

Demystifying End Tidal CO₂

Bonnie Jo Grieve, MD, Dousman, Wisconsin, bjgrieve@gmail.com

I am a new post-polio ventilator user. I had polio at age 4 in 1953, was completely paralyzed and probably in an iron lung briefly. Now I have severe kyphoscoliosis (front-to-back and side-to-side curvature of the spine) and new weakness.

Two years ago I was started on an S9 CPAP (ResMed) but was unable to breathe out against the pressure, so was switched to a Respironics AVAPS BiPAP (Philips Respironics) initially with low span settings. After a year of continued awakenings with tachycardia, I upped the settings to high span, IPAP currently at 20 and EPAP 5, and have been sleeping through the night ever since.

Every week brings new information about neuromuscular hypoventilation. In February 2013, IVUN hosted a phone conference featuring physiatrist Dr. John R. Bach and his recommendations regarding relying on noninvasive ventilation (NIV) for as long as possible for most neuromuscular ventilation needs. His books discuss NIV, pulse oxygen monitoring, CoughAssist with manual thrusts if necessary, and end tidal carbon dioxide (CO₂) monitoring for CO₂ retention. This raised questions about CO₂ monitoring.

Understanding CO₂

Carbon dioxide is a byproduct of the metabolism of oxygen and glucose for producing energy. CO₂ diffuses out of cells and into the blood in our lungs and diffusing into our alveoli before exha-

lation. It can be measured in two ways. One way is measured by drawing arterial blood gases (ABG). This measurement is represented as PCO₂ (the partial pressure of carbon dioxide, the relative concentration of the gas in our blood). The other is to measure CO₂ at the end of exhalation as we breathe air out, which is called End Tidal CO₂ (EtCO₂).

Measuring PCO₂ by ABG involves drawing blood from an artery, usually the radial artery at the wrist or sometimes the femoral artery in the groin, and lab analysis. Obtaining an EtCO₂ measurement is painless, usually with a tiny cannula (tube) placed under our masks, just inside our nose or mouth, whichever we use to exhale, or in the exhalation port of our ventilator set up. The EtCO₂ correlates with the PCO₂ from our arterial blood, but does not require any blood draw, just a small sample of the air we breathe out.

The Role of Breathing

Breathing accomplishes both bringing in oxygen and expelling CO₂ as a waste gas. The amount of breathing we do is usually determined by how much oxygen our chemoreceptors sense in our blood. If we breathe more, we take in more oxygen but exhale more CO₂, and our CO₂ goes down. If we breathe less, our CO₂ keeps being produced by our cells, but not enough is exhaled, so CO₂ rises. The situation gets complicated for those of us unable to respond adequately to our need for oxygen. Neuromuscular deficits may be too extensive to take in sufficient air to expand enough alveoli to absorb

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the oxygen we need. Or, too many alveoli may be blocked by mucus plugs from lung infection or inadequate coughing.

We are usually unaware of our CO₂ level. Many of us fatigue and breathe insufficiently off our ventilators, unknowingly allowing our CO₂ to rise to serious levels, which a CO₂ monitor would sense. If our breathing is inadequate, and our CO₂ rises too much, our alertness decreases, most often without our realizing it. As it rises further, we fall asleep, and may then proceed into a hypercapnic (high CO₂) coma, during which we simply stop breathing.

Determining the optimum range of CO₂ for a particular person is complex and requires medical expertise. With the assistance of pulmonology staff, understanding how to interpret monitoring data should be on a par with the many other technical considerations already required of ventilator users.

Emergency Room Monitoring

Emergency room (ER) staffs now often combine pulse oximeters with EtCO₂ monitoring to pick up both potential low oxygen and retained CO₂ concerns. They monitor minor surgery ventilation under conscious sedation (light anesthesia), head injury breathing, overdose breathing, COPD and asthma exacerbations. Monitoring both oxygen and CO₂ provides much more information on ventilation status without resorting to drawing arterial blood gases.

If a neuromuscular ventilator user comes in short of breath, they would most likely get a pulse oximeter put on their finger, an EtCO₂ cannula slipped just inside their nose or mouth, and get put on their favorite ventilator settings with or without trach suctioning and/or supplemental oxygen, as they awaited results of X-rays and ordinary blood tests. If their problem could be resolved, the pulse ox and EtCO₂ has saved them from getting blood gases drawn. If they did not improve, then they would have to consider the harder choices, arterial blood gases might be next, possible intubation for those on NIV, maybe ICU admission.

The inexpensive pulse oximeter lets us monitor our oxygen. A problem for some is how to handle a low pulse oxygen: should more attention be given to airway mucus clearance, should the vent be used more, or should oxygen be given? If too much supplemental oxygen is given, it may sate our chemoreceptors and reduce our drive to breathe, causing a toxic rise in our CO₂. This is why oxygen use has to be so carefully considered with neuromuscular ventilation needs.

EtCO₂ machines range in size from small handheld units the size of a paperback book meant for spot checks in an ER, to large multichannel ICU recorders with printers that may include up to a dozen monitored parameters. There are many companies manufacturing these units, including Philips Respironics, and there is an online aftermarket for used equipment. Cost is in the \$1000 to \$5000-plus range depending on the complexity of the machine. Philips Respironics even has a smaller transcutaneous capnograph which does not have a cannula to pick up gas for analysis, but rather a pulse ox/CO₂ combined sensor that attaches to open skin with a gel interface.

For serious ventilation management, it would be ideal to have one of these EtCO₂ monitors available as an adjunct to the pulse oximeter, but the high cost at this time is a problem. At present, there does not appear to be a simple, inexpensive drugstore version of an EtCO₂ monitor.

Although the EtCO₂ interpretation might seem complex at first, it is no more so than the many considerations already required for ventilator users. For those on part-time ventilation, awareness of CO₂ retention would alert that more ventilation is required. For those already on full-time ventilation, monitoring EtCO₂ would alert for inadequate ventilation from a variety of reasons, such as the onset of a new respiratory infection, increasing heart failure or a need for machine readjustments.

Meanwhile most of us will have to rely on our pulmonologist doing routine blood gas analysis for PCO₂ and leave the EtCO₂ monitor encounters for our trips to the ER. ■