Continuous, noninvasive tcPCO2 monitoring of patients with chronic respiratory failure using the SenTec Digital Monitoring System

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Introduction

The pulmonary system comprises two different aspects: the lung and the respiratory pump [1]. A failure of the lung results in hypoxemic respiratory failure (type 1 respiratory failure), whereas a failure of the respiratory pump results in hypercapnic respiratory failure (type 2 respiratory failure) [1]. PCO2 measurement has become part of the standard of care in the diagnosis and treatment of respiratory failure [1]. Pulse oximetry alone is unable to adequately detect hypo-ventilation, particularly in patients with healthy lungs, where no ventilation perfusion mismatch occurs [2-5]. In addition to day-time measurements, it is crucial that patients with borderline hypercapnia are also monitored during the night, as nocturnal hypoventilation might be missed if only daytime partial pressure of carbon dioxide (PCO2) measurements are performed [6].

There are invasive and noninvasive methods for monitoring PCO2. Blood gas analysis is the gold standard and provides more than just PCO2 values, but it has the drawback of being an invasive technique, which could cause the patient pain and could therefore falsify sleep studies [1]. It is also only able to provide a spot-check analysis. By contrast, transcutaneous PCO2 monitoring (tcPCO2) allows continuous noninvasive PCO2 measurement, is painless and does not disrupt the patient's sleep at night [7].

Clinical evidence

Numerous trials have evaluated the use of tcPCO2 in different clinical applications.

Noninvasive ventilation

tcPCO2 has proven to be reliable in predicting PCO2 during the initiation of acute noninvasive ventilation (NIV) therapy in COPD patients as well as in nocturnal monitoring of noninvasive ventilated patients with type 2 chronic respiratory failure [7-9].

It was shown that tcPCO2 measurement is able to reduce blood gas analysis during NIV initiation and that tcPCO2 values measured two minutes after a blood gas analysis were the best predictor of PaCO2 (=lag time) [9]. Furthermore, tcPCO2 was able to detect nocturnal hypoventilation during NIV check-ups more effectively than blood gas analysis, which only provides a spot-check of the respiratory situation (see figure 1). Continuous overnight tcPCO2 monitoring (SenTec Monitor System) revealed variations with a median of 12.3 mmHg, whereas capillary PaCO2 measurements showed variations with a median of only 6.3 mmHg [7]. German guidelines recommend tcPCO2 monitoring combined with blood gas analysis during the initiation of NIV [1, 6].

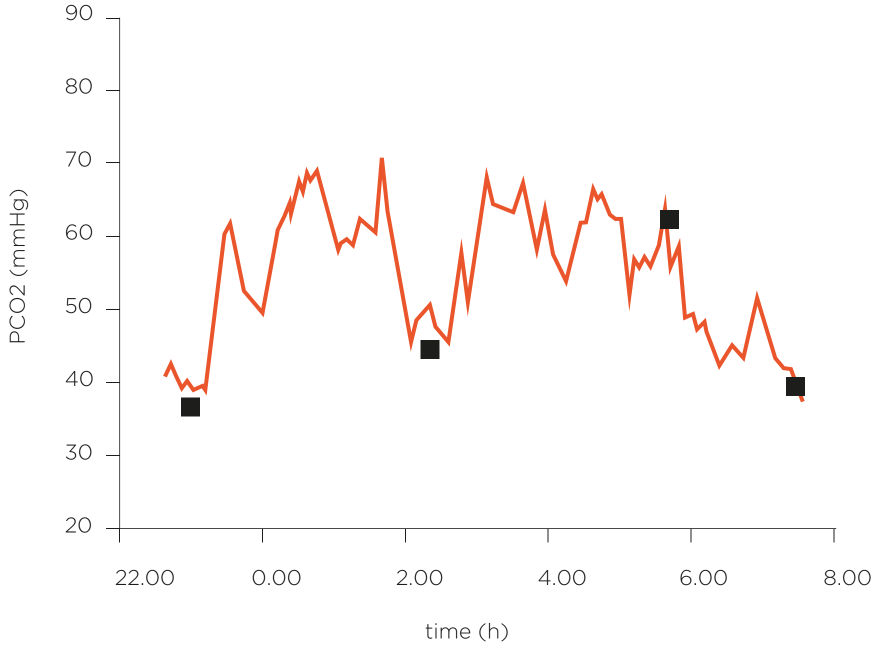

Figure 1: Overnight trend of PaCO2 (black boxes) and tcPCO2 (orange line) showing nighttime fluctuations of PCO2 [7]

Acute respiratory failure

tcPCO2 was also evaluated in a mixed cohort of patients with acute respiratory failure (ARF). It was shown to be superior to end-tidal CO2 (etCO2) in predicting PaCO2 in non-intubated ICU patients (primarily with acute exacerbated COPD, but also ARDS, heart failure etc.) [10]. Another trial used tcPCO2 in patients with ARF in the emergency department and demonstrated a significant correlation to PaCO2 (R^2=0.83, $p < .001$), with better agreement in normothermia compared to hyperthermia as well as PaCO2 values < 56 mmHg compared to > 60 mmHg [11].

Nasal high-flow oxygen therapy

Nasal high-flow (NHF) oxygen therapy is a technique that is increasingly used to treat ARF [12]. It has also recently been evaluated in the long-term domiciliary treatment of stable hypercapnic COPD patients. It was shown to improve health-related quality of life and to lower PCO2 values to a certain extent (adjusted treatment effect, -4.1 mm Hg, 95% confidence interval, -6.5 to -1.7 mm Hg) [13]. tcPCO2 measurements were used to demonstrate a decrease in PCO2 values in different NHF usage settings: short-term use in chronic stable COPD patients [14], in tracheostomized COPD patients [15] and in stable COPD patients at night [16]. Therefore, tcPCO2 measurements can be used to measure the extent of PCO2 decline during NHF therapy.

Weaning

In order to wean a patient from invasive ventilation, spontaneous breathing trials (SBT) are performed on a regular basis [17]. In this context, it is crucial that PCO2 is also monitored in addition to other parameters so that a decision can be made on when an SBT needs to be terminated. tcPCO2 was evaluated in patients undergoing prolonged weaning in a trial by Schwarz et al [18]. It proved to be a suitable method for monitoring PCO2 in patients undergoing invasive mechanical ventilation (MV) and prolonged weaning within the predefined clinically acceptable range of +/- 4 mmHg. This was in contrast to etCO2, which significantly underestimated PaCO2 (figure 2), particularly in patients with COPD due to a ventilation perfusion mismatch (mean difference -9.0 mmHg, limits of agreement -17.2 to -0.8 mmHg) [18].

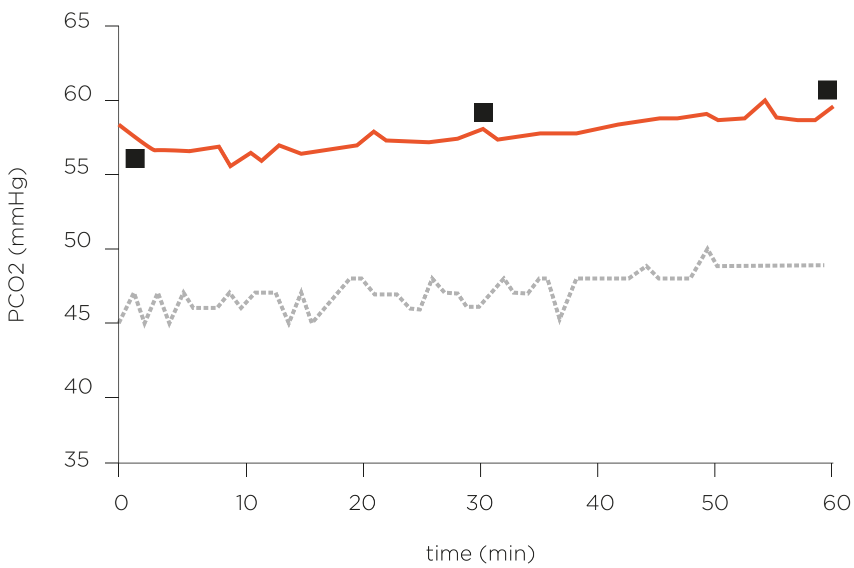

Figure 2: Patient with COPD, PaCO2 (black boxes), tcPCO2 (orange line) and etCO2 (dashed grey line) [18]

Outpatient setting and home care environment

Internationally, there is a trend towards a greater focus on outpatient care of patients with home mechanical ventilation (HMV). This relates to setting up MV at home rather than in the hospital [19] as well as outpatient check-ups of HMV [20]. In the Netherlands, tcPCO2 has become the standard method for monitoring ventilation in the home environment [19] and is therefore able to replace blood gas analysis for stable patients receiving noninvasive HMV. In Germany, check-ups of noninvasive HMV in an inpatient setting still represent the standard of care [21], but there are initial pilot projects in place aimed at following up patients in an out-patient center. In this context, tcPCO2 is used to evaluate short-term changes following adjustment of the ventilation settings [20]. As public healthcare systems are transitioning towards outpatient rather than inpatient care, noninvasive, easy-to-use, telemonitoring-compatible devices for monitoring gas exchange will be very useful in the future.

Functional assessment

tcPCO2 was also shown to reliably monitor PCO2 continuously in very severe COPD patients during a 6-minute walk test (6MWT); this could be of predictive value for the course of the disease and therefore provide useful information on the severity of respiratory pump insufficiency [22]. Interestingly, the trial revealed a very heterogeneous PCO2 response during the 6MWT: While 24% of the patients preserved their PCO2 values, 26% had reduced PCO2 due to hyperventilation and 50% had increased PCO2 [22].

Sedation during endoscopies

Numerous trials have demonstrated the use of tcPCO2 for monitoring patients at risk of hypercapnia undergoing sedation during an endoscopy [1]. It was shown to detect hypoventilation and hypercapnia during bronchoscopy [23-25], as well as during colonoscopies [26] and thoracoscopies [27].

Summary

tcPCO2 has proven to be beneficial in numerous clinical applications:

- it is **able to reduce the frequency of blood gas analysis** and to show a continuous trend of PCO2 between blood gas analyses
- it provides **short and long-term feedback** of changes in alveolar ventilation in mechanically ventilated patients (after adjustment of (noninvasive) ventilation as well as during episodes of spontaneous breathing in weaning)
- it can be used to **measure the extent of PCO2 decline during NHF therapy**
- it is able to **detect hypoventilation or hyperventilation** during clinical exercise tests (e.g. 6MWT)
- it is **superior to etCO2 in patients with lung diseases and ventilation perfusion mismatch**
- it is reliable in monitoring PCO2 in an **outpatient setting or in a home environment,** where blood gas analysis is not feasible

The SenTec Digital Monitoring System has proven to be accurate, reliable, easy to use and patient-friendly.

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