutaneous trending data throughout the night. Normal PCO₂ is between 35 and 45 mmHg.

2.2.2 If TCM values exceed the limits of normal for the duration defined in sleep center policies or an emergency protocol, the technologist should notify the sleep medicine physician on call for his/her recommendation.

2.2.3 The sleep physician reviews the PSG data, including the TCM data and completes the final report.

2.3 Scoring

In the adult and pediatric patient population transcutaneous monitoring is used for the detection of hypoventilation.

2.3.1 In adults hypoventilation during sleep is scored if there is either:
a. an increase in the PCO₂ measurement to a value greater than 55 mmHg for ≥10 minutes,
(or)
b. a ≥10 mmHg increase in PCO₂ measurement during sleep (in comparison to an awake supine value) to a value exceeding 50 mmHg for ≥10 minutes (2).

2.3.2 In pediatric patients hypoventilation is scored if >25% of the total sleep time shows a PCO₂ measurement of >50 mmHg (2).

2.4 Cleaning

Refer to the instrument instruction manual, or technical manual for manufacturer recommendations and guidelines for maintenance and cleaning of TCM equipment.

- 2.4.1** The device probe should be cleaned between patient applications, according to manufacturer recommendations.
- 2.4.2** The external portion of the monitor should be cleaned using manufacturer recommended methods before and after each use.

2.5 References

1. Restrepo, Ruben D. MD, Hirst, Keith R. RRT-NPS, Wettstein, Richard. AARC Clinical Practice Guideline: Transcutaneous Monitoring of Carbon Dioxide and Oxygen: 2012.
2. Berry RB, Albertario, CL, Harding SM, Lloyd RM, Plante, DT, Quan, SF, Troester, MM and Vaughn BV for the American Academy of Sleep Medicine. The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology and Technical Specifications, Version 2.5. www.aasmnet.org. Darien, Illinois: American Academy of Sleep Medicine, 2018.
3. **SenTec AG, Ringstrasse 39, CH-4106 Therwil, Switzerland, www.sentec.ch**